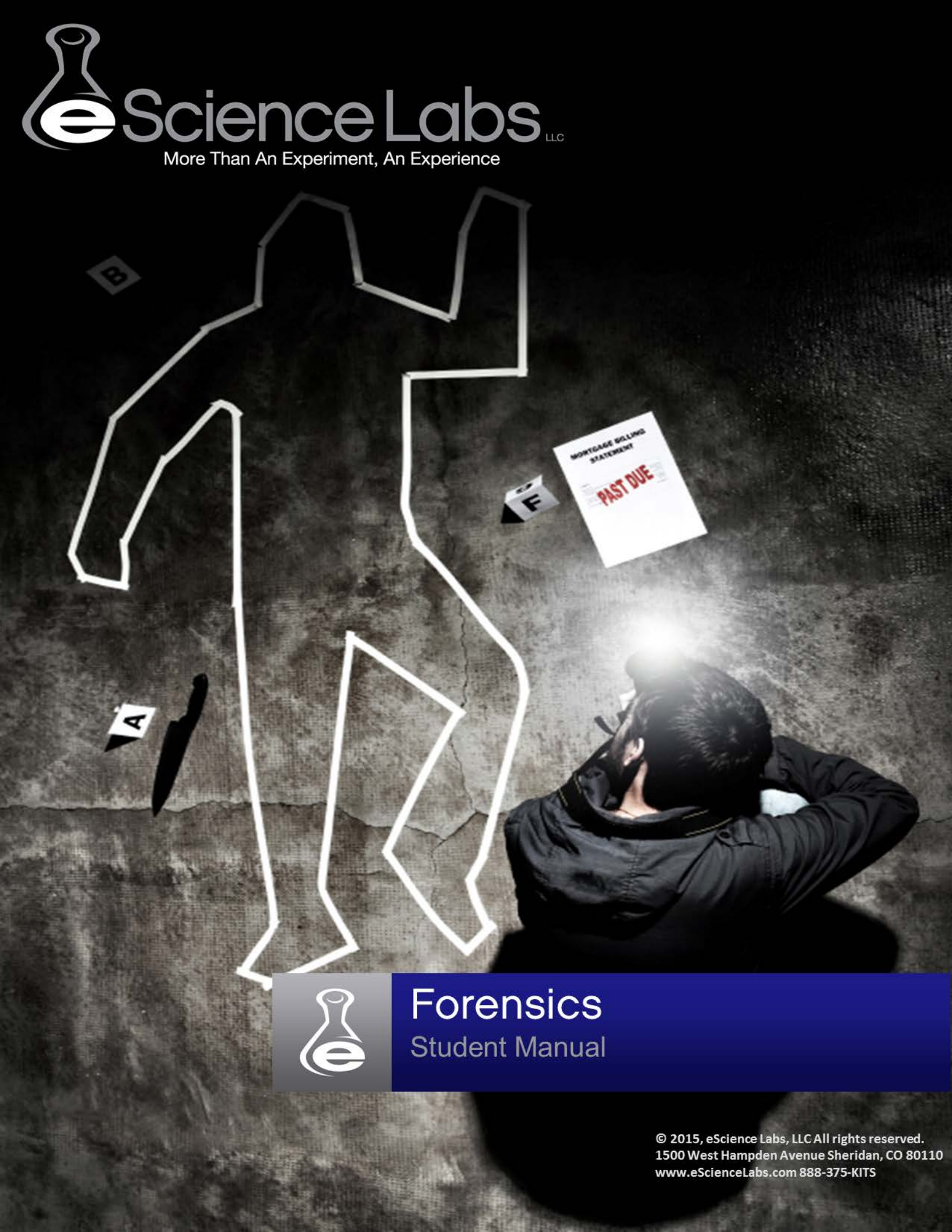
eScience Labs LLC

More Than An Experiment, An Experience



Forensics

Student Manual

1500 West Hampden Avenue Sheridan, CO 80110
www.eScienceLabs.com 888-375-KITS

FORENSICS LAB MANUAL

This manual was typeset in 11 Arial and 12 Chalet-London 1960. Arial font provided by Microsoft Office Suite, 2010. Chalet-London 1960 font licensed from House Industries, 2011.

The experiments included within this lab manual are suitable for supervised or unsupervised learning environments. eScience Labs assumes full liability for the safety and techniques employed within this manual provided that all users adhere to the safety guidelines outlined in the mandatory eScience Labs Safety Video, Preface, and Appendix. *All users must understand and agree to the eScience Labs safety guidelines prior to beginning their lab experiments*. eScience Labs does not condone use of the lab materials provided in its lab kits for any use outside of the curriculum expressly outlined within the lab manual.

ACKNOWLEDGEMENTS

The Forensics Lab Manual is a collaborative development which we are delighted to provide to higher education curriculum. Key contributors, including Cindy Higgins (M.S., Educational Instructional Design and Technology) and Dr. Max Houck (Ph.D., Forensic Chemistry), have brought creativity, rigor, intelligence, and industry applicability to this lab kit. We have greatly enjoyed working with this team, and look forward to serving students around the world with our hands-on lab experiments.

TABLE OF CONTENTS

USING YOUR FORENSICS LAB KIT

To successfully use and get the most learning and enjoyment out of your Forensics lab kit here are some tips before you begin:

- Refer to your course's syllabus for the due date and sequence of your lab assignments. Your instructor may not assign all of the labs or may not assign them in the order they are presented in the lab manual, on the Student Portal, or your school's Learning Management System (LMS).

- As soon as you receive your kit, compare the contents of your kit to the inventory insert that comes in your kit. If you are missing any items or any item was broken during delivery call eScience Labs at 1-888-375-5487 or email Help@esciencelabs.com immediately for a replacement.

- There are a few materials that you will need to complete your experiments that are not provided in your kits such as fresh produce or water. Review the Time and Materials section (after these tips) for a list of these items.

- The Time and Materials section also includes an estimate of the amount of time it will take a student to complete each lab to help you plan to set aside time to complete them. Some experiments may require a few days to a week for observation, so don't wait until the last minute to begin experiments.

- Before performing an experiment, read through the procedure thoroughly so that you know what to expect when you begin to handle materials.

Most importantly, have fun!

TIME AND MATERIALS REQUIRED

There may be a few additional materials required to complete your lab experiments which are not included in your eScience Labs kit. Please review the procedures and plan accordingly. Note that the times listed are approximations and may differ depending on the assignments required by your instructor and/or your previous subject knowledge.

If you are allergic to nitrile, please contact eScience Labs at info@esciencelabs.com and we will send you an alternative type of safety gloves. Some of your kit materials, such as rubber bands, may include latex. Always wear your nitrile safety gloves when working with these items!

Lab 1: Evidence and Crime Scenes

Time Required: 1 hour

Additional Materials: Camera (camera phones are acceptable), Scissors, Blue or Black Ink Pen, Computer, Internet Access

Lab 2: Fingerprinting

Time Required: 1.5 hours

Additional Materials: Camera (camera phones are acceptable), Right Hand Fingerprints, Left Hand Fingerprints, Paper Towel or Clean Towel, Soap and Water (for hand washing), Work Surface (See Step 1 in Experiment 1 Procedure), Glass Surface (window, bottle, etc.), Metal surface (chair, door knob, etc.), Skin Oil (from face)

Lab 3: DNA

Time Required: 2 hours (place ethanol in freezer 60 min. before beginning Experiment 1)

Additional Materials: Camera (a camera phone is acceptable), Fresh Soft Fruit (strawberry, grapes, banana, etc.), Scissors, Water, Hot Pad or Towel, Microwave Oven or Boiling Water Bath, Paper Towels, Scissors, Water

Lab 4: Blood

Time Required: 1.5 hours

Additional Materials: Camera (a camera phone is acceptable), Paper Towels, Pencil, Adjacent Floor and Wall, Flat Surface

Lab 5: Fiber and Hair

Time Required: 2 hours

Additional Materials: Camera (a camera phone is acceptable)

Lab 6: Impression Evidence: Shoes, Tires, Tools

Time Required: 1 hour

Additional Materials: Camera (a camera phone is acceptable),

Lab 7: Fractography and Glass

Time Required: 1.5 hours

Additional Materials: Camera (a camera phone is acceptable), Clean Cloth (in case of emergency), Durable Surface (ground or floor), Hydrogen Peroxide, H_2O_2 (in case of emergency), Water

Lab 8: Autopsy and Time of Death

Time Required: 2 hours

Additional Materials: Camera (a camera phone is acceptable)

Lab 9: Body Identification

Time Required: 1.5 hours

Additional Materials: Calculator (optional), Floor, Wall, Your Bare Foot, Camera (a camera phone is acceptable), Scissors

Lab 10: Questioned Documents

Time Required: 2 hours

Additional Materials: Camera (a camera phone is acceptable), Pencil, Ink Sample from Pen, Scissors, Timer or Clock

Lab 11: Fire Investigation and Arson

Time Required: 1 hour

Additional Materials: None

Lab 12: Toxicology

Time Required: 1 hour

Additional Materials: Camera (a camera phone is acceptable), Hot Water

Lab 13: Firearms

Time Required: 1 hour

Additional Materials: None

Lab Safety

Always follow the procedure in your laboratory manual and these general rules:

Lab Preparation

- Please thoroughly read the experiment procedure before starting.
- If you have any doubt as to what you are supposed to be doing and how to do it safely, please STOP and then:
  - ✓ Double-check the manual instructions.
  - ✓ Check the eScience Labs website for updates and tips.
  - ✓ Contact us for technical support by phone at 1-888-ESL-Kits (1-888-375-5487) or by email at Help@esciencelabs.com.
- Read and understand all labels on chemicals.
  - ✓ If you have any questions or concerns, refer to the Material Safely Data Sheets (MSDS) available at the eScience Labs website. The MSDS lists the dangers, storage requirements, exposure treatment, and disposal instructions for each chemical.
- Consult your physician if you are pregnant, allergic to chemicals, or have other medical conditions that may require additional protective measures.

Proper Lab Attire

· Remove all loose clothing (jackets, sweatshirts, etc.) and always wear closed-toe shoes.
· Long hair should be pulled back and secured. All jewelry (rings, watches, necklaces, earrings, bracelets, etc.) should be removed.
· Safety glasses should be worn at all times. In addition, wearing soft contact lenses while conducting experiments is discouraged, as they can absorb potentially harmful chemicals.
· When handling chemicals, always wear the protective glasses, gloves, and apron provided in your safety kit.

Performing Experiments

· Do not eat, drink, chew gum, apply cosmetics, or smoke while conducting an experiment.
· Work in a well ventilated area and monitor experiments at all times, unless instructed otherwise.
· When working with chemicals:
  ü Never return unused chemicals to their original container to avoid contamination.

- ü Never place chemicals in an unmarked container to avoid identification or proper disposal problems.
- ü Always put lids back onto chemicals immediately after use to avoid contamination or potential hydration problems.
- ü Never ingest chemicals. If this occurs, seek immediate help.

Call 911 or "Poison Control" 1-800-222-1222

· Never leave a heat source unattended.

- ü **If there is a fire, evacuate the room immediately and dial 911.**

Lab Clean-up and Disposal

· If a spill occurs, consult the MSDS to determine how to clean it up.
· Never pick up broken glassware with your hands. Use a broom and a dustpan and discard in a safe area.
· Do not use any part of the lab kit as a container for food.
· Safely dispose of chemicals. If there are any special requirements for disposal, it will be noted in the lab manual.
· When finished, wash hands and lab equipment thoroughly with soap and water.

Above all, use common sense. Read the manual carefully and pay close attention to the safety concerns prior to starting an experiment.

Forensics Student Portal

Student Portal Resources

Access your Student Resources with these easy steps:

If you purchased a kit directly from the eScience Labs website, your user account already has access to the Student Resources for your course. To access these, please visit the eScience Labs website, and click on the **Student** tab. Then, enter your username and password. On the following page, scroll down until you see the name of your lab kit or product SKU. This should be a hyperlink. Click this hyperlink. You will see a series of topics, each of which contain lab information or virtual assets.

If you purchased a kit from somewhere else (e.g., your bookstore), you'll need to set up a new user account. Begin by going to the eScience Labs website, and clicking the **Create Account** button in the upper right-hand corner. After you are registered and logged in, click the **HAVE A CODE** button, located on the right side of the home page. Enter the access code located on the underside of your lab kit box lid and press **Submit**. Click on the **Student** tab from the home page. On the following page, scroll down until you see the name of your lab kit or product SKU. This should be a hyperlink. Click this hyperlink. You will see a series of topics, each of which contain lab information or virtual assets.

You can find supplemental resources including, videos, simulations, and tutorials on the eScience Labs Student Portal. The following list outlines available resources by lab:

Evidence and Crime Scenes

- Evidence and Crime Scenes Concept Animation
- Evidence and Crime Scenes Lab Drill

Fingerprinting

- Fingerprinting Concept Animation
- Fingerprinting Lab Drill

DNA

- DNA Concept Animation
- DNA Lab Drill

Blood

- Blood Concept Animation
- Blood Lab Drill

Fiber and Hair

- Fiber and Hair Concept Animation
- Fiber and Hair Lab Drill

Impression Evidence: Shoes, Tires, Tools

- Impression Evidence: Shoes, Tires, Tools Concept Animation
- Impression Evidence: Shoes, Tires, Tools Lab Drill

Fractography and Glass

- Fractography and Glass Concept Animation
- Fractography and Glass Lab Drill

Autopsy and Time of Death

- Autopsy and Time of Death Concept Animation
- Autopsy and Time of Death Lab Drill

Body Identification

- Body Identification Concept Animation
- Body Identification Lab Drill

Questioned Documents

- Questioned Documents Concept Animation
- Questioned Documents Lab Drill

Fire Investigation and Arson

- Fire Investigation and Arson Concept Animation
- Fire Investigation and Arson Lab Drill

Toxicology

- Toxicology Concept Animation
- Toxicology Lab Drill

Firearms

- Firearms Concept Animation
- Firearms Lab Drill

Lab 1

Evidence and Crime Scenes

Lab 1 Evidence and Crime Scenes

LEARNING OBJECTIVES

- Collect and process evidence by utilizing a chain of custody form and collection methods that prevent contamination
- Document a crime scene using sketches, diagrams, and photomacrographic scales
- Identify the parts and demonstrate how to use a compound light microscope

INTRODUCTION

Arriving at a crime scene is like reading the last page of a story. You have to work your way back to the beginning in order to determine what happened, when it happened, to whom, and why. Figuring out what happened involves crime scene investigation and scientific analysis, more commonly known as **forensic science** or **criminalistics**.

The Crime Scene

A **crime scene** is any location where an act that broke the law has occurred. The first police officers to arrive secure the crime scene with yellow tape and supervision. They then mark certain areas related to the crime, taking care to avoid disturbing anything that might be linked to it (Figure 1). Associated with the police are **crime scene investigators** (CSI) who collect and analyze **evidence**, information, or objects that are relevant to solving the crime. CSIs and police work with a district attorney (DA) to utilize search warrants before collecting and processing evidence. They also employ practices and methods to ensure that the evidence they collect is **admissible** in court, meaning it is allowed to be presented during a trial. In addition to police officers, CSIs, and DAs, there are other types of investigators that have an important role at a crime scene. Investigators may include:

- detectives (interview witnesses and follow leads)
- medics (assist injured individuals)
- medical examiners or death investigators (determine preliminary cause of death if a crime involves a death)
- photographers (document a crime scene using cameras or other recording devices).

Lab 1 Evidence and Crime Scenes

Figure 1: A medical examiner and a photographer at an outdoor crime scene.

Knowledge Check

☐ ***What does a CSI need to obtain before entering a crime scene to collect evidence?***

Evidence

For evidence to be potentially admissible in a courtroom, the scientific theory on which it is based must be established and accepted by the scientific community. In other words, it must be based on a theory or technique that can be tested, has been offered for peer review, has an acceptable rate of error, has widespread acceptance, and is relevant to the issue. Therefore, not any piece of evidence collected by an investigator can be used to prosecute or exonerate a suspected criminal. Any new type of evidence may even undergo its own mini-trial in a court to be admissible. For example, the scientific study of DNA is a relatively new method, first used in courts in the late 1980's. Since it is accepted by science that DNA is unique to an individual, it may be admissible in court.

Evidence is classified into several categories based on its characteristics and is used as criminal proof. **Direct evidence,** such as confessions and eyewitness statements, is considered factual. In contrast, **circumstantial evidence** depends on inference to be considered factual. Forensic science is influenced by direct evidence, but more often obtains and analyzes circumstantial evidence. Evidence may be further identified as contact evidence or trace evidence.

Evidence comes from various sources and can be used in an investigation or court trial to identify remains, reconstruct a crime, convict a criminal, or exonerate an innocent person as long as it has been collected and handled properly. If evidence has been tampered with or mishandled, it may not be admissible in court, no matter how relevant it is to the crime.

Proving what happened beyond reasonable doubt in the justice system is why processing a suspicious or questionable incident can be a tedious process with extensive documentation. Not only must evidence be collected and labeled, evidence must be safeguarded to ensure that, when it appears in a court of law, it hasn't been tampered with. The outcome of a criminal cases typically depends upon the admissibility and strength of the evidence. Part of documenting and tracking evidence includes a **chain of custody**, a record of individuals who have had physical possession of the evidence and how they have handled it (Figure 2). To reduce the possibility that a piece of evidence is deemed inadmissible in court, a chain of custody should be consistently maintained from the time evidence is collected to the time it is stored for trial. Further, evidence should be handled by as few individuals as possible.

Figure 2: An example of an evidence bag, including a chain of custody form. © Cornishman | Dreamstime.com - Evidence Bag Photo

Searching a Crime Scene

When investigators arrive at a crime scene, they begin taking detailed notes, including information about the officers who secured the scene and individuals that have been at the crime scene since it was secured. They will also assess the need for additional investigators and determine how they will collect the evidence. While there are guidelines and accepted protocols, there are no set rules for crime scene investigation. As a result, CSIs use the law, the scientific method, and their professional judgment as they

proceed.

Once a crime scene is secure, investigators identify any potential hazards and systematically search for incriminating evidence. Systematic searches of a crime scene assure sufficient coverage and the most efficient use of resources. Searches are done in a set pattern that can include:

- **Spiral search**: Can be inward, starting at the scene's outer boundary and working toward the center, or outward, starting at the center of the scene or at the body and working towards the crime scene boundaries (Figure 3a).
- **Grid search**: For crime scenes with well-established boundaries, investigators comb the scene in a north-south and east-west direction (Figure 3b).
- **Line search**: Investigators form a line and walk in a straight line at the same speed from one side of a crime scene to the other (Figure 3c).
- **Quadrant search**: With the crime scene divided into zones, investigators cover a single area before moving to another until all zones have been searched (Figure 3d).
- **Wheel search**: Investigators start from the site of the crime and work outward in one direction, then return to the site on the same radial line. This pattern is repeated, shifting the angle similar to spokes on a wheel, working in a clockwise motion (Figure 3e).

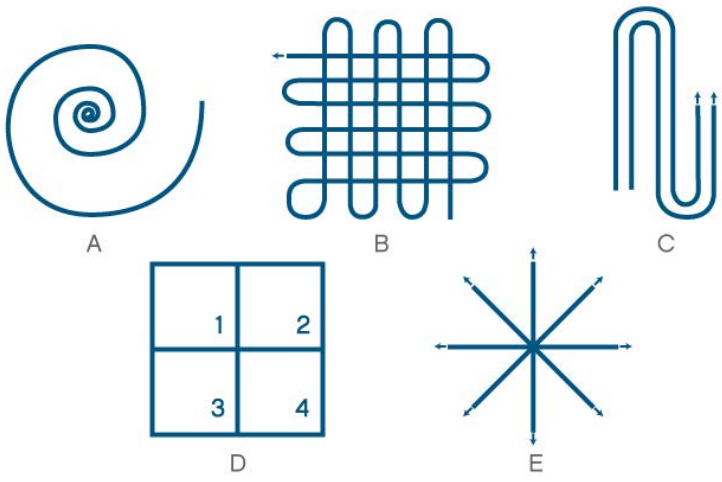


Figure 3: A visual of search patterns an investigator may employ at a crime scene.

Knowledge Check

☐ ***What systematic search consists of multiple investigators walking together at the same speed through a crime scene?***

Crime Scene Documentation

A crime scene may also be used as an exhibit during court testimony in the form of a photograph or diagram. Therefore, it is important to document a crime scene as soon as possible so that its original state is recorded. Investigators may document a crime scene by taking photographs, notes, and sketches. Before evidence is collected, it may be photographed to preserve a record of its original state and position at the crime scene. To scale an object found at a crime scene in a photography, a plastic, L-shaped ruler called a **photomacrographic scale** is used (Figure 4).

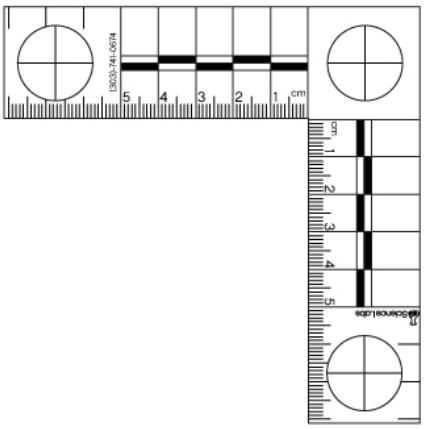


Figure 4: Photomacrographic scale. The circles are used to help ensure a camera's aim is perpendicular to the ruler.

A **crime scene diagram** is an illustrated, scaled record of the positions of evidence, object placement, body placement, and physical dimensions of the crime scene (Figure 5). This sketch serves as a memory aid and can be used to reconstruct a crime scene. The sketch should identify relevant objects at the crime scene and provide details for a more sophisticated rendering, if necessary. To orient the sketch, the letter "N" is used to designate the cardinal direction north, and a legend explains any symbols used to identify objects. Any measurements included should be recorded with consistent units. Objects that represent evidence are typically designated with a number. Other objects that are present, but not evidence, are designated with a letter.

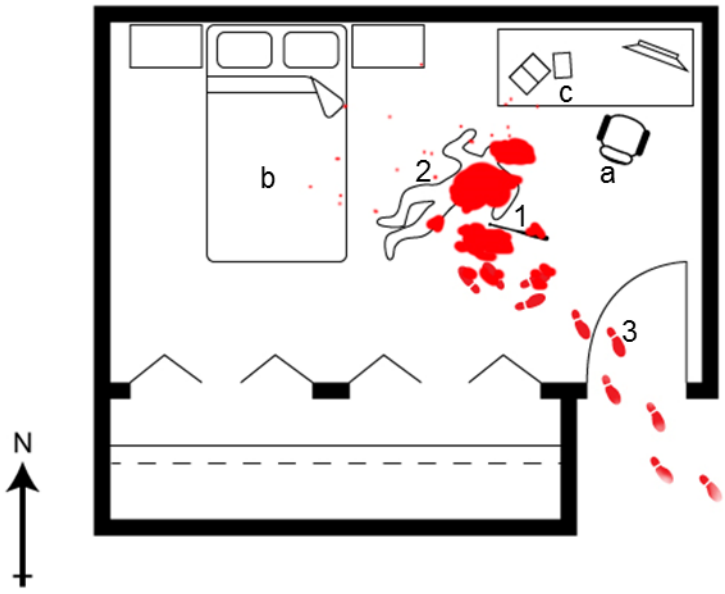


Figure 5: A crime scene diagram comprised of simple shapes to represent objects at the scene. Body position and bloodstains are also recorded. Evidence is labeled. Notice the direction north is indicated in the lower left hand corner.

Evidence Collection

Investigators bring evidence-gathering kits to crime scenes. These kits contain personal protective equipment, sticky tape, vacuums with special filters, cameras, containers, rulers, magnifying glasses, forceps, evidence labels, and lifting tape. When collecting evidence, it must be secured and packaged in a way that prevents loss. The type of evidence will dictate the type of container used to hold it. For example, regular envelopes will have gaps in the corners, allowing small items like fibers and soil to leak out. No matter the type of evidence, all investigators employ common methods to prevent contaminating or destroying evidence.

Personal protective equipment (PPE) helps safeguard evidence against contamination by CSIs and includes gloves, goggles, full body suits, shoe coverings, and face masks (Figure 6). The type of crime will dictate the type of PPE used by a CSI. It should always be assumed that, in cases where bodily fluids are present at a crime scene, the victims or suspects may be carrying pathogens.

As investigators collect evidence from a crime scene, they are cautious and aware of where they step and what they touch. Often, an investigator will try to follow a path they have already taken through a crime scene to reduce the number of shoe prints and avoid stepping on evidence that is not readily noticeable.

Figure 6: This CSI is wearing a full body suit, goggles, face mask, and gloves to protect herself and the crime scene from being contaminated.

Figures in Forensics

Edmond Locard
1877-1966

Edmond Locard was a French criminalist and forensic science pioneer. Locard was interested in applying science to the courtroom while studying medicine. In addition to starting a crime lab in France, he greatly advanced fingerprint science and used microscopes to help solve crimes. Locard once tied counterfeiters to fake coins made of tin, antimony, and lead using fiber dust found inside the suspects' pockets. His use of trace evidence illustrates his "Exchange Principle," which has become the fundamental tenet of forensic science: "When two objects come into contact with each other, they exchange trace evidence." Wrote Locard about a criminal, "It is impossible for a criminal to act, especially considering the intensity of a crime, without leaving traces of this presence." *Image Source: © 2015 http://www.police-scientifique.com/historique*

Microscopes

Once evidence has been collected, it is sent to a laboratory for further investigation. A common tool used to analyze trace amounts of evidence is a microscope. A **microscope** utilizes lenses and light to magnify an object, allowing minute details to be observed. Forensic scientists use a variety of microscopes, ranging from a compound light microscope to a scanning electron microscope, to identify evidence or compare evidence to an **exemplar** (a known sample). For instance, a scientist might identify a strand as a fiber using a stereomicroscope, which magnifies 3D samples. He or she will then take a closer look with a light microscope, which provides additional magnification to samples, and identify the fiber type (nylon, polyester, wool, etc.).

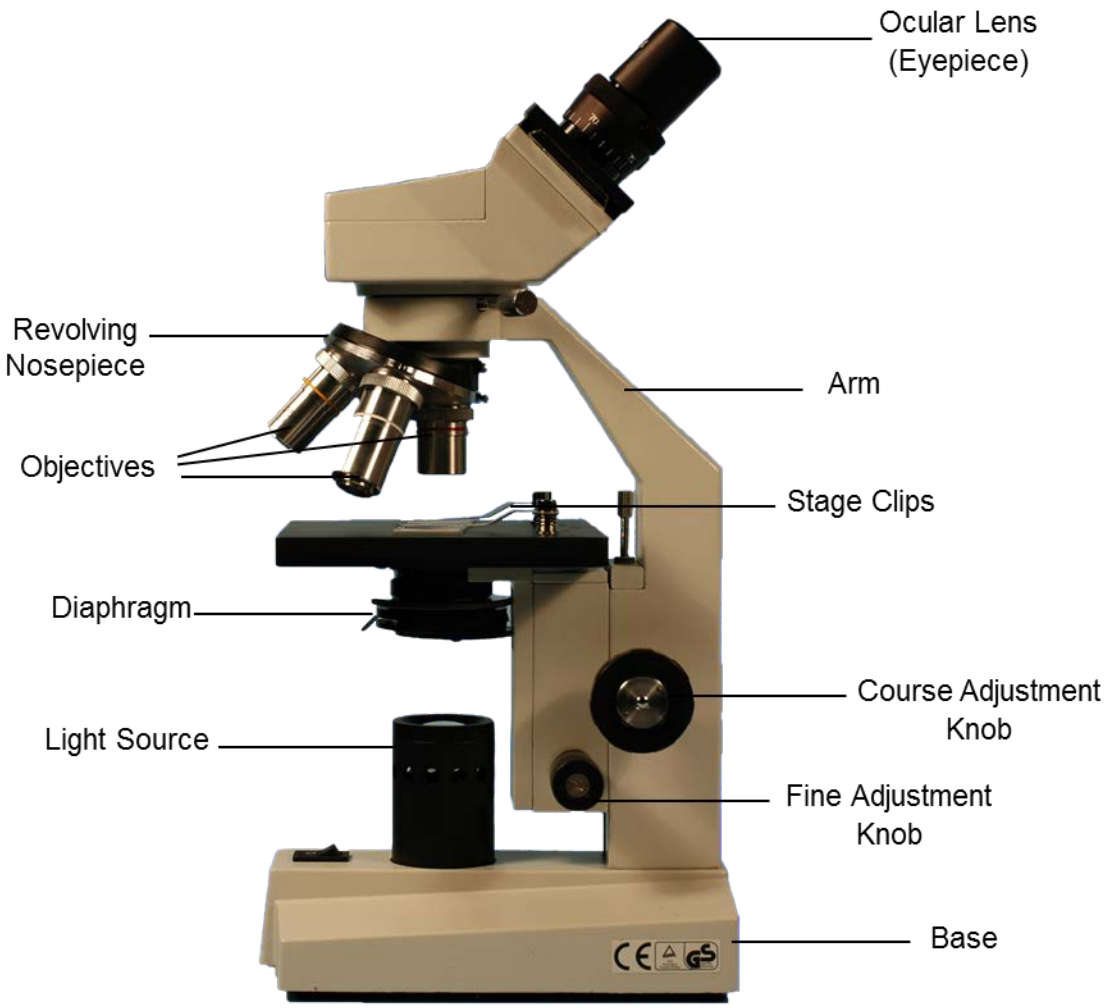


Figure 7: A typical compound light microscope with labeled parts.

The most common type of microscope is a compound light microscope (Figure 7). It allows viewers to see magnified images when a light beam passes through magnifying lenses. The lenses bend or refract light to make an observed object appear closer. Note the two sets of lenses: the ocular lens (close to your eyes) and the objective lenses (close to the "object" on the stage).

The total magnification of a compound light microscope is equal to the magnification power of the ocular lens multiplied by the magnification power of the objective lens. For example, if the ocular lens magnifies 10X and the objective lens magnifies 10X, the total magnification is 100X.

Most microscopes have similar parts. Refer to Figure 7 as you read through this list to familiarize yourself with these structures.

- **Base**: The flat foundation of the microscope.
- **Light**: Illuminates the object being viewed. This can be either in the form of a light source or a mirror that reflects ambient light onto the image. In the latter case, it is important to be working in an environment with adequate ambient light.
- **Stage**: Supports the slide or other material being viewed.
- **Diaphragm**: Controls the amount of light directed towards the object.
- **Stage Clips**: Secure the slide in place on the stage.
- **Revolving Nosepiece**: Rotates the objective lenses, allowing one of them to be positioned over the slide.
- **Arm**: Connects the lower base and the upper head of the microscope (also used to carry the microscope).
- **Head**: Supports both the ocular lens and the revolving nosepiece.
- **Ocular Lens (eyepiece)**: The lenses on the microscope typically have a magnification of 10X. If your microscope has a pointer, which is used to indicate a specific area of the specimen, it is attached here and can be viewed when looking through the oculars. Monocular microscopes have a single ocular eyepiece, while binocular microscopes have two ocular eyepieces.

How to Use a Microscope

The following steps describe the proper use of a compound light microscope.

1. Always carry a microscope with one hand securely around the arm and the other underneath the base for support.

2. Place the microscope on a table, plug it in, and turn on the light source (or adjust the mirror as necessary).

   Note: When cleaning a microscope, do not use paper towels or cloths, as this will scratch the lens. To preserve the microscope, use only lens paper that will not scratch the optics.

3. To prevent damage to the lens or slides, always start and end with the scanning power objective lens (the shortest one) above the light source.

4. Place your prepared slide on the stage and secure it with the stage clips. It is helpful to visually orient the slide so the object to be viewed is directly in the middle of the opening on the stage where the light is directed up toward the slide. This may require adjusting knobs that move the stage left and right or towards and away from the arm.

5. Adjust the distance between the two oculars until only one object is seen when using a binocular microscope. Record this distance and set your microscope to this distance every time you use it. The lenses may be re-adjusted if someone else uses the microscope.

6. Turn the coarse adjustment knob to bring the stage all the way up to the scanning power objective (lowest-power) lens. While looking through the lens, use the coarse adjustment knob to *slowly* lower the stage until the specimen comes into focus.

7. To adjust the light, open or close the diaphragm located over the light source. The specimen should not be gray or exceptionally bright when properly illuminated. Most compound light microscopes have a condenser lens embedded in the stage, located above the light source. By adjusting the amount of light that passes through the condenser lens, the concentration of light passing through a specimen can be changed.

8. When the object is in general focus, rotate the revolving nosepiece to the next-highest objective. Switch to the fine adjustment knob to obtain more precise and greater detail after focusing with the coarse adjustment knob. It may also be necessary to adjust the light, because more light reduces the contrast (sharpness).

   Note: Once you move to the next objective after the scanning objective, do not use the coarse adjustment knob. Whenever you use a high-power lens, *only use the fine adjustment knob*. If the object was well-focused while viewing with the low-power lens, very little adjustment should be necessary.

9. You may then scan the slide for specimens outside the field of view by turning the mechanical stage knobs (if these knobs are present).

Note: If you turn the knob to the right, the image will appear to be moving toward the left, due to image inversion caused by the lenses.

10. Slowly rotate the high-power lens into place (the next longest lens) if you need higher magnification. This will bring the tip of the lenses very close to the slide. Make sure the objective lens does not touch the slide.
11. If you cannot bring the object into focus, return to the low-power lens, focus the object, and then return to the high-power lens.
12. Move the revolving nosepiece to the scanning objective lens position before removing the slide when finished.

EXERCISE 1: COLLECTING AND PROCESSING EVIDENCE

Crime scene investigation requires careful examination to collect and keep a record of evidence. Upon discovery, evidence must be properly collected and packaged for later laboratory examination. In this exercise, you will collect and process trace evidence from a "crime scene."

Materials

- (1) Chain of Custody Form
- Crime Scene Scenario
- (1) Sheet of Lifting Tape
- Masking Tape
- (1) Pair of Disposable Gloves
- (1) Paper Photomacrographic Scale
- (1) Permanent Marker
- (2) Plastic Bags (to be used as evidence bags)
- (1) Sock
- *Camera/Smart Phone
- *Scissors

*You must provide

Note

Your kit comes with a print out of Figures 8 and 9. If you need to print it again, the figures are located at the end of this lab. The crime scene scenario can be found in the procedure below.

Procedure

Part 1: Collecting Evidence

1. Use scissors to cut out the photomacrographic scale.
2. Put on a pair of disposable gloves.
3. Place the sock on the ground or floor.

   Note: To make the "crime scene" more realistic, you may want to place the sock outside on a sidewalk.
4. Read the following crime scene scenario:

   Case Number 04-2327: On January 21 of this year at 6:36 PM, police were dispatched to Greenfield Park after a report of an attempted robbery with possible homicide. The victim,

Dean Fischer, was walking through the park when a man came up behind him, hit him on the back of the head, and attempted to take his wallet. Mr. Fischer attempted to defend himself and a short scuffle ensued. The suspect started to flee when Mr. Fischer grabbed his shoe to stop him. The suspect's shoe, along with his sock, came off during the scuffle. In an attempt to get away before police arrived, the suspect stabbed the victim and grabbed his shoe, but did not pick up his sock before he fled. Mr. Dean Fischer was pronounced deceased at the scene. Five hours later, police took Roger O'Barger into custody.

5. As a crime scene investigator, one of the pieces of evidence you collect is the sock. Place the photomacrographic scale next to the sock and use a camera to take a photograph of it. Use your knowledge of crime scene photography to take the most reliable photograph.

   Note: You will need to download, scan, or print the photograph to be included with your lab report.
6. Using a gloved hand, collect the sock and place it in a plastic evidence bag.
7. Tear off a piece of masking tape the same length as the opening of the evidence bag.

   Note: The masking tape represents evidence tape. Typically, evidence tape has a mechanism to reveal when it has been tampered with. For example, some evidence tape has a self-voiding feature. If pulled off of the evidence bag, perforated letters that state "VOID" remain on the bag.
8. Seal the top of the evidence bag with the masking tape.
9. Use the permanent marker to write your initials, the case number, the date, and Item #1 on the masking tape.

Part 2: Chain of Custody

1. Use a permanent marker and the crime scene scenario in Part 1, Step 4 to complete the top of the chain of custody form with the case number, offense, victim, suspect, date/approximate time seized, and location of seizure.
2. In the Description of Evidence section, use a permanent marker to catalogue Item #1. Include the quantity and a description of the item.
3. Use a permanent marker to complete the Chain of Custody section using information from the crime scene scenario follow-up below:

The same day you collect the evidence, you transport it to a laboratory that specializes in fibers. You give custody of Item #1 to Dr. Dan Brown, fiber expert. Dr. Brown states he will lift possible trace evidence from Item #1 and identify any trace evidence found as Item #2. He will then analyze samples obtained from Item #2 under a microscope to compare the fibers to a possible matching sock seized from the suspect and any additional fibers found.

4. You will now act as if you are Dr. Dan Brown working in the laboratory. You will lift possible trace evidence from the sock collected at the crime scene.
5. If you have removed your gloves, be sure to put them back on. Open the evidence bag containing Item #1 and remove it from the bag.
6. Peel and discard the clear plastic cover to expose the adhesive side of one sheet of lift tape.
7. Place the adhesive side of the lift tape on the sole of the sock. Lightly press the tape down, and then remove it by pulling it up and off the sock.
8. Place and gently press the adhesive side of the tape with possible trace evidence to the backing of the attached black background.
9. Place the lift tape sheet into a plastic evidence bag.
10. Tear off a piece of masking tape the same length as the opening of the evidence bag.
11. Seal the top of the evidence bag with the masking tape.
12. Use the permanent marker to write Dan Brown's initials, the case number, the date, and Item #2 on the masking tape.
13. Complete the chain of custody form to record Item #2. Continue using the scenario below to complete the chain of custody form:

    Immediately after Dr. Brown is finished using the evidence, he places it back in the evidence bag, reseals it, and adds his initials to the evidence tape. On January 28, Dr. Brown gives custody of Items #1 and #2 to Amanda Scopes, a DNA analyst. She attempts to collect a sample of DNA from the inside of the sock to compare to a sample taken from the suspect. She places the evidence back in its evidence bag, reseals it, and adds her initials to the evidence tape. On February 2, Amanda Scopes gives custody of Items #1 and #2 to Officer William Dune. That same day, he registers Items #1 and #2 in the evidence room at the Greenfield Police Station, where they remain until the trial is held.

14. Use the permanent marker to add the initials of any person that opened the evidence bags.
15. Use a camera to take a picture of the evidence bags containing Items #1 and #2 with the

initials on the evidence tape visible. This may require multiple photographs.

Note: You will need to download, scan, or print the photographs to be included with your lab report.

Greenfield Police Department

EVIDENCE CHAIN OF CUSTODY TRACKING FORM

Case Number: _____ Offense: _____

Submitting Officer: (Name/ID#) _____

Victim: _____

Suspect: _____

Date/Time Seized: _____Location of Seizure: _____

Description of Evidence		
Item #	**Quantity**	**Description of Item** (Model, Serial #, Condition, Marks, Scratches)

Chain of Custody				
Item #	**Date/Time**	**Released by** (Signature)	**Received by** (Signature)	**Comments/ Location**

This Evidence Chain-of-Custody form is to be retained as a permanent record by the Greenfield Police Department.

Figure 8: Chain of Custody form. This form has been modified from the original source to accommodate the exercise. Source: Technical Working Group on Biological Evidence Preservation. The Biological Evidence Preservation Handbook: Best Practices for Evidence Handlers. U.S. Department of Commerce, National Institute of Standards and Technology, 2013.

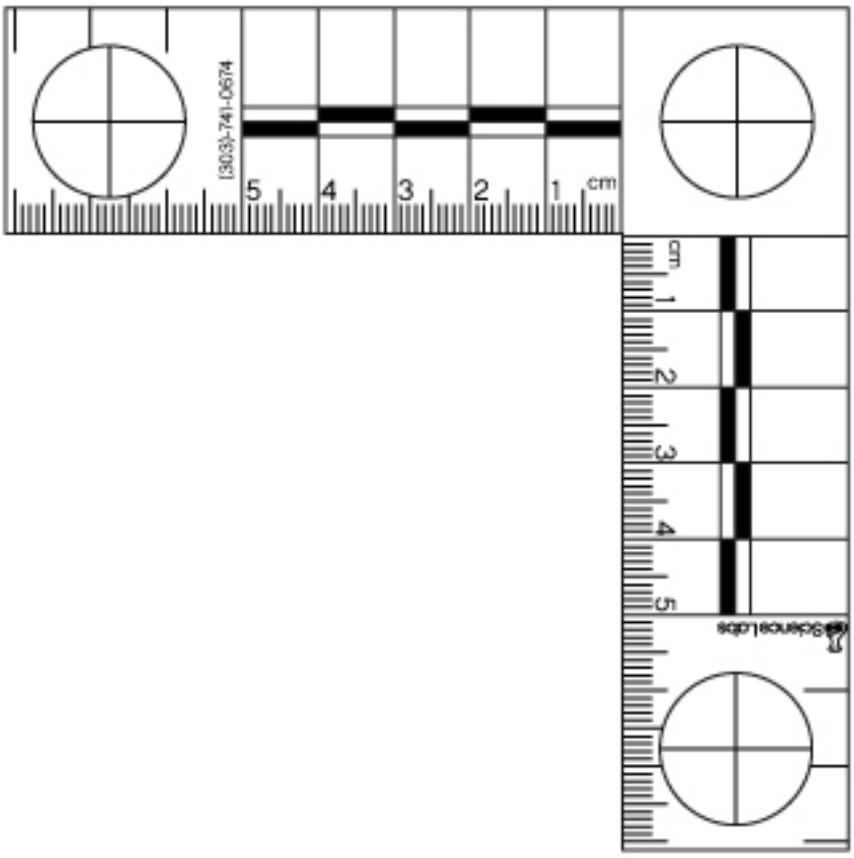


Figure 9: Photomacrographic scale.

EXERCISE 2: CRIME SCENE DOCUMENTATION

In this exercise, you will document the Greenfield Park crime scene by completing a crime scene diagram. Be sure to refer back to the scenario in Exercise 1 to create an accurate account of the crime scene.

Materials

- Crime Scene Notes
- (1) Crime Scene Sketch
- (1) Protractor
- (1) Ruler
- *Blue or Black Ink Pen
- *Camera (a camera phone is acceptable)

*You must provide

Note

Your kit comes with a print out of Figure 10. If you need to print it again, it is located at the end of the lab. The crime scene notes can be found in the procedure below.

Procedure

1. Use a blue or black ink pen to record the case number in the upper left hand corner of the sketch.

2. Use the pen to record the location of the crime scene under the case number.

3. Use the pen to record the date of the crime this year under the location.

4. Use the following crime scene notes, a ruler, and a protractor to complete the sketch of the crime scene. Use the scale ¼" = 1'.

   Note: You will need to include your crime scene sketch in your lab report. This may require scanning or downloading a picture of it from a camera to a computer.

   - *The perimeter of the crime scene is 36'0" in the north to south direction by 28'0" in the east to west direction.*
   - *The sock left by the suspect is sketched as a small rectangle and labeled as "1."*
   - *A light pole located 3'0" northwest of the body is labeled "A."*

- *A tree located 16'0" southeast of the victim's body is labeled "B."*
- *The victim is labeled "C."*
- *The sidewalk where the crime took place is 5'0" wide.*
- *The sock is located 7'0" east of the light pole.*
- *The sock is also located 17'0" from the tree at an angle of 65º from the measurement between the sock and the light pole.*
- *The direct distance between the tree and the light pole is 21'0".*
- *Witnesses report that the suspect fled down the sidewalk towards the northeast end of the crime scene.*

5. Create a legend that explains labels 1, A, B, and C.

6. Use a camera to take a photograph of your crime scene diagram.

Note: You will need to download, scan, or print the photographs to be included with your lab report.

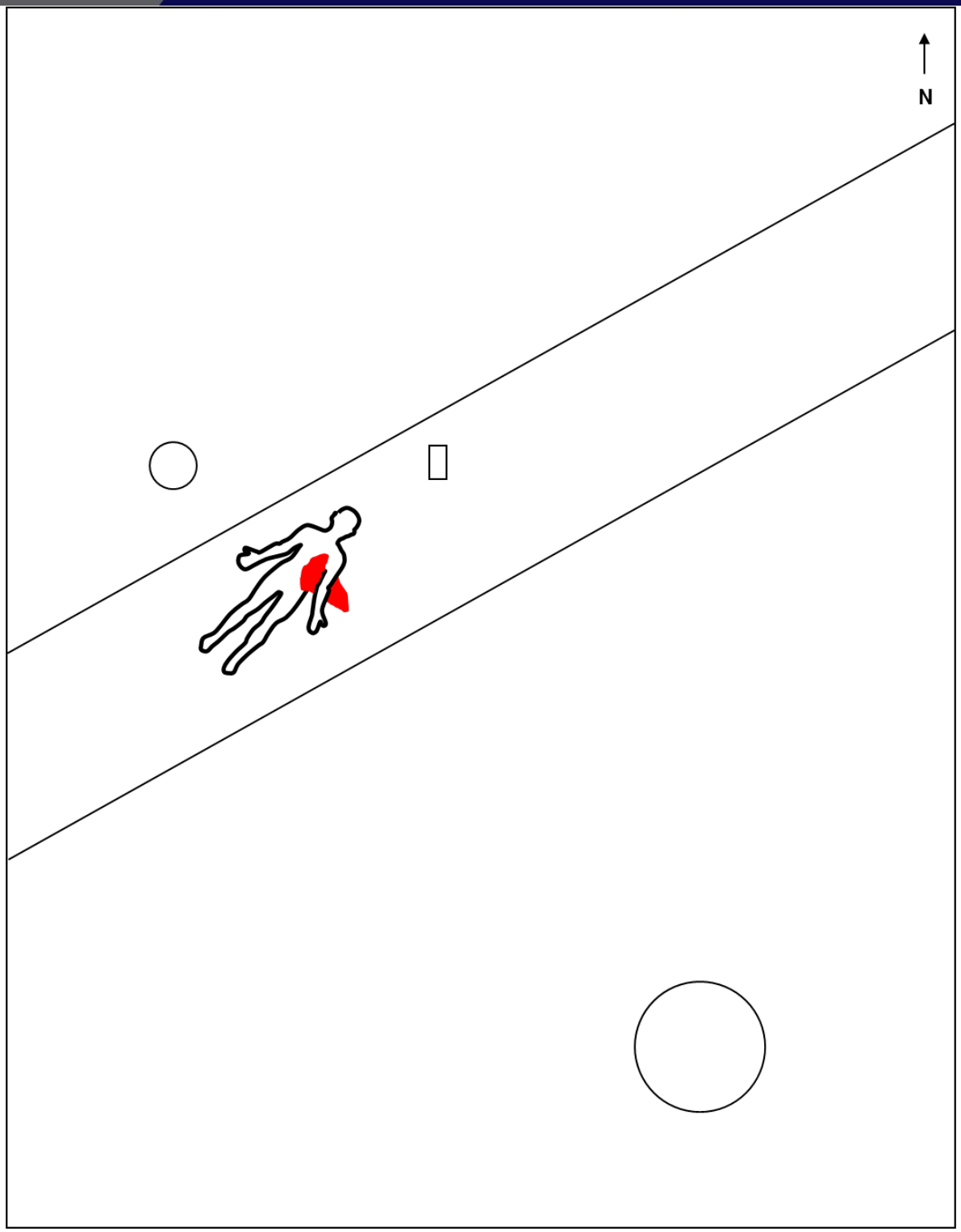


Figure 10: Greenfield crime scene sketch to be completed.

EXERCISE 3: VIRTUAL MICROSCOPE

Microscopes are used across the field of forensics. From observing cell specimens to comparing fracture patterns on glass, microscopes can help forensic scientists see minute, but important, details on crime scene evidence. While there are different types of microscopes, most have common structures and function in a similar way. In this exercise, you will practice using a virtual compound light microscope to observe specimens at varying magnifications.

Materials

- Virtual Microscope on Student Portal
- *Computer
- *Internet Access

*You must provide

Note

Review the directions for signing in to the Student Portal at the beginning of this manual if uncertain how to access this information.

Procedure

1. Log into your eScience Labs Student Portal account and locate the Virtual Microscope activity located in the Evidence and Crime Scene section.
2. Take a tour of the virtual microscope by clicking the “Start Tour” button on the right hand side of the screen and learn how to use the different controls to effectively use the simulation.
3. Once you are comfortable using the virtual microscope, switch views so that you are looking at the microscope.
4. Select the “letter e” slide in the top right corner of the page.
5. Manipulate the stage until the letter e is positioned over the light source.
6. If the microscope light is off, turn it on.
7. Switch views so that you are looking through the ocular lens and at the slide.
8. Move the oculars until your field of view becomes a complete circle.

9. Use the 4X objective lens, coarse adjustment knob, and the fine adjustment knob until you can clearly observe the letter e in the field of view.

    Hint: This is achieved when a red circle appears over the letter e.

10. Manipulate the stage to move the letter e to the measurement line in the center of the field of view.
11. Rotate the objective lens to the next power and find a clear image of the letter e.
12. Repeat Steps 10 and 11 until the letter e no longer fits in the field of view. Observe at what magnification this occurs.
13. Switch views so that you are looking at the microscope.
14. Remove the letter e slide and select the cheek smear slide on the right side of the page.
15. Manipulate the stage so that the sample is over the light source.
16. Switch views and bring the cells within the red circle into focus using the 4X, then 10X, objective lenses. Use what you know about operating a microscope to do this.
17. View the slide under the 40X and 100X objective lenses.
18. On the left hand side of the screen, select the "Try This" box. Under measurement, select the m1 box to open an activity that will instruct you how to measure the letter e. Observe the height of the letter.

    Note: If the software freezes after clicking the "Try This" button, refresh your browser and start again. You will have to go through the tutorial tour again in order for the "Try This" box to become available.

Lab 2

Fingerprinting

Lab 2 Fingerprinting

LEARNING OBJECTIVES

- Explain the role of fingerprints in forensics
- Perform a fingerprint rolling technique and analyze minutiae
- Collect a fingerprint sample using a dusting technique

INTRODUCTION

The patterns of raised skin found on the fingers of every individual are known as **fingerprints** (Figure 1). Fingerprints develop in the womb, and except for changing in size during growth, the pattern of each fingerprint will remain the same throughout a person's life. They are **biometrics**, measurable biological features used for identification purposes. Forensic investigators utilize fingerprints to corroborate evidence that a suspect was present at a crime scene. If fingerprints are properly collected and in good condition to be analyzed, they may be admissible in court.

Figure 1: A fingerprint.

Knowledge Check

☐ ***Is fingerprint evidence always admissible in court?***

Skin and Fingerprints

Skin consists of three layers of tissue: the epidermis, dermis, and hypodermis (Figure 2). The epidermis is the outermost layer of skin. Certain areas of this layer have a feature called **friction ridge skin.** The palms of the hands, fingers, soles of the feet, and toes have raised lines called **ridges** and grooves. Depressed areas between the ridges are called **furrows.** Friction ridge skin, along with **pores** (the tiny openings in the skin that secrete sweat and oils), allow the hands and feet to firmly grasp surfaces. Friction ridge skin forms in the 12th to 16th week of fetal development through a combination of genetic and environmental factors. Therefore, a person's genetic make-up dictates how friction ridge skin will form, but random events, such as the fetus's position at a particular moment or the composition and density of the surrounding amniotic fluid, influence the distinctive patterns that form.

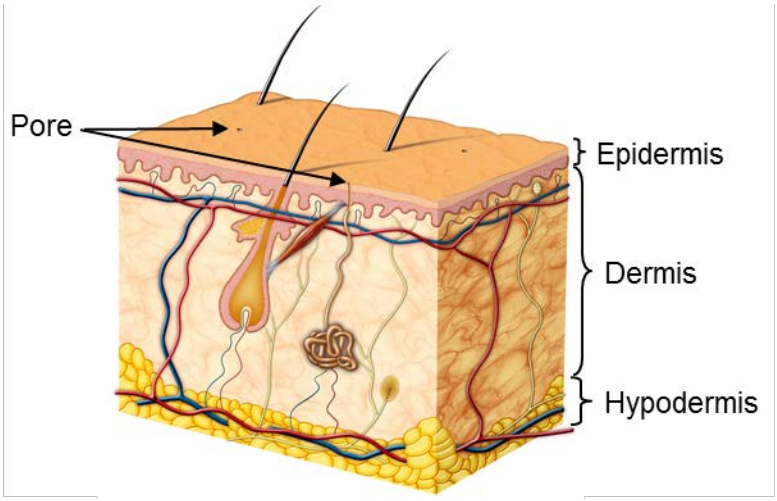


Figure 2: Basic skin anatomy.

Fingerprint Characteristics

Print ridges on finger tips are found in basic patterns with small, distinguishable variations known as **minutiae** (Table 1).

Table 1: Common Ridge Minutiae

Name	Illustration
Bifurcation (Fork)	
Double Bifurcation	
Dot	
Delta	
Ridge Ending	
Eye	
Bridge	
Island	
Spur	
Trifurcation	

The three basic patterns of finger friction ridge skin include:

Loops: Ridges enter from one side of the finger (either left or right), form a loop or hairpin turn, and exit on the same side of the fingertip from which they entered. Loop patterns can be further classified as radial loops (enter and exit toward the thumb) or ulnar loops (enter and exit toward little finger). More than 50% of people have looped fingerprints, making it the most common pattern (Figure 3).

Figure 3: Loop ridge pattern. The shaded area highlights the looped shape.

Whorls: Ridges form almost concentric circles or spirals in the center of the fingertip. Whorls can be further classified as plain whorls, central pocket loops (one ridge that makes a complete circuit without touching another ridge), double loops (two loops within the whorl), and accidental whorls (combination of other patterns). About 30% of people have whorl ridge patterns (Figure 4).

Arches: Ridges enter from one side of the fingertip, create a wave or tent shape, and exit on the opposite side from which they entered. Arch patterns can be further classified as plain arches or tented arches (sharper rise than plain arch). This is the least common fingerprint pattern (Figure 5).

Figure 4: Plain whorl ridge pattern.

Figure 5: Plain arch ridge pattern.

Collecting Fingerprint Evidence

Forensics can identify a victim, suspect, or witness by the ridge pattern that remains when a fingertip comes into contact with an object. Fingerprint residue varies, but is typically a combination of sweat, oil, dust, or other residue. A **latent fingerprint** is not visible to the naked eye. Specialized lighting or chemicals may be applied to areas suspected of containing latent fingerprints. In contrast, **patent prints** are visible to the naked eye. For example, if someone touches a substance, such as blood, grease, ink, or paint, and then touches a surface, a visible print is transferred to the object. Another type of visible fingerprint impression is a **plastic print**, which is a three-dimensional fingerprint impression left in a material, such as soap.

Figure 6: A police officer uses a powder processing technique to reveal latent fingerprints on a window sill.

The characteristics of the surface where a latent print is found determine which evidence collection method is used to document the print. For non-porous, smooth surfaces, such as a metal window sill, an investigator may use powder processing, in which a surface is dusted with a powder that sticks to fingerprint residue to reveal the fingerprints (Figure 6). The prints can then be photographed before lifting with an adhesive tape. Fingerprint powders are produced in a variety of colors to allow for the best contrast when photographing and observing prints. For porous surfaces, such as paper, technicians may use a substance that will seep into the surface grooves, such as a gel-lifter. Technicians may also use

chemicals that react with fingerprint residue to reveal fingerprints. The revealed prints can then be documented by photography. One example of a chemical that reveals latent fingerprints is ninhydrin, which binds to chemicals in the fingerprint residue and turns purple. Another example is silver nitrate, which reacts with salt in sweat residue to form silver chloride. When exposed to ultraviolet light, the fingerprint is visible as a silver color.

Recovering fingerprint impressions from fabric surfaces is more difficult than smooth, non-porous surfaces, but techniques used on plastics can reveal latent fingerprints. One example is vacuum metal deposition, which uses fine layers of gold and zinc in a heated vacuum chamber. For plastic, glass, metal, or other hard surfaces, cyanoacrylate, a compound commonly found in Super Glue®, can be heated to reveal prints. The fumes released from heating bind to fingerprint residue in a fume chamber, polymerize, and leave a chalky deposit that can be photographed. Lighting techniques can also be used to make latent prints visible.

Knowledge Check

☐ ***Is there one method for collecting fingerprints? Why or why not?***

Fingerprint Analysis

Not all fingerprints collected at a crime scene can be used to identify a suspect. Partial fingerprints or fingerprints collected from surfaces that result in poor quality prints may not reveal enough detail to distinguish minutiae. In addition to the quality of a collected fingerprint, there are other factors that need to be considered when analyzing fingerprints. While it is accepted that fingerprints are unique to every person, the uniqueness of a fingerprint has not been confirmed in scientific studies. Furthermore, there is no defined standard for what constitutes a match. For some prints, eight points may be sufficient. Others may require more to support a conclusion. Examiner skill, experience, subjectivity, and bias may also affect the determination of a fingerprint match. There have been cases in which multiple experienced fingerprint analysts have declared a fingerprint match, yet the suspect was later proven to be not guilty.

Computer programs, such as the Integrated Automated Fingerprint Identification System (IAFIS) used by the FBI and state and local authorities, are used to standardize fingerprint analysis and aid in narrowing possible matches in a relatively short time.

Lab 2 Fingerprinting

Henry Faulds
1843-1930

Figures in Forensics

While a Scottish medical missionary in Japan, Henry Faulds (1843-1930) studied fingerprints and established dactylography, the study of fingerprints for identification purposes. He tested whether fingerprints could be changed by shaving, sanding, or burning the skin, among other removal techniques. They could not: the same patterns returned after the fingers healed. Image Source: http://commons.wikimedia.org/wiki/File:Henry_Faulds2.jpg

EXPERIMENT 1: FINGER ROLLING TECHNIQUE AND MINUTIAE IDENTIFICATION

In this experiment, you will learn the general technique for fingerprint rolling. When a person has their fingerprints taken, they do not participate in the pressing or rolling of their fingerprints. Rather, fingerprints are rolled by a trained fingerprint technician. For the purposes of performing this experiment, you will take your own fingerprints. To simulate this, you will use your left hand to roll your right hand fingerprints and your right hand to roll your left hand fingerprints.

Materials

- (1) Fingerprint Ink Pad
- (1) Fingerprint Card
- (1) Hand Lens
- Masking tape
- *Camera/Smart Phone
- **Right Hand Fingerprints
- **Left Hand Fingerprints
- *Paper Towel or Clean Towel
- *Soap and Water
- *Flat Surface (see step 1 in Procedure)

*You must provide

**Discuss any needed accommodations with your instructor

Procedure

Fingerprint analysts have a recommended position to record fingerprints. The forearm should be parallel with the floor when rolling fingerprints onto the fingerprint card. Based on your height, find a flat surface, such as a table or countertop, that easily allows your forearm to be parallel to the floor. Place the fingerprint card on the surface so that the top row with the right hand labels is near the edge of the surface where you will perform the fingerprint rolling. Secure the top of the card to the surface with a piece of masking tape to keep it from falling off the table.

> Note: An actual fingerprint station will typically have a card holder to secure the fingerprint card and only expose the row being printed.

1. Remove the plastic seal and cover from the ink pad.

2. Wash your hands with soap and water. Then, dry them with a clean paper towel or towel.

3. Prepare to roll your right thumb. To do this, all other fingers should be tucked under the palm of your hand and into a fist as if you were giving a thumbs up.

4. Firmly roll your right thumb from left to right (Figure 7) over the ink pad to evenly cover the skin from one edge of the fingernail to the other, and from the crease of the first joint to the tip of the thumb.

   Note: Pressing your thumb too hard may fill the grooves of your fingerprint with ink. This will prevent you from obtaining a clear fingerprint to analyze. It may be helpful to perform a trial fingerprint on a piece of scrap paper.

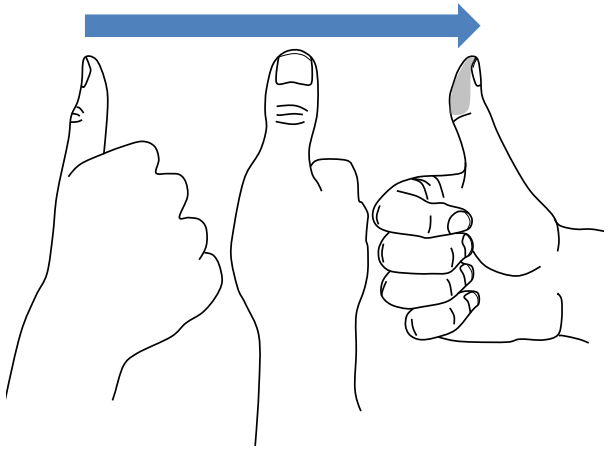


Figure 7: The thumb is rolled from one side of the nail to the other.

5. Use your left hand to position your right thumb over the area on the fingerprint card under the "RIGHT THUMB" label.

6. Place the right edge of your thumb print on the area so that the edge of your nail is touching the card. Roll your thumb from right to left, and then off the card. A quality fingerprint should clearly contain the ridge skin from nail to nail. This creates a rectangular fingerprint.

   Note: If you were fingerprinting an individual, you would stand to their left. When rolling the thumbs, you would roll them towards your body.

7. Obtain the prints for your right forefinger, right middle finger, right ring finger, and right little finger in

their allotted space using the same technique. However, for these figures, roll the print from left to right.

Note: If you were fingerprinting an individual, you would stand to their left. When rolling the fingers, you would roll them away from your body.

8. Wash your hands with soap and water to remove the ink from your hands.
9. Shift the fingerprint card away from your body so that the left hand row lays flat near the edge of the surface.
10. Use the same technique to obtain your left hand fingerprints. Remember to use your right hand to roll your left hand fingers.
11. Shift the finger print card away from your body so that the bottom row lays flat near the edge of the surface
12. Take a flat print of your right thumb by pressing it flat on the ink pad.
13. Use your left hand to press your right thumbprint flat on the bottom row of the fingerprint card labeled "RIGHT THUMB".
14. Apply ink to each of your four right hand fingers.

    Note: An actual fingerprinting station will have an ink pad large enough to apply ink to all four fingers simultaneously.

15. Use your left hand to press your four right fingers flat onto the area of the finger card labeled "RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY."
16. Wash your hands with soap and water to remove the ink from your hands.
17. Repeat these steps with your left hand. Remember to use your right hand to press your left hand fingers.
18. When you are done taking your fingerprints, wash your hands with soap and water.
19. Use a hand lens to identify the basic pattern (arch, whorl, or loop) of each fingerprint. Record these patterns in Table 2.
20. Use a camera to photograph your fingerprint card.

Note: You will need to download, scan, or print the photograph to be included with your lab report.

21. Use Table 1 in the introduction and a hand lens to identify minutiae characteristics. Also look for additional unique characteristics, like scars or creases.

Results Tables

Table 2: Fingerprint Observations

Finger	Observations
Right Thumb	
Right Forefinger	
Right Middle Finger	
Right Ring Finger	
Right Little Finger	
Left Thumb	
Left Forefinger	
Left Middle Finger	
Left Ring Finger	
Left Little Finger	

EXPERIMENT 2: LIFTING FINGERPRINTS

In this experiment, you will practice dusting and lifting fingerprints from metal and glass surfaces.

Materials

- (1) Disposable Pipette
- (1) Fingerprint Brush
- Fingerprint Powder
- (2) Sheets of Lifting Tape
- (1) Permanent Marker
- (1) Ruler
- (1) Sheet of Printer Paper
- (1) Disposable Gloves
- *Camera/Smart Phone
- *Fingertips
- *(1) Glass Surface (window, bottle, etc.)
- *(1) Metal Surface (chair, door knob, etc.)
- *Skin Oil (from face)

*You must provide

Lab Safety

You will dust for fingerprints using a fine powder on different surfaces. Choose surfaces that are easy to clean and do not pose a concern for possible stains.

Procedure

1. Place a sheet of printer paper on a table or counter top.

2. Pour a small amount of fingerprint powder onto the printer paper.

3. Rub one of your index fingers on an oily part of your face, such as your nose or cheek.

4. Press the oiled fingertip on several areas of a metal surface.

5. Put on a pair of disposable gloves.

6. Use a camera to photograph the surface before it is dusted for fingerprints.

Note: You will need to download, scan, or print the photographs to be included with your lab report.

7. Lightly dip the tips of the dusting brush into the powder and generously shake the brush over the paper to remove excess dust.

   Note: Prints can easily be overdeveloped by using too much powder.

8. Lightly twirl the fingerprint dusting brush in a circular motion over an area where you applied a fingerprint. The twirling motion will help cover all sides of the ridge detail. To avoid overdeveloping the fingerprint, ensure the brush does not contact the surface too much.

9. Use a disposable pipette to puff air over the fingerprint and remove excess dust.

10. If the fingerprint is overdeveloped, repeat steps 7 – 9 as needed until a viable fingerprint is developed. This is a skill that requires practice. Do not proceed to the rest of the procedure until you are satisfied with the fingerprint. You only receive two sheets of lift tape in your kit, one for each surface.

11. Use a camera to photograph the revealed fingerprint.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

12. Peel and discard the clear plastic cover to expose the adhesive side of the lift tape. Be careful to avoid contaminating the black background with fingerprint dust.

13. Place the adhesive side of the lift tape on the fingertip area and cover the entire print.

14. Carefully remove the tape from the surface by gently peeling it away. The print should lift with the tape.

15. Press down the adhesive side of the tape against the black background. Use the edge of a ruler to remove any bubbles from the tape. Use caution to keep the print intact.

16. Use a permanent marker to label the top of the tape with the date and your initials under the corresponding labels. Under the case # and date write “metal.”

17. Repeat this procedure on a glass surface using the tape labeled “glass.”

18. Use a camera to photograph the lift tape with fingerprints.

Note: You will need to download, scan, or print the photographs to be included with your lab report.


DYS DYS DYS DYS DYS DYS DYS DYS DYS DYS DYS
385b 388 389I 389II 390 391 392 393 426 438 439 441
17 16 13 15 19 14 17 16 13 15 19 14

Lab 3

DNA

Lab 3 DNA

LEARNING OBJECTIVES

- Identify DNA structure and function and explain its role in forensics
- Perform a DNA extraction
- Perform gel electrophoresis and analyze the results to determine unknowns

INTRODUCTION

All living things are made of **cells**, the basic unit of life. The human body is composed of trillions of cells, which can be differentiated into approximately 200 subtypes, ranging from skin cells to blood cells. All cells contain the same genetic content, which is unique to an individual. Although humans share approximately 99.9% of the human genome, the unique variance that remains allows for accurate identification. This can be utilized in crime scene investigation to identify individuals through **DNA profiling.**

Biological evidence is any object collected at a crime scene that contains cell or tissue samples. This includes blood (Figure 1), saliva, skin cells, semen, and sometimes hair. When collecting biological samples, it is best to collect the entire surface on which the sample is located. For example, if blood is found on a shirt, the entire shirt should be collected. If this is not possible (e.g., the sample is on the ground or the floor), a sterile swab is used to collect the sample, which is then stored in a breathable container. It is important to use a breathable container because biological samples stored in air tight containers are more susceptible to moisture and mold damage.

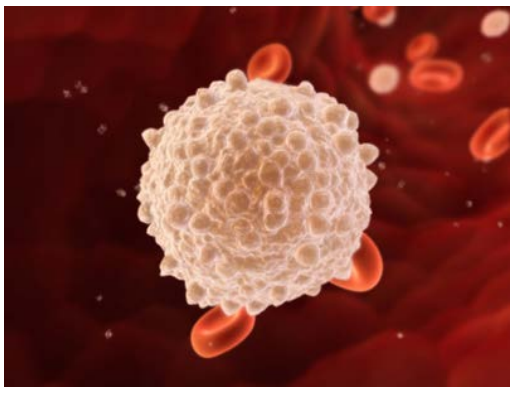


Figure 1: White blood cells contain DNA housed in a nucleus, while mature red blood cells do not. This lack of nucleus allows mature red blood cells more space to carry oxygen and more flexibility to fit through blood vessels.

DNA

Most of a cell's hereditary information is encoded by the genome and stored in the cell nucleus. A portion is also located in the mitochondria. The **genome** is the sum of all the genes present in a cell and is composed of strands of macromolecules, called **nucleic acids**. Specifically, the genome is composed of **deoxyribonucleic acid (DNA)**. A **DNA molecule** consists of two entwined sets of nucleotides. **Nucleotides** consist of a nitrogenous base, a sugar molecule, and a phosphorous atom surrounded by four oxygen atoms. Together, the sugar molecules and phosphate atoms create the "backbone" of a DNA molecule.

The two sets of nucleotide sequences are held together by hydrogen bonds between the nitrogenous bases. There are four different nitrogenous bases in DNA: adenine (A), cytosine (C), guanine (G), and thymine (T). Guanine and adenine are classified as **purines** due to their double ring structure. In contrast, cytosine and thymine are classified as **pyrimidines** due to their single ring structure. Nucleotides bond together in a specific fashion, referred to as **complementary base pairing**. Adenine shares two hydrogen bonds with thymine (A - T) and cytosine shares three hydrogen bonds with guanine (C - G). When these hydrogen bonds are formed, the complementary bases are considered **base pairs**. These bonds also influence the structure of DNA. Imagine a rope ladder that has been twisted. The twisted structure of a DNA molecule is called a **double helix**. The sides of the ladder are the sugar phosphate backbone and the rungs of the ladder are the base pairs (Figure 2).

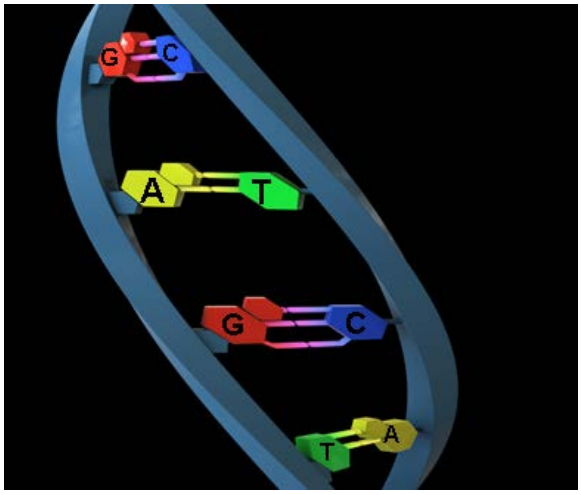


Figure 2: A simplified model of DNA. The hydrogen bonds between complementary base pairs and the sugar phosphate backbone gives DNA its double helix shape. Notice the double ring and single ring structure of the purines (G and A) and the pyrimidines (C and T).

Genes

According to the Human Genome Project (http://www.genome.gov/11006943), there are over 3,000,000,000 base pairs in the human genome. These base pairs are responsible for encoding approximately 22,000 genes, each composed of an average of 3,000 base pairs. **Genes** are segments of DNA that code for proteins, the functional building blocks of cells. Genes are located on all 23 pairs of human chromosomes (Figure 3). Because each chromosome exists as two copies (except for the sex chromosomes, X and Y), there are two **alleles**, or versions, of each gene. These genes can be transcribed into ribonucleic acid (RNA) and further translated into proteins.

While most of a cell's DNA is located within the nucleus, **mitochondrial DNA** (**mtDNA**) is found in the mitochondrion. The **mitochondrion** is a cell structure responsible for converting energy into usable forms for the body. Each cell may contain hundreds of mitochondria. As a result, there are many more copies of mtDNA per cell than nuclear DNA because there is only one nucleus per cell. mtDNA is also unique from nuclear DNA because it is only passed down through the maternal line of inheritance. In other words, males are not able to contribute mtDNA to their offspring. This is helpful to forensic scientists because they can refer to the mtDNA of female relatives for genetic information.

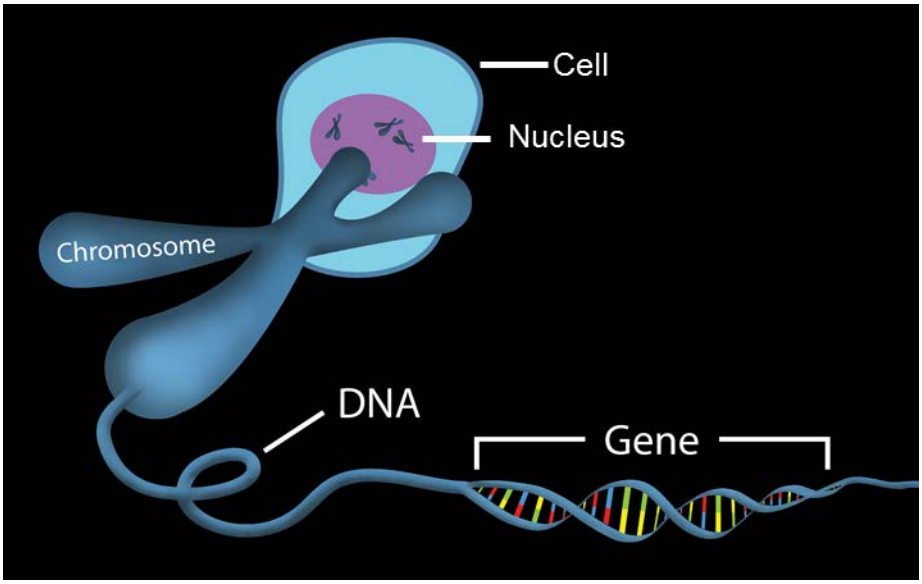


Figure 3: Chromosomes are composed of tightly coiled strands of DNA molecules. Genes are portions of DNA that encode usable information.

Knowledge Check

☐ *How do genes relate to DNA and chromosomes?*

Short Tandem Repeats

DNA profiling would be very difficult without a marker or flag within the genome to indicate where genes are likely located. **Short tandem repeats (STRs)** are portions of DNA estimated to comprise approximately 30% of the human genome. Interestingly, STRs do not code for any translated genetic material or affect the human phenotype (physical appearance). Just like the coding portions of DNA, STRs are inherited from parents and considered part of the genetic makeup. They are one of the most effective ways to analyze genetic content because it is easier to amplify shorter segments of DNA. Since STRs are more prevalent than gene-encoding DNA, CSIs are more likely to collect STRs at a crime scene than an entire genome.

STRs are typically composed of a sequence of three to seven bases that repeat within a DNA molecule (Figure 4). These sequences are flanked by non-STR DNA sequences at either end. The repeated group of bases comprising the STR may include one or more different bases, and can be repeated many times, reaching up to 450 bases. While this may seem long, remember that the human genome contains approximately 3,000,000,000 base pairs. The short length of STRs enhances their molecular stability, making them ideal for forensic analyses in which sample preservation is critical.

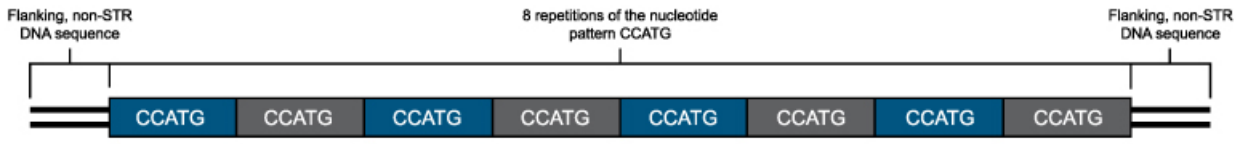


Figure 4: Example of an STR sequence. The blue and gray segments represent a repeating STR segment. In this example, the STR CCATG is repeated eight times. The STR sequence lies between non-STR DNA sequences.

While the precise biological function of STRs is not fully understood, they create space between the gene coding portions of DNA. A database has been created that matches STR sequences to genes located in close proximity. Therefore, STRs can provide a link to the genes present in a sequence of DNA.

DNA Extraction

When biological evidence containing DNA is collected at a crime scene or a DNA sample is taken from a suspect, the DNA located within the cell nucleus. To perform DNA analyses, such as an STR analysis, the DNA must first be extracted from the cells. DNA extraction begins by spinning the sample in a centrifuge, causing the cells to collect at the bottom of the centrifuge tube as a pellet. The remaining liquid media is removed, and the cells are lysed (broken) in a detergent solution of soap and salt. In a laboratory, this is usually sodium dodecyl sulfate (SDS). This lysis breaks down the cell membrane and nuclear membrane, releasing DNA, RNA, and proteins from the cells into the detergent solution. Next, the freed DNA is separated from the RNA and proteins. To do this, scientists take advantage of one of DNA's physical properties: solubility. DNA is soluble in water, but not in alcohol. Adding alcohol to the detergent solution causes the DNA to separate, or **precipitate**, out of the solution. Salt can facilitate precipitation by neutralizing the negatively charged phosphate backbone of DNA, causing it to agglomerate with itself (Figure 5).

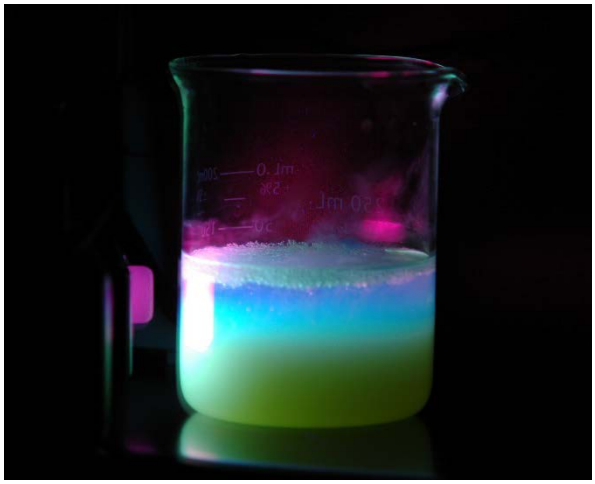


Figure 5: A DNA extraction. DNA is visible at the top of the solution after being dyed with a substance that glows under black light.

Polymerase Chain Reaction (PCR)

Even after DNA has been extracted from a sample, there may not be enough present to be detected. To amplify, or make many copies of, the extracted DNA for analysis, a **polymerase chain reaction** (**PCR**) is often performed. Unlike cell division, which occurs in the nucleus, PCR can replicate small or broken fragments of DNA. The short length of STRs makes them an ideal candidate for PCR.

PCR can create millions of DNA copies in only a few hours and requires very small amounts of DNA to begin the process. Under ideal conditions, PCR follows an exponential growth pattern. The amount of DNA doubles with every reaction cycle. A PCR setup includes:

- **Template DNA**: Acquired from the sample. In forensics, an STR is often used for the template DNA.

- **Primers**: A nucleic acid strand synthesized within a laboratory to match a portion of the template DNA sequence. Two primers are required, one for each strand of the template DNA after it is unwound. The primers ensure that the DNA polymerase attaches to the template DNA in the correct location.

- **Free Nucleotides**: Provide the DNA polymerase with a stock of nucleotides to copy the template DNA.

- **Thermostable DNA Polymerase**: An enzyme required to copy the template DNA. It attaches to the primers and recruits the correct free nucleotides to the template DNA until it is fully copied. In PCR, the polymerase must be stable enough to withstand temperatures capable of unwinding DNA without denaturing in structure. *Taq* polymerase is often used (derived from extremophile bacteria living in thermal springs).

The mixture is heated to just below boiling to **denature** or “unzip” the template DNA strands. This causes the DNA to uncoil and nucleotides to become available for copying. It is then cooled to a temperature that facilitates hydrogen bonding between the primers and the denatured DNA. This step is referred to as **annealing**. Next, the temperature is raised slightly to allow the DNA polymerase to use the primer-DNA hybrids as templates to synthesize and elongate new DNA molecules. The mixture is then heated again to denature the strands and the process starts over. This cycle is typically repeated 30 - 40 times, producing millions or billions of copies of the original DNA template (Figure 6). This procedure has revolutionized molecular biology, genomics, forensics, and diagnostic testing.

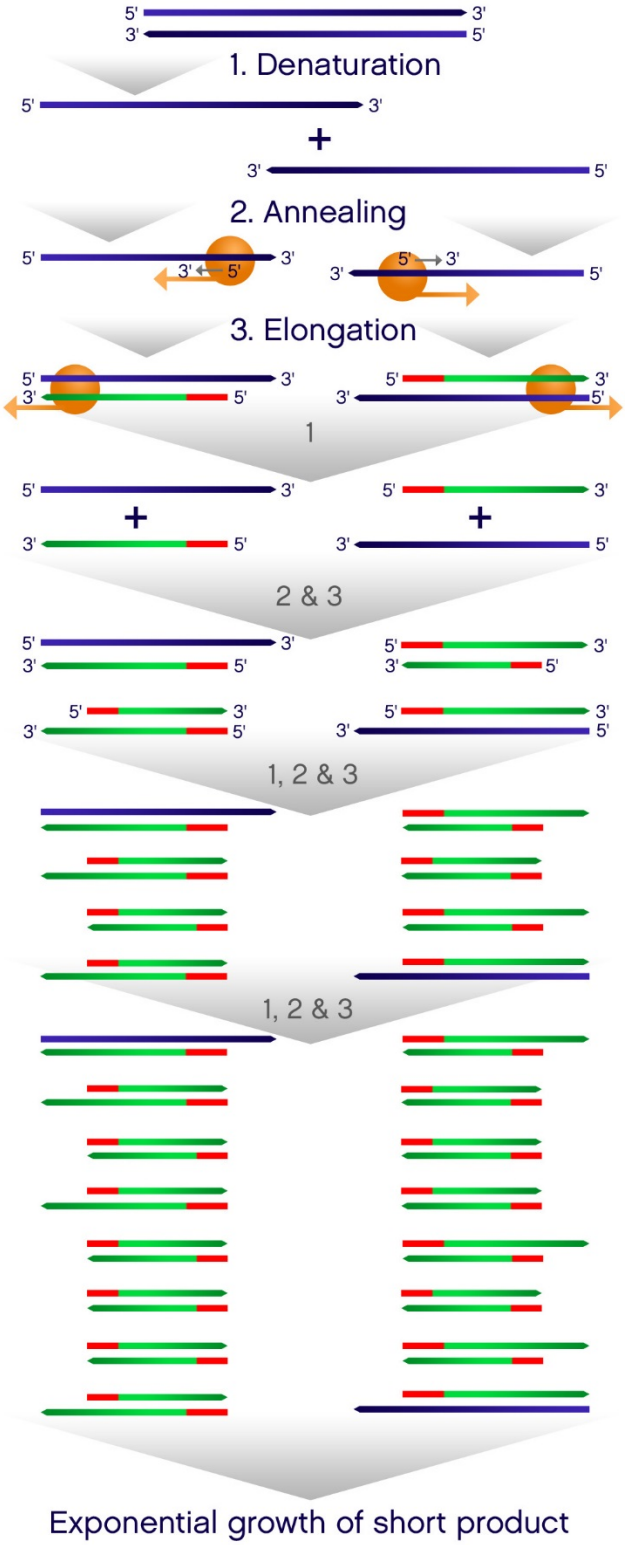


Figure 6: The PCR process.

Knowledge Check

☐ *Why is PCR performed prior to gel electrophoresis?*

Gel Electrophoresis

After a sequence, such as an STR, has been amplified through PCR, it must then be measured before it can be analyzed for matches to samples from suspects or victims. **Gel electrophoresis** is a molecular technique that uses an electric current to separate macromolecules by molecular weight and charge through a permeable gel. The gel is a three-dimensional medium with pores of a specific size that act as a sieve for the molecules passing through the gel. The gel has a loading zone in the form of wells where molecular samples can be deposited. Loading an electrophoresis gel with samples requires patience and practice (Figure 7). The sample must be carefully and slowly pipetted into the wells at the top of the gel. Once in the wells, the molecules are stimulated by an electric current flowing through the gel and migrate through the gel at different rates. These rates are largely dependent on the molecular size and charge of the sample. For example, smaller molecules, which can easily fit through the pores in the gel, migrate at a high rate and therefore travel a farther distance down a gel. In contrast, larger molecules may get physically caught in the gel. Therefore, they migrate at a slower rate and do not travel as far as smaller molecules. Additional factors that affect migration are gel density and the strength of the electric field.

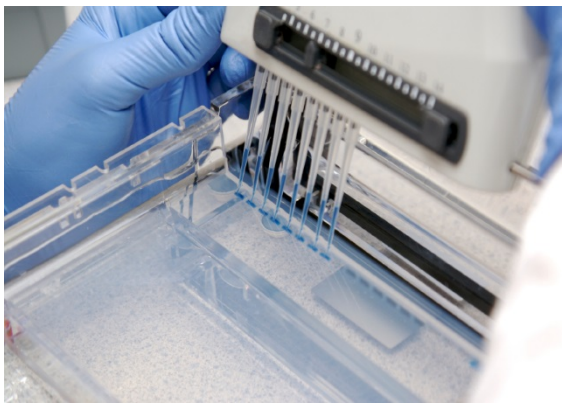


Figure 7: Micropipettes are often used to fill wells in a gel electrophoresis procedure.

As the sample moves through the gel, similar sized components group together and form bands. If the samples within the gel are then dyed, distinct bands can be seen (Figure 8). These bands can be correlated to a molecular marker (or standard) to determine the molecular weight of the sample in each band. This

provides evidence that can lead to the biomolecular identification of each component. Electrophoresis can be used to compare the genomes of different organisms or individuals, as well as to locate and identify a specific gene of interest.

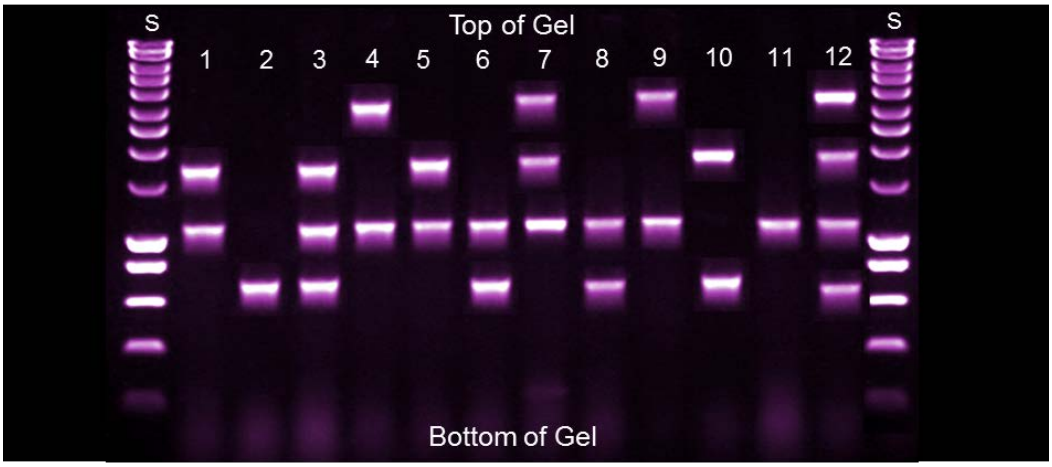
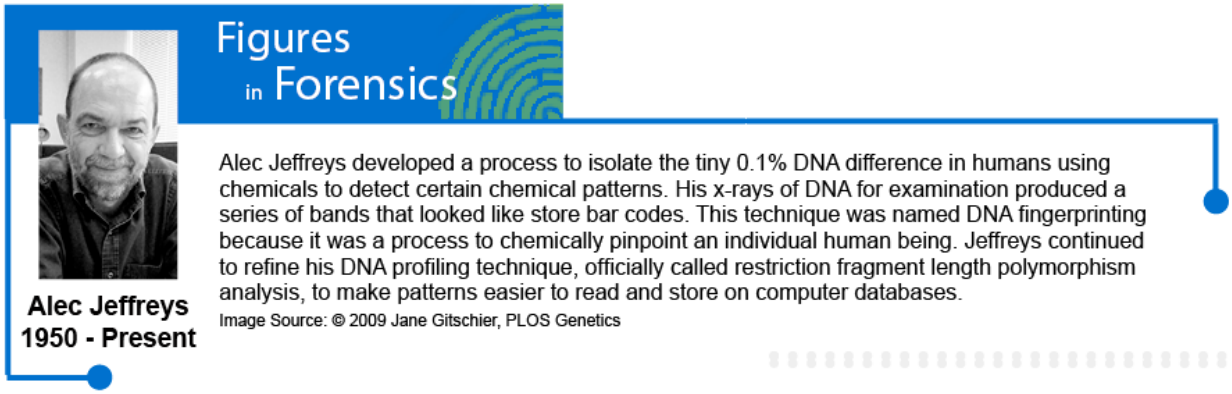


Figure 8: A fluorescent dye that binds DNA can be used to visualize DNA bands after the gel has been run. Each band indicates a different length DNA strand. Therefore these bands represent genetic alleles. Standard samples, shown on the sides, allow for comparison of unknown samples. Samples travel from the top of the gel to the bottom of the gel in columns. In this image, 12 samples are visible with one standard sample on each side.

There are hundreds of different STR sequences found in the human genome. The more sequences identified using PCR and gel electrophoresis techniques, the more likely a forensic scientist is to determine the identity of an individual, because a smaller percentage of the population will have the same combination of STR alleles.



EXPERIMENT 1: DNA EXTRACTION

In this experiment, you will perform a modified DNA extraction using a soft fruit, such as strawberries, grapes, or bananas. You will then apply your knowledge of DNA to forensics.

Materials

- (1) Cheesecloth
- DNA Extraction Solution
- (1) Funnel
- (1) 10 mL Graduated Cylinder
- Ice Cold Ethanol (place in freezer 60 minutes before use)
- (1) Rubber Band
- (1) Sealable Plastic Bag
- (1) 50 mL Standing Tube with Cap
- (1) Wooden Stir Stick
- (1) Pair of Disposable Gloves (located in your safety kit)
- *Camera/Smart Phone
- *Fresh Soft Fruit (strawberry, grapes, banana, etc.)
- *Scissors
- *Water

*You must provide

Procedure

1. Place the bottle of ethanol in the back of a freezer for approximately 60 minutes.

2. While the ethanol is in the freezer, put on your gloves and break the soft fruit into several pieces.

3. Place the pieces of soft fruit (approximately the combined size of five grapes) into a sealable plastic bag, press the air out, seal the bag, and mash thoroughly with a fist.

4. Use a 10 mL graduated cylinder to measure and pour 10 mL of DNA extraction solution into the plastic bag with the mashed fruit. Remove excess air and seal the bag completely.

   Note: If the DNA extraction solution bottle has a dropper lid, carefully remove it to make pouring easier.

5. Mix well by kneading the bag for 2 minutes.

6. If the cheesecloth in your kit is folded, unfold it so that it is one layer thick.

7. Create a filter by placing the center of the cheesecloth over the mouth of the standing test tube and pushing it into the tube to approximately the 20 mL mark (Figure 9).

8. Secure the cheesecloth with a rubber band around the top of the test tube (Figure 9).

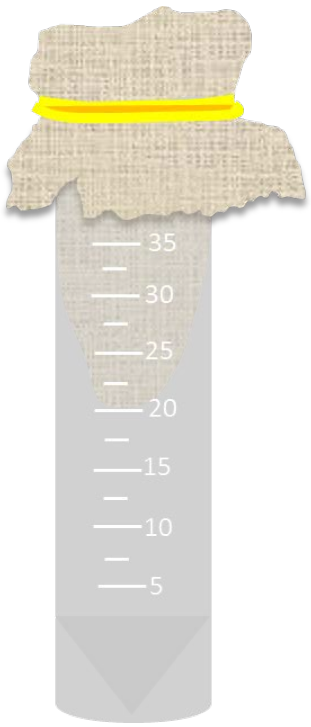


Figure 9: How to create a cheesecloth filter. Push the unfolded cheesecloth into the tube and secure it with a rubber band.

9. Use the scissors to cut a small (approximately half an inch wide) hole in the bottom corner of the plastic bag and filter your extraction by slowly pouring it into the cheesecloth until the cheesecloth is full.

10. Allow the fruit extraction solution to rest for 20 min. You may wish to add more fruit extraction solution during the 20 min as space in the cheesecloth becomes available. Expect approximately 5 mL or less of the solution to filter into the standing test tube.

    Note: Allow gravity to filter the solution. Do not press the solution down, as solid particles may enter the filtered solution.

11. While the fruit extraction solution filters, rinse the 10 mL graduated cylinder with water.
12. After 20 min have passed, keep the filtered solution in the standing test tube and discard the remaining pulp that becomes caught in the cheesecloth.
13. After 60 min have passed, remove the ethanol from the freezer.
14. Use the 10 mL graduated cylinder to measure 5 mL of ethanol.
15. Place the neck of the funnel into the standing test tube and hold the standing test tube at a 45° angle.
16. While holding the test tube with funnel in one hand, slowly pour 5 mL of ice-cold ethanol into the standing test tube with the other hand. Pouring the ethanol slowly keeps it from mixing with the fruit extraction solution. A distinct layer of ethanol should rest at the top of the test tube.
17. After approximately 5 min, the DNA will precipitate, or come out of, solution. If there is a light source nearby, hold the test tube up to the light to better observe the cloudy clumps and strands of DNA.
18. Gently insert the wooden stir stick into the standing test tube and slowly raise and lower the tip several times to spool and collect the DNA. If there is an insufficient amount of DNA available, it may not float to the top of the solution in a form that can be easily spooled or removed from the tube. However, the DNA will still be visible as white/clear clusters by gently stirring the solution and pushing the clusters around the top.
19. Use a camera to take a picture of your completed experiment.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

20. When you have completed the DNA extraction, clean up by thoroughly rinsing labware that may be reused, such as the graduated cylinder. Discard items that cannot be reused, such as the stir stick and plastic bag, into a trash receptacle.

EXPERIMENT 2: GEL ELECTROPHORESIS

In this experiment, you will prepare an agarose gel and use an electric current to separate dyes of different molecular weights and charges. You will also analyze two unknown dyes and determine their composition based on results from your known samples.

Materials

- 15 mL of 0.8% Agarose
- 15 mL of 1X TBE Buffer
- Methyl Orange
- Ponceau G
- Pyronin
- Unknown #1
- Unknown #2
- Xylene Cyanol
- (2) Alligator Clips
- (1) 9V Battery
- (1) 100 mL Beaker
- (1) Carbon Fiber Fabric
- (1) 100 mL Graduated Cylinder
- (6) Micro-Tip Pipettes
- (1) Mini Gel Electrophoresis Chamber with 6-Tooth Comb
- (1) Ruler
- (1) Transfer Pipette
- (1) Pair of Disposable Gloves
- (1) Pair of Safety Glasses
- *Hot Pad or Towel
- *Microwave Oven or Boiling Water Bath
- *Paper Towels
- *Scissors
- *Water
- *Camera/Smart Phone

*You must provide

Procedure

1. Put on your safety glasses and a pair of disposable gloves (located in your lab safety kit).

2. Insert the gel chamber comb into the slots at one end of the gel box. The comb will cause the agarose to mold around its teeth and create wells once the gel has cooled and solidified. The teeth of the comb should not touch the bottom of the chamber.

   Note: The end of the gel chamber that you insert the comb into will be referred to as the "top" end of the chamber and the opposite end will be referred to as the "bottom" end of the chamber (Figure 10).

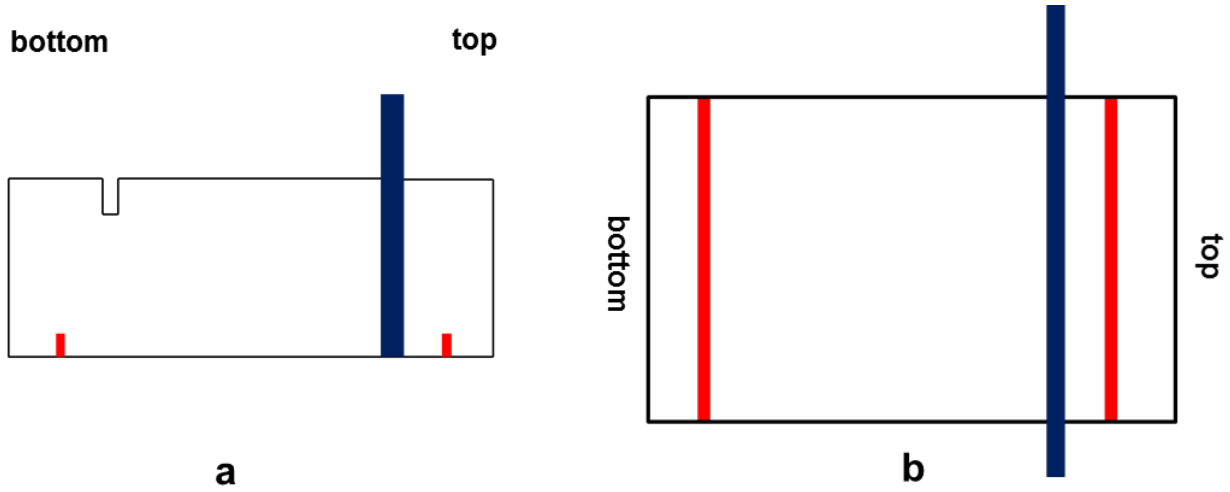


Figure 10: Side view (a) and top view of the gel chamber (b). The dark blue line represents the comb and the red lines represent the inner walls of the chamber. The side of the chamber where the comb is placed is called the "top" of the chamber.

3. Prepare the 0.8% agarose by loosening the cap on the agarose bottle and placing it in a microwave (Step 3a) or hot water bath (Step 3b). Note that the microwave option is typically much easier to execute. Monitor the bottle very closely. The agarose needs to be completely melted to avoid solid chunks of gel in the chamber, but can also boil over the edge of the bottle very quickly.

   LAB SAFETY: Agarose becomes very hot very quickly. It is extremely important to watch the bottle very closely to prevent unintentional boiling over or explosions. Do not touch the bottle immediately after heating. Instead, make sure the bottle has cooled to touch and use a hot pad or towel when removing the bottle from the heat source.

   a. If using a microwave, turn the microwave on normal heat and heat the agarose in increments

starting at 8 - 10 seconds. After each increment, stop the microwave, protect your hands from heat, and gently swirl the container to evenly distribute the heat. Once the agarose starts to melt, stop the microwave every 3 – 5 seconds to swirl the agarose. It should take approximately two minutes to prepare agarose in the microwave.

b. If using a boiling water bath, allow for more than two minutes to melt the entire contents of the container. Be sure that the water does not cover the agarose container or mix with the contents of the container.

4. Use a hot pad or towel to remove the bottle from the microwave or boiling water bath. The bottle and cap will be hot.

5. While the agarose is still melted, carefully pour it into the gel chamber until it reaches the top of the two inner chamber walls. Only pour enough agarose to fill the area between the two raised inner walls of the chamber (Figure 11).

Hint: The inner walls are easiest to view from the side. They are located approximately $^{1}/_{4}$ inch from the top and bottom ends of the chamber. It may help to be eye level with the chamber when pouring the agarose. When looking straight on from a side view, you can see the height of the grooves and where to stop when pouring the agarose.

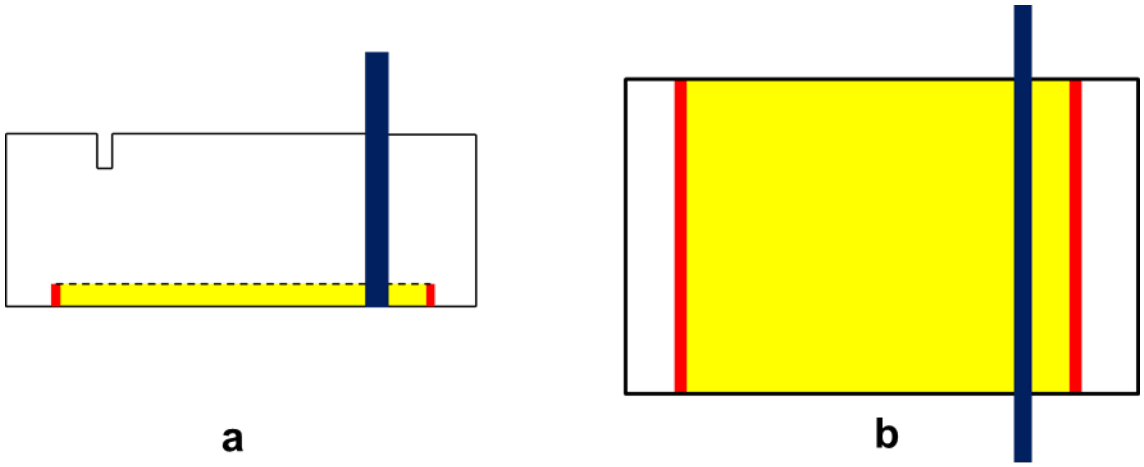


Figure 11: Side view (a) and top view of the gel chamber (b). The yellow area represents the area to be filled by the agarose.

6. While the agarose is still liquid, it is important to remove any air bubbles that may have been introduced

while pouring. Gently tap the side of the gel chamber without causing the agarose to spill over the inner chamber walls. You may also use a disposable transfer pipette to "poke" or move any bubbles to the sides of the chamber.

7. Allow the agarose to rest until it is solidified (approximately 10 – 15 min).

8. While the agarose solidifies, use a ruler and scissors to measure and cut two 5.5 x 4 cm pieces of carbon fabric.

9. Fold the fabric pieces in half with the 4 cm edges touching each other so that they are two layers thick.

10. Set the carbon fabric pieces aside, along with the 9V battery and two alligator clips. You will need them immediately after you load the samples to the gel.

11. Place the gel chamber on a piece of paper towel. Use the 100 mL graduated cylinder to measure and pour 15 mL of 1X TBE buffer. This will completely submerge the agarose (Figure 12).

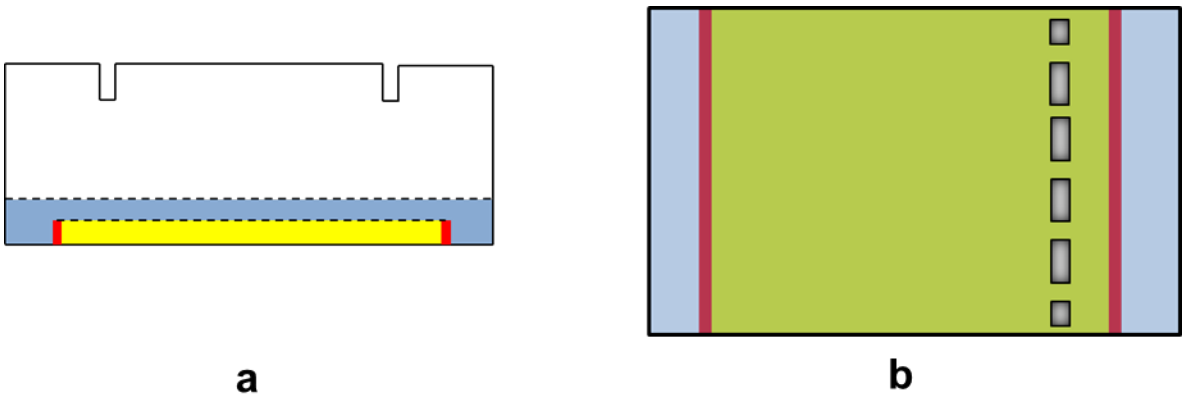


Figure 12: Side view (a) and top view of the gel chamber (b). The blue area represents the TBE buffer solution once it has been poured into the gel chamber. The comb has been removed and six sample wells are visible.

12. Carefully remove the comb without breaking the gel. To do this, gently wiggle the comb to loosen it. Then, pull the comb directly up and out of the gel. You should now see six wells in the gel (Figure 12). This is where you will pipette the samples.

13. Use six micro-tip pipettes to load the dye samples from left to right in the following order: pyronin, methyl orange, ponceau G, xylene cyanol, Unknown #1, and Unknown #2. To load the dyes, perform the following steps:

a. If the dye bottle has a dropper lid, carefully remove it and place it on a clean paper towel.

b. Use the micro-tip pipette to pick up 20 µl of the first dye, pyronin. 20 µl will fill the narrow, bottom portion of the pipette.

c. Expel any air that is at the tip of the pipette so that it is not introduced into the well. Do this by squeezing the bulb until the dye is at the mouth of the pipette and holding the bulb in that position until you are ready to release the dye into the well. Use a clean paper towel to remove excess dye off the outside of the pipette so as to not introduce any dye into the TBE solution.

d. Submerge the tip through the TBE buffer targeting the desired well and slowly dispense the dye sample into the well by gently squeezing the bulb on the pipette even further. Keep the bulb firmly squeezed until the pipette is completely removed from the TBE buffer to avoid sucking any TBE or dye back into the pipette. See Figure 13 for reference.

Figure 13: When loading the samples, try not to squeeze an air bubble into the well. This will make the dye come out of the well. Dyes seen here are not in the same order as the procedure.

e. Replace the dropper lid and cap on the bottle of dye.

f. Using a clean micro-tip pipette and a new well for each sample, repeat Steps 13a - 13e for each dye sample.

Note: The dyes have been mixed with a sucrose solution to increase their density and ensure your sample will fall gently into the well. However, it is still important to apply the electric current

relatively quickly after pipetting the samples to avoid allowing the dyes to diffuse out of their respective wells.

14. Fasten one piece of carbon fabric on the inside of each end of the gel chamber by clamping one alligator clip over the fabric at the top end of the chamber (the end closest to the wells) and the other alligator clip over the fabric at the bottom end, as shown in Figure 14. The carbon fabric should not touch the TBE buffer.

    Note: Do not fold the carbon pieces over the edge of the gel chamber. Capillary action will cause the TBE buffer solution to run up the carbon fabric, over the sides of the chamber, and drip onto your workspace.

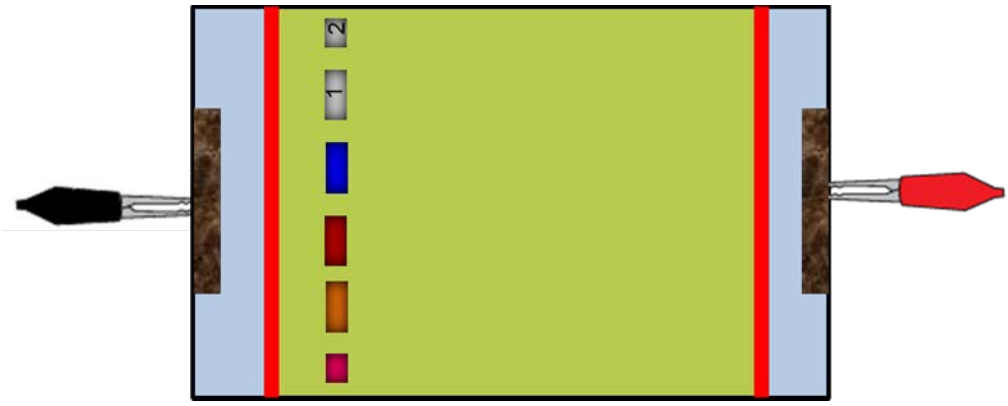


Figure 14: Top view of gel chamber. Notice how the carbon paper (brown shape) is clipped to the inside wall of the chamber by the alligator clip.

15. Attach the end of the top end alligator clip to the negative terminal on the 9V battery. Attach the end of the bottom end alligator clip to the positive terminal on the 9V battery, as shown in Figure 15.
16. Observe the gel box carefully over the next hour. Gels must be analyzed immediately after electrophoresis because the color bands can diffuse and bleed over time.

    Note: Placing a blank, white sheet of paper or a light colored surface under the gel chamber will make it easier to see dye separation.

17. Once separation of the dyes has been achieved, disconnect the alligator clips from the battery.

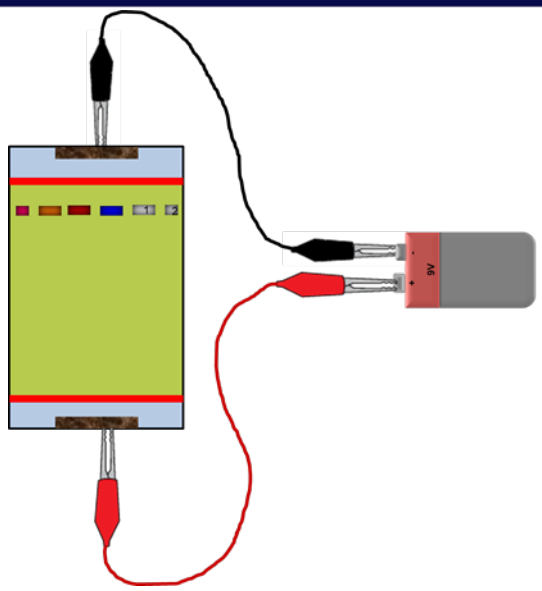


Figure 15: Top view of gel chamber. The top end of the chamber has been connected to the negative terminal of the battery and the bottom of the chamber has been connected to the positive terminal of the battery.

18. Take a picture of your gel. It may help to place the gel on a blank, white piece of paper or a light surface. Record the number of bands visible for each dye sample in Table 1.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

19. Use a ruler to measure the distance from the wells to the center of the bands for each dye and record the distance for each band in Table 1. To do this, carefully place the gel chamber over a ruler. Use a negative sign to indicate distances traveled toward the top of the gel chamber and a positive sign to indicate distances traveled toward the bottom of the gel chamber.

    Note: Dyes may travel in both directions.

20. When you have completed the gel electrophoresis, clean up by thoroughly rinsing labware that may be reused, such as the graduated cylinder. Discard items that cannot be reused into a trash receptacle.

Results Tables

Table 1: Gel Electrophoresis Dye Migration Distance and Band Separation

Well	Sample Name	# and Color of Bands	Migration Distance per Band (mm)
1			
2			
3			
4			
5			
6			

Lab 4

Blood

Lab 4 Blood

LEARNING OBJECTIVES

- Explain the role of blood and bloodstain patterns in forensic science
- Analyze and identify bloodstain patterns by performing bloodstain analyses

INTRODUCTION

Blood, a type of biological evidence, consists of red blood cells, white blood cells, and a liquid called plasma (Figure 1). Blood is fundamental to crime scene investigation because it can provide a wealth of information about a crime. Many aspects of the crime, including the height of the blood source was located, how much blood was spilled, the angle of impact, and the force at which the blood was spattered, can be determined using blood. It can also aid in identification through blood typing and genetic (DNA) analysis.

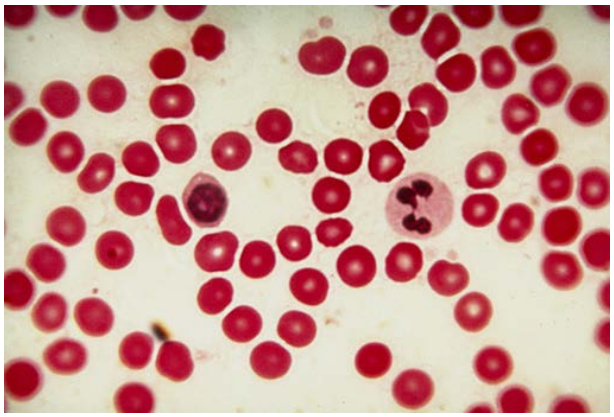


Figure 1: Red blood cells (bright red) and white blood cells (light pink with a dark nucleus) are suspended in plasma.

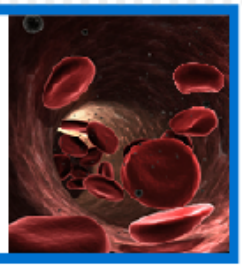
Blood

To fully understand the power of blood in forensics, one must understand the molecular components of blood cells. The adult human body contains approximately five liters of blood, accounting for nearly 8% of a person's body weight. The majority of blood consists of **plasma**, an aqueous solution composed of over 90% water that contains proteins, minerals, blood cells, and cell fragments. Plasma contributes to approximately 55% of blood. Among the cells suspended in plasma, red blood cells, also called erythrocytes, are predominant, composing 45% of blood. Additionally, white blood cells and platelets are also suspended in plasma.

Lab 4 Blood

Did You Know?

There are several different types of blood cells, although erythrocytes are predominant. These cells are responsible for transporting oxygen from the lungs to tissues and cells throughout the body. They are able to do this highly specialized function because of a special iron-containing protein called hemoglobin. Hemoglobin possesses a special binding site for oxygen, which can be released into tissues. Hemoglobin also gives blood its characteristic scarlet color; however, it emits a purple-blue hue when deoxygenated. This is why veins appear purple. Other types of blood cells are white blood cells, including macrophages, neutrophils, and basophils, which perform specialized functions during an immune response. Finally, platelets function to stop bleeding by forming clots at the sight of wounds.



Testing for Blood

The presence of blood at a crime scene often indicates a physical struggle and provides clues about the criminal event. However, the first step to using blood in forensic analysis is to determine if an unknown sample is actually blood. The following tests can be performed to determine the presence of blood in an unknown substance and if a blood sample is from a human or other animal:

- **Kastle-Meyer blood test:** Used in preliminary crime scene investigations due to the simplicity and low cost of the test. Phenolphthalein (a chemical indicator), followed by a drop of hydrogen peroxide, are added to the unknown sample. If blood is present, the iron in the blood cell protein hemoglobin will oxidize phenolphthalein, turning it a vivid pink color.
- **Luminol test:** A potential bloodstain is sprayed with luminol reagent. If the unknown sample produces a light blue glow after contact, the sample is likely blood. This method is accurate, but not always practical, because the glow is very faint and requires a dark environment to clearly view the results.
- **Bluestar test:** Similar to the luminol test, but produces clearer results that do not require a dark environment.
- **A precipitin test**: After a sample is confirmed to be blood, this test determines the presence of human blood versus another animals' blood.

Lab 4 Blood

Figures in Forensics

Paul Theodar Uhlenhuth 1870-1957

Paul Theodor Uhlenhuth, a German bacteriologist, experimented with blood serum. When he injected a chicken's blood into a rabbit, and then mixed the serum from the rabbit blood with an egg white, the egg proteins separated from the mix. This act of separation led to his 1901 discovery of a test to distinguish animal blood from human blood, termed the species precipitin test. Until that time, animal blood and human blood could not be distinguished. Image Source: © U.S. National Library of Medicine, History of Medicine Division, http://ihm.nlm.nih.gov/luna/servlet/view/search?q=B025272

Bloodstain Analysis

The patterns of bloodstains found at the crime scene can indicate what occurred during a crime. Like all other matter, blood follows the laws of physics as it is projected and hits a surface. It may provide information about the type of weapon, the time since the crime occurred, the injuries involved, or even the handedness of the criminal.

Angle of Impact

The characteristics of a bloodstain depend on the angle at which blood spatter hits a wall. For example, a drop of blood that hits a surface head-on at a 90º angle will have a fairly circular shape. As the angle of impact becomes smaller, a bloodstain usually takes on a more elongated, elliptical shape. This makes sense because, the more horizontal the path taken by the spatter, the more horizontal motion it will have when it hits the surface.

Origin and Direction of Travel

The direction from which blood spatter came can also be determined by analyzing bloodstain patterns. If blood spatter hits a surface from left to right, the right side (or the direction in which the drop traveled) will generally come to a point and the left side of the stain will be rounded (Figure 2). If multiple spatters from the same origin occur, their direction of travel can be traced to where they intercept to determine where the origin was. This can be useful to determine if a body has been moved.

Figure 2: Direction of travel from left to right.

Parent Drop

The original source from which the rest of the spatter was created is referred to as the **parent drop**. It is usually characterized by a larger bloodstain with smaller spatter emanating from it.

Figure 3: A parent drop on the left and a satellite drop on the right. Note how the satellite drop has it pointed end in the opposite direction that the blood was traveling.

Satellite Spatter

Smaller drops of blood that originate from a parent drop and rest in a position that surrounds the parent drop are called **satellite spatter**. They may take on a circular shape or, with enough velocity, take on an elongated shape. Satellite bloodstains typically have a more pointed end oriented opposite the direction of travel (Figure 3).

Spine

Spines are pointed or curved lines that extend out from the parent drop.

EXPERIMENT 1: BLOODSTAIN ANALYSIS - HEIGHT AND VOLUME

While blood samples are often used as evidence of who was involved in a crime, the bloodstain itself is also useful to learn about what happened during a crime. In this experiment, you will simulate bloodstains and distinguish between the effect of height and volume on the resulting patterns.

Materials

- Simulated Blood
- (3) Pieces of Cardstock
- Masking Tape
- (1) Permanent Marker
- (1) Ruler
- (1) Tape Measure
- (1) Transfer Pipette
- (1) Pair of Disposable Gloves
- (1) Pair of Safety Glasses
- *Camera/Smart Phone
- *Paper Towels
- *(1) Pencil
- *Adjacent Floor and Wall

*You must provide

Lab Safety

The simulated blood sample may cause stains to cloth or other materials. Small amounts of simulated blood will get on the walls and floor where the experiment is performed. Complete this experiment in an area where blood splatters will not cause concern or protect the wall and floor with paper towels or other absorbent material.

Procedure

Part 1: Single Drop from Different Distances

1. Put on a pair of disposable gloves and safety glasses.
2. Use a ruler and permanent marker to divide one piece of cardstock into six areas of approximately equal size. Label the center of the cardstock “Part 1: Single Drop from Different Distances.”
3. Use the permanent marker to label one edge of the top left area “15 cm” (Figure 4). Label the remaining areas “30 cm,” “45 cm,” “60 cm,” “75 cm,” and “100 cm,” as shown.

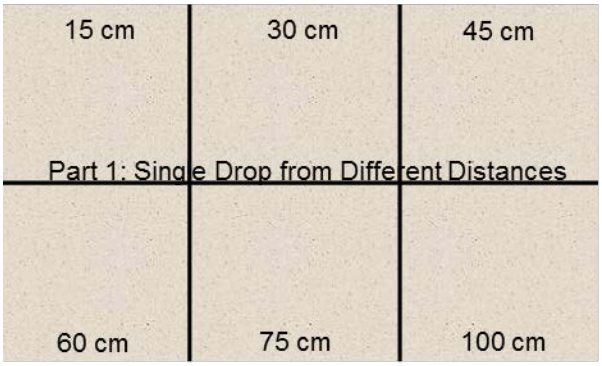


Figure 4: Cardstock setup for part 1.

4. Use two pieces of masking tape to secure the tape measure to a wall adjacent to a clear floor space so that the 0 cm mark is touching the ground (Figure 5).
5. Place the cardstock on the floor so that the 15 cm area is directly in front of the tape measure (Figure 5).
6. Remove the cap from the simulated blood sample bottle and use a transfer pipette to remove several drops of blood from the bottle.
7. Hold the ruler perpendicular to the 15 cm mark in one hand.
8. Holding the transfer pipette vertically, line up the tip of the pipette with the 15 cm mark. Use the ruler as a guide to ensure the pipette is 15 cm above the cardstock and positioned over the cardstock, so that when it is dropped, it hits the targeted area (Figure 6).
9. Carefully squeeze one drop of simulated blood from the pipette onto the cardstock so that it lands on the 15 cm area.

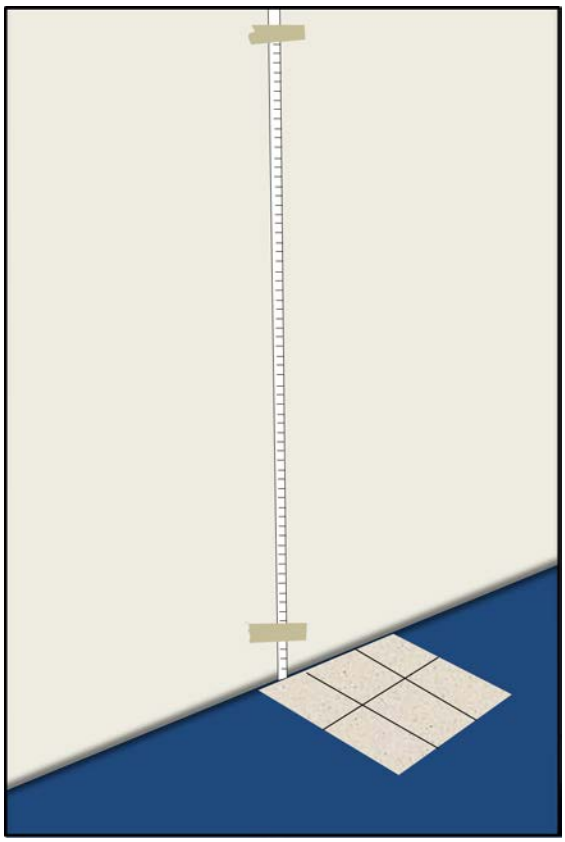


Figure 5: Setup for the tape measure and cardstock.

10. Repeat five more times at the following heights, making sure to adjust the position of the cardstock for each height: 30 cm, 45 cm, 60 cm, 75 cm, and 100 cm.

    Note: You may want to wait 1 - 2 minutes between each drop to allow the bloodstain time to dry.

11. Wait approximately 5 minutes or until the bloodstains have completely dried. You may wish to continue to Part 2 while you wait for the bloodstains to dry.
12. Use the ruler to measure the diameter of each bloodstain. Record the diameters in Table 1.
13. Record observations about the bloodstain patterns for each distance in Table 1.
14. Use a camera to take a photograph of the cardstock after it is dry.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

15. Set the Part 1 cardstock aside.

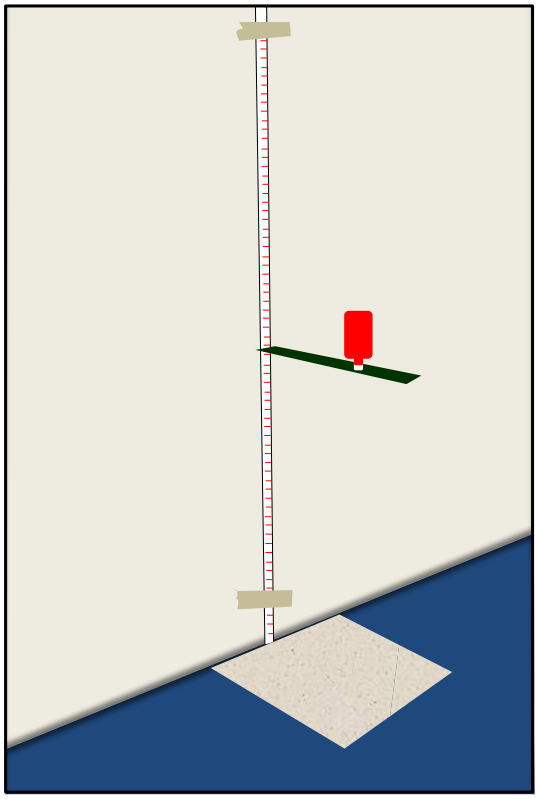


Figure 6: Set up for the ruler and transfer pipette.

Part 2: Multiple Drops from One Distance

16. Use a ruler and permanent marker to divide one piece of cardstock into six areas of approximately equal size. Label the center of the cardstock “Part 2: Multiple Drops from One Distance.”
17. Use the permanent marker to label one edge of the top left area “1 Drop.” Label the remaining areas as “2 Drops,” “3 Drops,” “4 Drops,” “5 Drops,” and “6 Drops,” as shown in Figure 7.

Figure 7: Cardstock setup for part 2.

18. Place the cardstock on the floor so that the 1 Drop area is directly in front of the tape measure (Figure 5).
19. Hold the ruler perpendicular to the 15 cm mark in one hand.
20. Use the transfer pipette to remove the simulated blood sample from the bottle. Holding the transfer pipette vertically, line up the tip of the pipette with the 15 cm mark. Use the ruler as a guide to ensure the dropper is 15 cm above the cardstock and positioned over the cardstock so that when it is dropped it hits the targeted area (Figure 6).
21. Carefully squeeze one drop of blood from the pipette onto the cardstock so that it lands on the 1 Drop area. Observe the splatter pattern and record your observations about the spatter pattern in Table 2.
22. Repeat for 2, 3, 4, 5, and 6 drops of simulated blood, making sure to adjust the position of the card stock for each set of drops. Be careful to squeeze the pipette slowly so one drop leaves the pipette at a time. Observe how the blood spatter's pattern changes with each additional drop.

    Note: You may want to wait 1 - 2 minutes between each drop to allow the spatter time to dry.
23. Allow the spatters to dry for approximately 10 minutes. You may wish to continue to Part 3 while you wait for the bloodstains to dry.
24. Use the ruler to measure the diameter of each bloodstain. Record the diameters in Table 2.
25. Record the bloodstain patterns for each distance in Table 2.
26. Use a camera to take a photograph of the cardstock after it is dry.

    Note: You will need to download, scan, or print the photographs to be included with

your lab report.

27. Set the Part 2 cardstock aside.

Part 3: Bloodstain with Force

28. Use the permanent marker to label the top of the third piece of cardstock as “Part 3: Bloodstain with Force.”
29. Place the cardstock on the floor so that the center of the cardstock is directly in front of the tape measure.
30. Use a transfer pipette to extract 2 mL of simulated blood from the bottle.
31. Hold the ruler perpendicular to the 15 cm mark in one hand.
32. With your other hand, hold the transfer pipette vertically, such that the tip of the pipette is 15 cm above the cardstock. Use the ruler as a guide to ensure the dropper is 15 cm above the cardstock and positioned over the center of the cardstock so that when it is dropped it hits the targeted area (Figure 6).
33. Quickly squeeze the simulated blood sample onto the center of the card.
34. Record your observations about the bloodstain pattern in Table 3.
35. Allow the cardstock to dry for approximately 10 minutes.
36. Use the ruler to measure the diameter of the bloodstain. Record the diameter in Table 3.
37. Use a camera to take a photograph of the cardstock after it is dry.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.
38. Replace the lid on the bottle of simulated blood. You will need the simulated blood for the next experiment.

Lab 4 Blood

Results Tables

Table 1: Bloodstain Diameter of a Single Drop at Varying Distances

Distance from Impact (cm)	Bloodstain Diameter (mm)	Observations
15		
30		
45		
60		
75		
100		

Table 2: Bloodstain Diameter of Varying Drops at the Same Distance

Number of Drops	Bloodstain Diameter (mm)	Observations
1		
2		
3		
4		
5		
6		

Table 3: 2 mL Bloodstain Diameter with Force

Height (cm)	Bloodstain Diameter (mm)	Observations
15		

EXPERIMENT 2: BLOODSTAIN ANALYSIS - ANGLE OF IMPACT

In this experiment, you will simulate and analyze bloodstain patterns caused by different angles of impact.

Materials

- Simulated Blood
- (2) Pieces of Cardstock
- (1) Clipboard
- Masking Tape
- (1) Permanent Marker
- (1) Protractor
- (1) Ruler
- (1) Transfer Pipette
- (1) Pair of Disposable Gloves
- (1) Pair of Safety Glasses
- *Camera/Smart Phone
- *(1) Pencil
- *Paper Towels
- *Flat Surface

*You must provide

Procedure

1. Use the masking tape to secure a protractor to the edge of a flat surface, such as a table top (Figure 8). To do this, line the origin (the hole on the flat side) up to the top edge of the flat surface. Secure the flat side of the protractor with a piece of masking tape. To keep the protractor from falling towards you, place a second piece of masking tape perpendicular to and over the first piece, through the protractor, and onto the top of the flat surface.

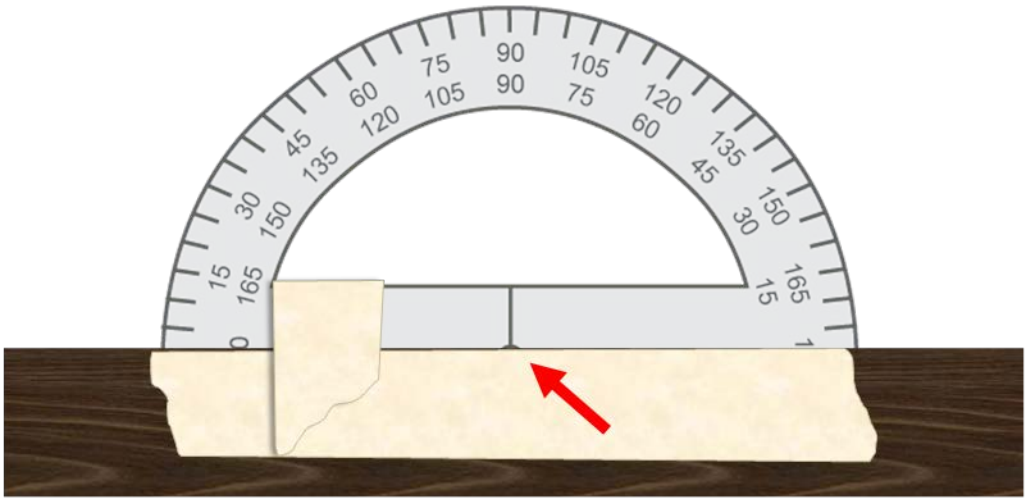


Figure 8: Protractor setup. The red arrow indicates the protractor origin.

2. Use a permanent marker to label the top of a piece of cardstock "60º angle." Under the label, write "Trial 1," "Trial 2," and "Trial 3" evenly spaced out (Figure 9).

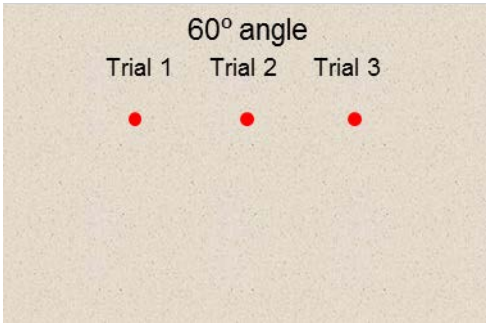


Figure 9: Cardstock setup. The red circles indicate the targeted area to hit with the crime scene blood.

3. Cut the cardstock such that the piece of paper fits within the area of the clipboard (e.g. no edges are overhanging).

4. Line up the bottom edge of the clipboard (the side opposite the clip) with the origin of the protractor. Use masking tape to secure it to the flat surface. This will create a "hinge" that allows the clipboard to rotate and create different angles with the flat surface. See Figure 10 for reference.

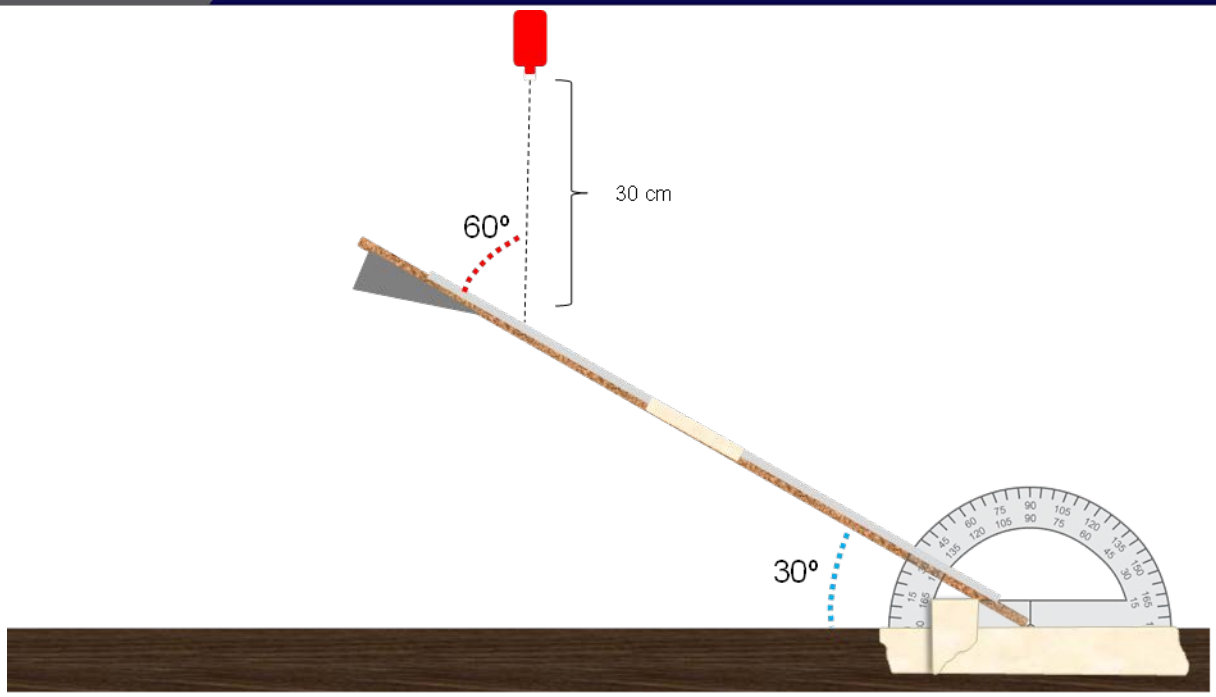


Figure 10: Experimental setup. The blue, dotted line indicates the angle at which you hold the clipboard to the flat surface. The angle created by the clipboard and drop of blood is the angle of impact, denoted by a red, dotted line. The arrow indicates the protractor origin. The crime scene blood sample is oriented approximately 30 cm above the clipboard.

5. Remove the cap from the simulated sample and use a transfer pipette to obtain several drops of simulated blood sample.
6. Lift up the free edge of the clipboard (edge with the clip) until a 30° angle is created between the clipboard and the flat surface. This creates an angle of impact of 60°. See Figure 13 for reference.
7. While holding the clipboard in place with one hand, orient the transfer pipette containing the simulated blood vertically, approximately 30 cm above the center of the cardstock.
8. Gently squeeze one drop of simulated blood from the transfer pipette onto the cardstock under the Trial 1 label.
9. Repeat two more times, dropping the blood under the Trial 2 and Trial 3 labels on the cardstock. Performing three trials helps to visualize the natural variances which occur in bloodstains.
10. Hold the clipboard at a 30° angle (60° angle of impact) until the majority of the simulated blood has been absorbed by the paper. As it dries, examine the three bloodstains. Record your observations

about the shape and any visible bloodstain components in Table 4.

11. Use a ruler to measure the length and width of each bloodstain. Record the lengths and widths in Table 4

12. Calculate the average length and width, and record the average length in Table 6.

13. Repeat the procedure using a 60° between the clipboard and the flat surface (30° angle of impact). Record data in Table 5.

14. Use a camera to take a photograph of the cardstock after it is dry.

    Note: You will need to download, scan or print the photographs to be included with your lab report.

Results Tables

Table 4: Average Bloodstain Length and Width at 60° Angle of Impact (From a Height of 30 cm)

Bloodstain Dimension	Trial 1	Trial 2	Trial 3	Average	Observations
Length (mm)					
Width (mm)					

Table 5: Average Bloodstain Length and Width at 30° Angle of Impact (From a Height of 30 cm)

Bloodstain Dimension	Trial 1	Trial 2	Trial 3	Average	Observations
Length (mm)					
Width (mm)					

Lab 5

Fiber and Hair

Lab 5 Fiber and Hair

LEARNING OBJECTIVES

- Explain the role and limitations of hair and fiber evidence in forensics
- Perform a fiber analysis

INTRODUCTION

Fabric products, including clothing, carpet, rope, and building components, are formed from fibers. **Fibers** are thread-like materials with a length far greater than their diameter. Fibers may originate from plant (Figure 1) or animal sources, or be manufactured. Fibers may be transferred either **directly** (primary transfer) or **indirectly** (secondary transfer). Both depend on the fabric type, as well as the duration and nature of contact. Direct fiber transfer can occur from person-to-person contact. Indirect fiber transfer occurs when an intermediary transfers the fibers, such as when carpet fibers from a house attach to a person's shoes and are transferred to their car.

Related to fibers in size, hair is also easily shed and can cling to material. Associating a hair to a particular individual without DNA analysis isn't currently possible. Similar to fibers, hairs have only class characteristics, but can be useful in including or excluding suspects or establishing the strength of association between people, places, and things.

Figure 1: Cotton fabrics are produced from the fibrous materials that surround the seeds of the cotton plant.

Fiber and Hair Evidence Collection

To analyze fibers found at a crime scene, forensic technicians collect fibers with tweezers, a vacuum with a specialized filter, or lift tape. Another technique for collecting fibers is static lift. **Static lift** relies on static electricity, which can make fibers "stick" to another surface, allowing them to be picked up. However, this and other methods (e.g., certain adhesive tapes) have the potential for contamination, which is a particular concern for transfer evidence.

Fiber evidence can't pinpoint an alleged offender conclusively, but can aid in corroborating evidence. The less common a collected fiber is, the better it corroborates evidence. Fabric details yield class evidence, which means one fiber might be associated with a particular source in a different place, but not necessarily with the same source. Factors that give fibers greater forensic importance include the number of fibers found and the location of the fibers on the body or items. The more fibers that are found in a meaningful location, the more likely contact between a victim and suspect occurred.

Fibers

A fabric's construction affects the number and types of fibers transferred during contact. Tightly woven or knitted fabrics shed less than loosely knit or woven fabrics. For example, fabrics composed of filament yarns shed less than fabrics composed of spun yarns. Fabric age also affects shedding: newer or damaged fabrics tend to shed.

Natural fibers used in fabrics originate from plants and animals. Cotton and flax used in linen are two common plants that have their own processing techniques influencing identification. Wool, which originates from animals, can have varying diameters. The diameter can be as fine as that found in clothing or as coarse as carpet. Other animal fibers include alpaca, cashmere, and mohair. Short pieces of these natural fiber are twisted together into continuous threads or yarns and woven into fabric.

While man-made fibers can originate from natural materials, many originate from synthetic materials, such as polyester, spandex, nylon, acrylic, and rayon (made from wood pulp and cotton). Manufactured fibers are created by **extrusion,** the process of solubilizing a polymer and then forcing the melted fluid through tiny holes to form continuous rubbery strands that solidify into various shapes.

Hair

Hair is a specialized skin cell that consists mostly of a protein called keratin. The thread-like protrusion of a hair is referred to as the **hair shaft** and consists of three concentric layers (Figure 2). The innermost layer is the **medulla**, consisting of rounded cells. The **cortex** is the middle layer. This layer contains the pigment melanin, which gives hair its color. It may also contain air pocket patterns that analysts can compare with other hairs using a comparison microscope. Pigment granules vary in shape, color, and distribution, which are used as points of comparison when distinguishing individuals' hairs. Surrounding the cortex is the scaly, transparent hair **cuticle**. The cuticle can be used to determine whether a hair is human or not and to match other hairs utilizing individualized scale patterns. Connecting a hair to the blood stream is the **hair root** embedded in the **follicle** below the scalp.

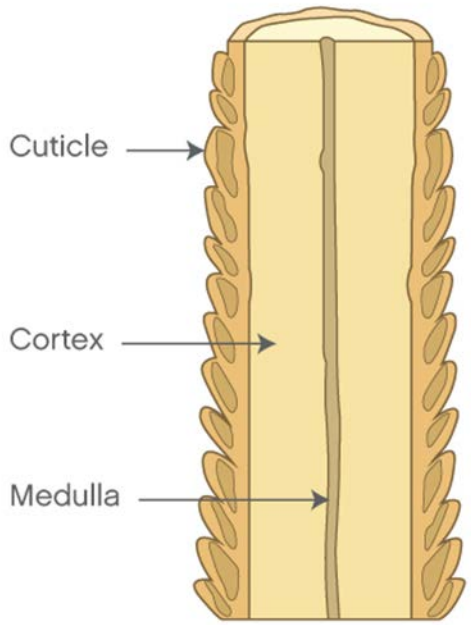


Figure 2: Layers of a hair shaft.

Hair Analysis

Hair can absorb toxins, which can provide a timeline of exposure to a toxin of interest. Hair grows on average about half an inch in length each month. Therefore, toxin levels in a hair shaft can reveal when an individual was exposed to a toxin, such as arsenic.

Hair strands do offer the possibility of DNA extraction for identification, but there are some things to

consider when hair is the sample source. Nuclear DNA (located inside of a cell's nucleus) can only be isolated when the root of the hair has tissue from the follicle attached. Extracting nuclear DNA is difficult, since the shaft itself doesn't contain nuclear DNA and hair samples often do not include follicle tissue. However, the previously living cells that compose hairdo contain mitochondrial DNA (mtDNA). Unlike nuclear DNA, mtDNA is housed in the organelle that produces energy for a cell. As a result, there are many more copies of mtDNA per cell than nuclear DNA (there is only one nucleus per cell). mtDNA is also unique from nuclear DNA because it is only passed down through the maternal line of inheritance. In other words, males are not able to contribute mtDNA to their offspring. This is helpful to forensics scientists because they can refer to the mtDNA of female relatives for genetic information if a sample cannot be obtained from a person of interest.

Hair is classified by color and body area origin without microscopes. Each body part generates a certain type of hair. Facial hairs are typically coarse with sharp ends due to shaving, pubic hairs are typically coarse and wiry, and limb hairs are typically arc-like in shape and often tapered at the tips. Other hairs, such as fringe hairs, which originate from the neck, sideburns, abdomen, upper leg, and back or axillary hairs from the underarm, chest, and near the eyes are not routinely analyzed, but may help to corroborate information obtained during an investigation or be useful for DNA analysis.

When microscopically examining hair samples, analysts perform a subjective assessment of the objective characteristics, which depends in part on the observer's judgment and experience. They also try to have many (50 - 100) exemplar hairs for a thorough comparison because individual hairs on the same body may differ tremendously. Microscopy is only one tool for the forensic examination of hairs. However, DNA analysis is needed for forensic verification.

Lab 5 Fiber and Hair

EXPERIMENT 1: FIBER ANALYSIS

Fibers composed of different materials behave differently when exposed to flames. The scent, residue, and behavior in flames will vary based on the type of fabric. For example, some fibers burn easily, while others will shrink away from the flame. In this experiment, you will investigate the difference between natural and synthetic fibers as it relates to their behavior when exposed to flames.

Materials

- (1) 12'' by 12'' Aluminum Foil
- (1) Butane Lighter
- (1) Hand Lens
- Masking Tape
- (1) Metal Tweezers (located in dissection tools kit)
- Cotton Fiber Samples
- Polyester Fiber Samples
- Rayon Fiber Samples
- Silk Fiber Samples
- Unknown Fiber Samples
- Wool Fiber Samples
- *Camera/Smart Phone

*You must provide

Lab Safety

Use caution when working with flames. The foil will protect the surface you are working on if you drop a burning fiber. Wear safety glasses, secure long sleeves by rolling them up, and tie back long hair. **Do not wear gloves or an apron when working with the flames.** They are flammable and will cause more injury to your hands than a burn to bare skin. Additionally, some fibers may produce a strong odor. Work in a well ventilated area. If you follow the procedure as written, your hands and clothes will never be near a flame, but accidents can still happen. Have an emergency plan to extinguish flames, such as a fire extinguisher or container of water, easily accessible.

Procedure

1. Place a 12” by 12” piece of aluminum foil on your work surface.
2. Use masking tape to secure the edges of the foil to the work surface.
3. Use the hand lens to observe the wool, rayon, silk, polyester, cotton, and unknown fibers for characteristics, such as relative color, size, braiding, etc. Record your observations in Table 1.
4. Use a camera to photograph each type of fiber. Include the photographs in Table 1.

   Note: You will need to download, scan, or print the photographs to be included with your lab report.

5. Use the tweezers to remove a piece of cotton fiber from the bag. Adjust the fiber so that it is in line with the tweezers (Figure 3).

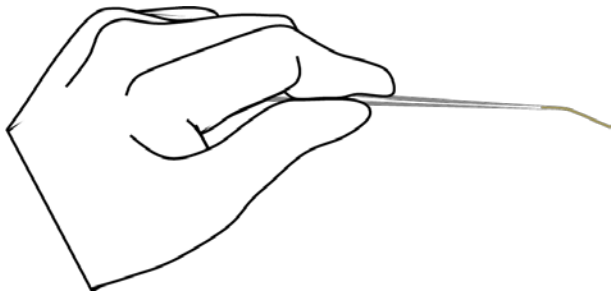


Figure 3: Reference image showing how to hold the fiber with the tweezers.

6. While holding the tweezers with the cotton fiber in one hand, light the butane lighter with the other hand.
7. Slowly move the fiber toward the flame, but do not put it in the flame.
8. Observe the behavior of the fiber as it approaches the flame. Does it shrink away from the flame? Does it start to melt? Does it start to curl? Does it catch on fire without touching the flame? Turn off the lighter and record your observations of the fibers’ behavior as it approaches the flame in Table 2.
9. If your fiber did not catch fire, pick it up with the tweezers. If the fiber burned all the way down, use the tweezers to pick another piece of cotton fiber out of the bag.
10. Light the lighter with your other hand and move the fiber toward the flame until it touches the flame.
11. Observe its behavior in the flame. Does it burn with a glowing ember? Does the flame

flicker or spark? Does the fiber curl? Record your observations in Table 2.

12. Use the tweezers to pick up a cotton fiber from the bag. Light the lighter with your other hand, move the fiber into the flame, and then remove it. Observe the fiber's behavior after it has been removed from the flame. Does the fiber keep burning until it reaches the tweezers? Does the flame extinguish before the entire fiber burns? Is there smoke present? Record your observations in Table 2.
13. Observe any odor that may be associated with the fiber. Is the odor faint or strong? Is the odor more like a burning plastic, burning hair, etc.? Record odor observations in Table 2.
14. Use a hand lens to observe the burnt end of the fiber.
15. Feel the fiber between your fingers. Does it have a hard or soft residue? Is the residue ashy? Record your observations of the residue in Table 2.

    Note: While the fiber samples are small and should immediately be cool to the touch after they extinguish, use caution when touching the burnt ends.
16. Repeat Steps 5 – 15 for the wool, rayon, silk, polyester, and unknown fibers.

Lab 5 Fiber and Hair

Results Tables

Table 1: Initial Observations of Fibers

Fiber Type	Observations	Photograph
Cotton		
Wool		
Rayon		
Silk		
Polyester		
Unknown		

Table 2: Flame Test Observations

Fiber Type	Approaching Flame	In Flame	Removed from Flame	Odor	Residue
Cotton					
Wool					
Rayon					
Silk					
Polyester					
Unknown					

Lab 6

Impression Evidence: Shoes, Tires, Tools

Lab 6 Impression Evidence: Shoes, Tires, Tools

LEARNING OBJECTIVES

- Explain the role of shoe, tire, and tool mark analysis in forensics
- Perform a tire track analysis

INTRODUCTION

Impression evidence is created when two objects come into contact with each other and leave characteristics on the surface of one or both of the objects. Impressions can be two dimensional (2D) or three dimensional (3D). 2D impressions have length and width, but no depth, such as shoeprints on a tile floor. 3D impressions have depth, length, and width, such as the dent a tool leaves after striking a surface. Sometimes, impression evidence contains **pattern evidence**, class characteristics common to a group of objects, such as a shoe tread associated with shoes produced by a certain company. When possible, the surface containing the impression evidence should be collected and transported to a laboratory for analysis. If the impression cannot be collected, a CSI can lift a 2D impression or make a mold of a 3D impression. **Lifting** an impression involves transferring it from one surface to another with an adhesive material, such as tape. Making a **mold** of an impression involves applying a material to the impression that fills in all of the details of the impression and hardens to preserve its 3D shape.

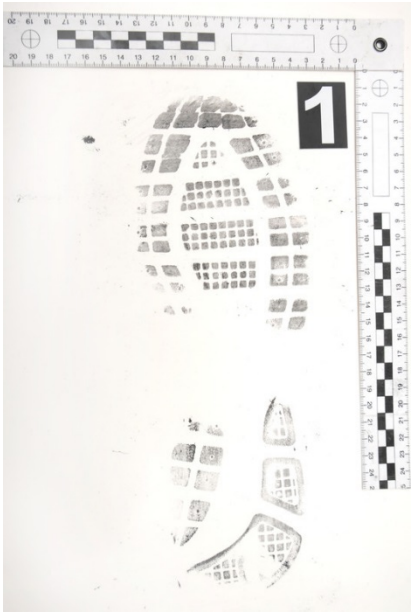


Figure 1: Photograph of a footprint with a photomacrographic scale.

Photographing Impression Evidence

Before a mold or lift of impression evidence is created, a crime scene photographer documents the impression via photograph to record the impression in its original state and position at the scene (Figure 1). Photographing impression evidence, such as shoeprints, is done with the camera lens positioned parallel or 90 degrees to the impression. A photomacrographic scale is also included next to the impression so that the true size can be gauged and a scale can be produced. If the camera is not oriented exactly 90 degrees above the impression, the actual size of the impression cannot be determined, leading to misinterpretation of evidence. To help maintain a 90 degree angle with the impression, photomacrographic scales include circles. Photographing the impression with lighting at various angles helps to capture its details.

Figure 2: Tire tread.

Tire Treads and Tracks

The surface design of a tire that increases friction and minimizes slippage is referred to as the **tread.** Tire treads are produced in many intricate designs that can be traced to a specific tire manufacturer. Vehicle tires can also accumulate material, such as gravel and dirt, in the tread. Additionally, tires sustain damage, such as cuts, and undergo normal wear. All these characteristics are useful in tire examination (Figure 2). **Tire tracks** show the relationship between two or more tires (Figure 3).

When possible, tire impressions from each tire should be collected. Tire impression evidence analysis may reveal:

- The approximate dimensions of a suspect vehicle (wheel base measurement and turning diameter)

- Sequence of events in regards to vehicle movement
- Tire tread characteristics (noise reduction feature, design, and unique wear patterns)

Figure 3: Tire tracks.

Knowledge Check

☐ ***True or false? A tire tread can indicate the relationship between two or more tires.***

Tool Marks

Another type of impression evidence that may be found at a crime scene is a **tool mark**, impressions that are the result of two objects brought into contact with each other. Tool marks are commonly found on doors, windows, or other openings where forcible entry has been attempted. Sometimes, tool marks may even be present on skeletal remains if stabbing or dismemberment occurred. The tool and tool mark will be photographed with a scale and examined for any trace evidence (Figure 4). Mikrosil™, a material useful in microscopic observations, is often used for making casts of fine details.

Figure 4: Screwdriver documented with a scale.

EXPERIMENT 1: TIRE TRACK ANALYSIS

In this experiment, you will analyze tire track patterns.

Materials

- (1) Fingerprint Ink Pad
- (1) Toy Car
- (1) Permanent Marker
- (1) Ruler
- (3) White Construction Paper Sheets
- *Camera/Smart Phone

*You must provide

Procedure

1. Use the permanent marker to label the bottom of a sheet of construction paper “Linear Path.”
2. Remove the lid of the fingerprint ink pad and apply ink to the entire surface of all four tires of the toy car by rolling each tire across the ink pad.
3. Place a ruler parallel to the long edges of the construction paper. This will help the toy car maintain a linear path.
4. Place the toy car just above the label on the construction paper facing away from you. Keeping your hand on the car, roll it in a linear path alongside the ruler until the front tires reach the end of the paper (Figure 5). Leave the car where it rests when you stop rolling it.

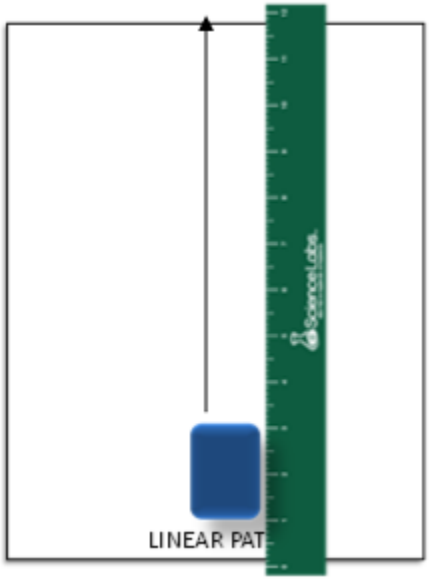


Figure 5: Setup for analyzing the linear path. The blue rectangle represents the car and the arrow indicates the direction to roll the car.

5. Use the permanent marker and the position of the car to label which tire created each track.
6. Use a camera to photograph the tire tracks.

   Note: You will need to download, scan, or print the photographs to be included with your lab report.

7. Use the permanent marker to label the bottom of a second sheet of construction paper "Curved Path Right to Left."
8. Use the fingerprint ink pad to apply ink to the entire surface of all four tires of the toy car.
9. Place the car on the bottom right hand corner of the construction paper and roll the car in a curved path from the bottom right corner to the top left corner of the paper until the front tires reach the edge of the paper (Figure 6). Leave the car where it rests when you stop rolling it.

   Note: You may need to hold the paper flat with one hand while rolling the car with the other. You may need to use less pressure when rolling the car on a curved path than when you rolled the linear path.

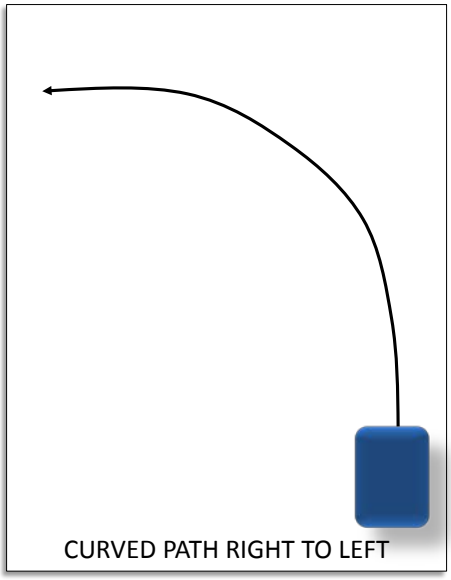


Figure 6: Setup for analyzing the curved path from right to left. The blue rectangle represents the car and the arrow indicates the direction to roll the car.

10. Use the permanent marker and the position of the car to label which tire created each track.
11. Use a camera to photograph the tire tracks.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

12. Repeat Steps 7 – 11 with a new sheet of paper. Label the paper “Curved Path Left to Right” and roll the car on a curved path from the bottom left corner to the top right corner of the paper.

Lab 7

Fractography and Glass

Lab 7 Fractography and Glass

LEARNING OBJECTIVES

- Explain the role of glass analysis in forensics
- Identify fracture and impact patterns using the 3R rule

INTRODUCTION

When glass is found at a crime scene, it may seem to be of little forensic value to the untrained eye. While most crime scene glass consists of clear, small fragments that appear indistinguishable from one another, glass has unique properties that can be used to associate a fragment to a potential source. Glass examinations can be physical, fitting broken pieces together like a puzzle, or chemical, analyzing the constituent elements that make up the glass. Glass fractures are random events (Figure 1). Thus, pieces from two different broken samples do not break exactly the same way. If a physical fit is not possible, then the glass samples are analyzed chemically.

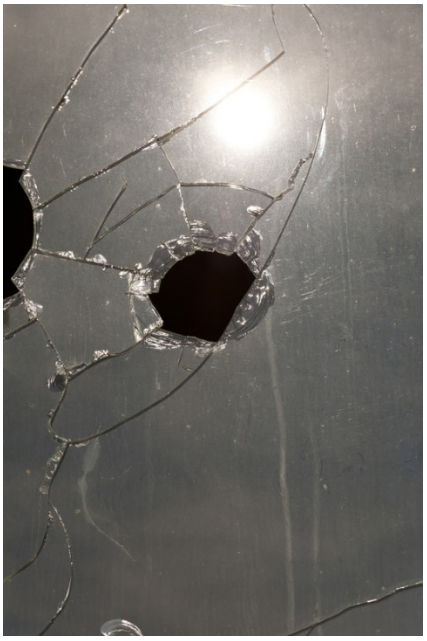


Figure 1: Fracture patterns are random and very difficult to replicate.

Visual Examination

Made primarily from silica sand, glass composition can best be distinguished by its atomic structure, which lacks the orderly arrangement of crystalline solids. Glass type is also determined by its chemical purity, which affects its color, clarity, and strength - each useful in identification. Glass thickness can reveal its

application. For example, a light bulb is composed of thin glass, whereas a glass door is composed of much thicker glass. Other materials used in glass production and the batch process, such as temperature, cause chemical and physical variations from batch to batch.

Knowledge Check

☐ *Would a forensic expert duplicate a fracture pattern in the courtroom? Why or why not?*

Glass is often collected at burglarized buildings or vehicles. Examples include headlight glass, window glass, and bottle glass. Examination and analysis of glass is done at several levels, starting visually with the unaided eye. During visual examination, a scientist might record glass color, curvature, imprints, and any labels. Repairs and small cracks will glow under ultraviolet light. When a piece of glass breaks into relatively large pieces, they can be put back together like a puzzle to show how they were once joined. Matching a piece of glass (or other breakable material) to a particular object is called **mechanical fit** or **fracture match**. Stress marks, which indicate a force was applied to the material, may be observed with a microscope. However, most glass evidence is too small to physically match to another piece and isn't unique enough to trace to a parent source. Nevertheless, glass fragments can be useful as class evidence. Forensic investigators first determine whether a sample is glass by analyzing a specimen's chemical and physical properties. Examples include testing a sample's hardness and reaction to heat.

Refractive Index

A reliable and accurate method to compare glass samples is to determine the **refractive index**, a calculation that is based on the fact that light slows down and bends when it passes through an object, especially denser objects. This phenomenon is why objects, such as a straw in a glass of water, appear to be bent. The refractive index is a ratio of the velocity of light in a vacuum to the velocity of light in a particular medium. To perform this measurement, a glass sample is placed in oil with a known refractive index under a microscope with a heated stage. As the sample gets hotter, the oil's refractive index alters slightly until it is the same as the glass. The edges of glass are no longer visible and the glass seems to disappear because the light is bending the same way. The FBI hosts a database that lists the refractive index values for about 2,000 types of glass.

Fracture Analysis

Glass is flexible to a certain limit, and once that limit is exceeded, it breaks. Fragments of broken glass may be transferred onto anything within a reasonable distance of the fracture. One factor that influences glass transfer is the distance between an object and the fracture. The closer an object is to breaking glass, the more likely it is that glass fragments will be transferred to it. Another factor is the amount of fragments transferred, which decreases as distance from the break increases. The clothing type worn by an individual can also factor into the probability of glass transferring. Rough clothing, such as a wool sweater, has a higher probability of retaining glass than slick clothing, such as silk. The size of a glass fragment may also influence the probability that it is transferred to an object. It is more probable that larger glass fragments will fall off of an object before smaller pieces.

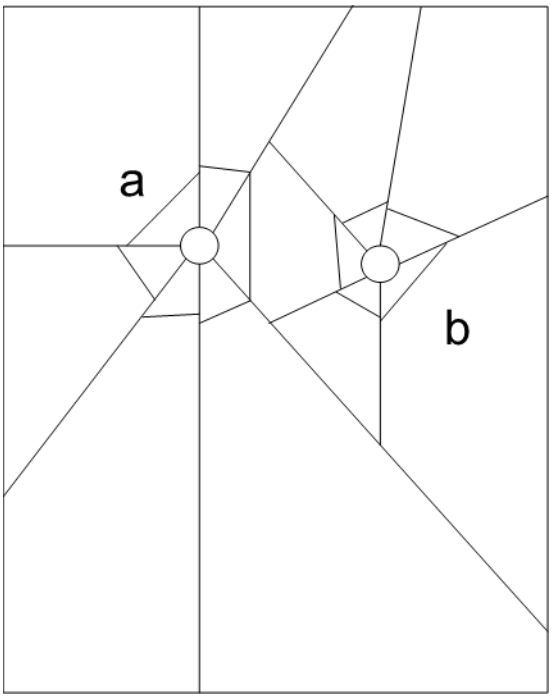


Figure 2: Two holes, a and b, fractured a piece of glass.

Studying the results of glass fractures can also reveal details relevant to a crime. For example, the sequence of gun shots through a window can be determined by the fracture pattern in the glass. Figure 2 depicts two holes in a piece of glass. It can be inferred that Hole b was created after Hole a because the fractures extending from Hole b terminate at the fractures extending from Hole a. This would only occur if Hole a was already present when Hole b occurred.

The side of impact can also be distinguished from the side opposite the impact by observing stress marks on the edge of broken glass samples. Scientists determine force direction using the **3R Rule** which states: **R**adial fractures are at **r**ight angles to the **r**everse side of impact. This means that when a radial fracture is present in a piece of glass, the side opposite impact will display stress marks at right angles, while the side that was impacted will not. Figure 3 depicts the edge of a broken piece of glass with a radial fracture. The side opposite impact will display stress marks at an approximately right (90°) angle to the edge of the glass.

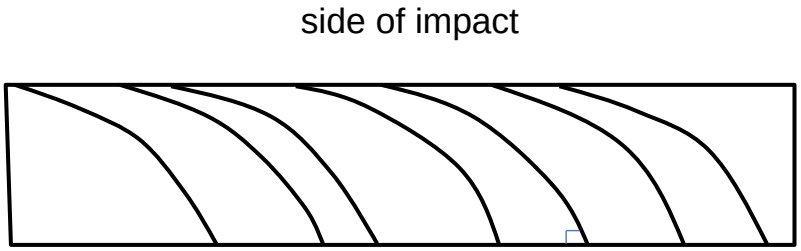


Figure 3: The rectangular shape represents the edge of a broken piece of glass. The curved lines represent stress marks. Stress marks form fairly right angles with the side opposite of impact. The blue square indicates the side with approximately right angles.

EXPERIMENT 1: FRACTURE ANALYSIS

In this experiment, you will fracture a glass sheet to observe fracture patterns and confirm the 3R rule.

Materials

- (1) 8.5'' x 11'' Foam Sheet
- (1) Glass Sheet (with attached piece of packing tape)
- (1) Hammer
- (1) Hand Lens
- Masking Tape
- (1) Metal Tweezers (located in dissection tool kit)
- (1) Nail
- (1) Permanent Marker
- (2) 9'' x 12'' Sealable Plastic Bags
- (1) Sheet of Black Construction Paper
- (1) Pair of Disposable Gloves
- (1) Safety Glasses (located in your safety kit)
- *Camera/Smart Phone
- *Clean Cloth (in case of emergency)
- *Durable Surface (ground or floor)
- *Hydrogen Peroxide, H_2O_2 (in case of emergency)
- *Band-Aid™

*You must provide

Lab Safety

You will be working with broken glass. Wear gloves and safety glasses at all times. Handle the glass with tweezers when possible. If you cut yourself on a piece of broken glass, apply pressure to the cut with a clean cloth. If the cut is minor (does not require stitches) rinse with hydrogen peroxide and apply a Band-Aid™. If the cut is major and requires stitches, apply pressure to the cut and *seek medical attention immediately*.

Procedure

1. Put on your gloves and safety glasses.
2. Wrap the edges of the glass sheet with masking tape (Figure 4).

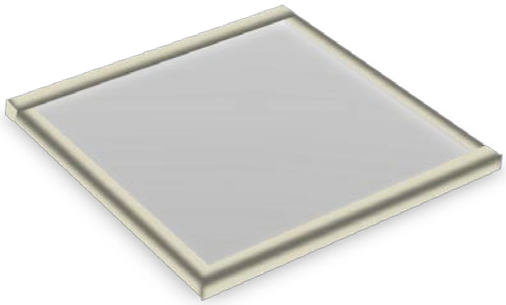


Figure 4: A sample image of the glass sheet with edges wrapped in masking tape.

3. Use a permanent marker to label the masking tape on one side “IMPACT.” This is the side of the glass you will impact with a hammer and nail. It does not matter if the impact side has the clear tape.
4. Place the glass sheet in a 9” x 12” sealable plastic bag.
5. Press the air out and seal the bag.
6. Place the sheet and bag inside of a second 9” x 12” sealable plastic bag.
7. Press the air out and seal the bag.
8. Place a sheet of foam on a durable surface, such as the ground or floor.
9. Place the glass sheet and bags on the foam surface with the side labeled “impact” facing up. This is the side of the glass you will impact.
10. Position a nail on the surface of the glass and apply a force to the nail with a hammer. You will need to supply a good amount of force to create a consistent fracture, but use caution so that the glass does not completely shatter. Begin with a few light taps of the hammer to get a feel for the process and how much more force you will need to apply. Gradually increase the force until the glass fractures.
11. In an area that is relatively clear of fractures and a few inches away from the first impact, apply another force to the glass with the hammer and nail.
12. Carefully remove the glass sheet and inner plastic bag from the outer plastic bag.
13. Carefully remove the glass sheet from the inner plastic bag and set it on a sheet of black construction paper. The tape should hold the glass together, but if the sheet separates into more than one piece, put the pieces back together as you set them on the construction paper.
14. Use a camera to photograph the fractured glass sheet.

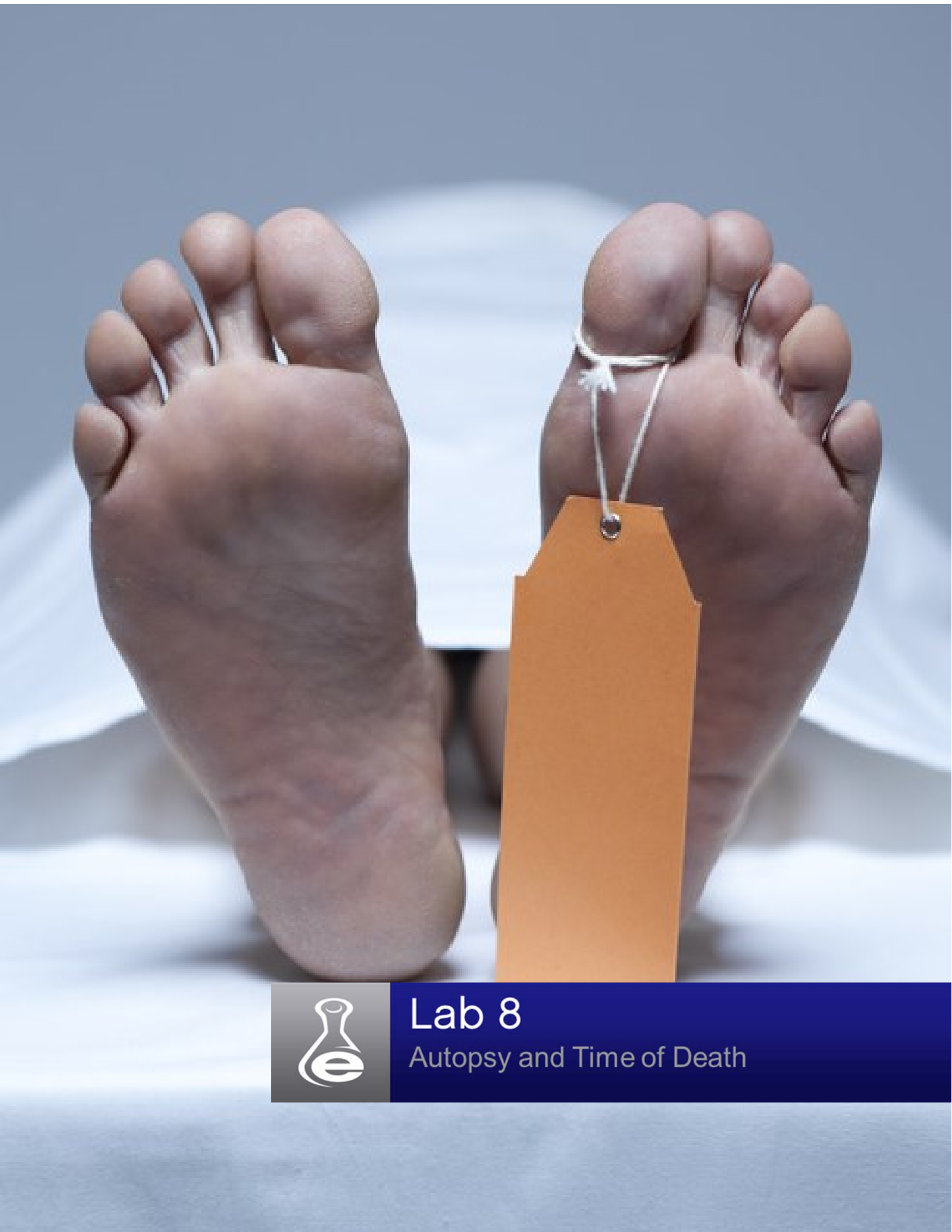
Note: You will need to download, scan, or print the photographs to be included with your lab report.

15. Observe the fractures in the glass, taking note of your observations.
16. Use a permanent marker to label a large shard of glass with the letter “I” for impact.
17. Use tweezers to remove the shard of glass from the sheet. This may require removing some masking tape from the edges.

    LAB SAFETY: Use caution when handling glass.
18. Examine the edges of the shard with a hand lens taking note of your observations. Use the 3R rule to confirm the side of impact.

    LAB SAFETY: Use caution when working with broken glass. Do not remove all of the masking tape or clear tape from the sheet. They are intended to keep the shards together and make disposal safe.
19. When you have completed the experiment, slide the construction paper with the glass sheet and shards into the inner plastic bag, seal it, and then place it into the outer plastic bag. Seal the outer bag.
20. If available, place the bags and glass sheet into a small cardboard box, seal the box with tape, and dispose of the box in a trash receptacle.

    Note: If you are completing this experiment in your home, it may be safest to store the glass sheet and bags near the trash (away from children and pets) and dispose of the glass right before you take the trash out. This will avoid glass shards sitting in the trash can for long periods of time in which they may cut the bag or the person taking the trash out.



Lab 8

Autopsy and Time of Death

Lab 8 Autopsy and Time of Death

LEARNING OBJECTIVES

- Cite factors that aid pathologists in estimating time of death
- Summarize the steps of an autopsy examination

INTRODUCTION

Upon discovery of a corpse, establishing a time of death is important to help determine the circumstances of a crime. There are several ways to discuss time of death. **Physiological time of death** is defined as the time vital organs cease to function. **Legal time of death** is defined as the time a body is discovered or pronounced dead. Since a physiological time of death is often not available, a medical examiner will determine an **estimated time of death** or **post-mortem interval** (the time elapsed since a person has died) based on their knowledge of the human body and decomposition. Changes to the body that can be studied after death include body temperature (**algor mortis**), degree of skin discoloration due to blood settling (**livor mortis**), stiffening of the muscles (**rigor mortis**), stomach contents, and more advanced stages of decomposition.

Time of Death

Time of death is computed from a person's body temperature as it adjusts to the temperature around it. The average body temperature for a living person is 98.6°F (37°C). A body loses heat on an exponential decay curve, but the temperature decrease is approximated linearly for the purposes of estimation. As the body begins to decompose, the temperature will rise due to bacterial action. Other variables that influence body temperature loss after death include temperature of the surrounding environment and the type of environment. Algor mortis is considered an inaccurate means of estimating time of death since there are many variables influencing the temperature of a body after death.

Livor mortis occurs when gravity pushes blood downward toward the ground once the heart is no longer pumping it through blood vessels. This causes a person's body to change from a normal flushed color to purple in areas nearest the ground, whereas areas farthest away from the ground become pale. These color changes, also known as **lividity**, occur about 30 minutes to several hours after death and become permanent after six hours. Livor mortis can be indicative that a body has been moved if the pools of blood in the skin are in a place that gravity would not allow.

Rigor mortis occurs after death when muscles become rigid and unable to relax, causing body joints to

become fixed in place. The stiffening occurs as a result of a breakdown in a biochemical chain reaction. In living cells, the movement of calcium in and out of cells regulates muscle contraction and relaxation. For the movement of calcium to occur, the energy molecule adenosine triphosphate is required. After death, the remaining ATP in the body is quickly used up, causing calcium to become trapped in cells. This build up of calcium causes the muscle to stay contracted, leading to the body becoming rigid.

Muscles stiffen starting at the face and proceed downward ending at the toes. Muscles are solidly locked 12 hours after death. The body will remain stiff until the process reverses, with the muscles relaxing about 48 hours after the time of death. Because rigor mortis is highly variable due to the environment, it is not considered as reliable as other indicators of time of death.

Knowledge Check

☐ ***Which body change explains the gradual reduction of body temperature after death?***

Stomach contents can also be used for time of death estimation by analyzing the process of digestion. Digestive functions cease when a person dies. Therefore, the degree to which stomach contents are broken down can help infer the last time the deceased ate food, providing a reference to when they were alive. The stomach empties itself four to six hours after food enters it, depending on the type and amount of food ingested. If stomach contents are undigested, then it can be inferred that death occurred soon after eating. If empty, death probably occurred more than six hours after eating.

Eyes can be another indicator of how long it has been since an individual passed away. If the eyes are open at time of death, a film will form as the eyes dry. The breakdown of blood cells releases potassium, which makes the eyes appear cloudy about two to three hours after death. This process takes longer if the eyes were closed at death. If tested soon after death (within 3 – 4 days, before the eyes dry out), vitreous humor, the gelatinous liquid found behind the lens, can be a clue to time of death, based on known rates of potassium diffusion from the retina. However, test results can be affected by environmental conditions, victim age, and additional factors. It is also possible to analyze potassium, urea, and hypoxanthine in the vitreous humor of the eye with computer programs to estimate time of death.

Body appearance and smell also give a time of death estimate. As the body decomposes, enzymes break

down the cells and tissues (**autolysis**). As the body putrefies (decays), bacteria multiply, destroying tissues and causing bloating. Red blood cells release hemoglobin, causing blood vessels to appear on the skin surface. The orderly decay of bodies enables time of death estimates, although environmental and body conditions should also be considered when making a timing prediction. Putrefaction either proceeds until the soft tissue liquefies and the cadaver becomes skeletonized, or it halts due to changes in the environment leading to mummification or the formation of **adipocere** (the conversion of body fat to a solid white, waxy substance).

Entomology

In some situations, a forensic entomologist, a scientist that specializes in insects, aids in estimating the post mortem interval. Visual observations of the cadaver, along with the stage of insect development, enable entomologists to calculate post mortem interval based on known insect life cycles (Figure 1). For example, blowflies can smell dead flesh from more than a mile, and will show up in minutes to feed on a body. Soon after, blowflies lay thousands of eggs in body openings and wounds that hatch into flesh-eating maggots within 12 hours, depending on the temperature. Colder weather slows down the life cycle process. Beetles then come to eat the maggots in a predictable amount of time, and millipedes, spiders, and other organisms come to feed on insects involved with the body.

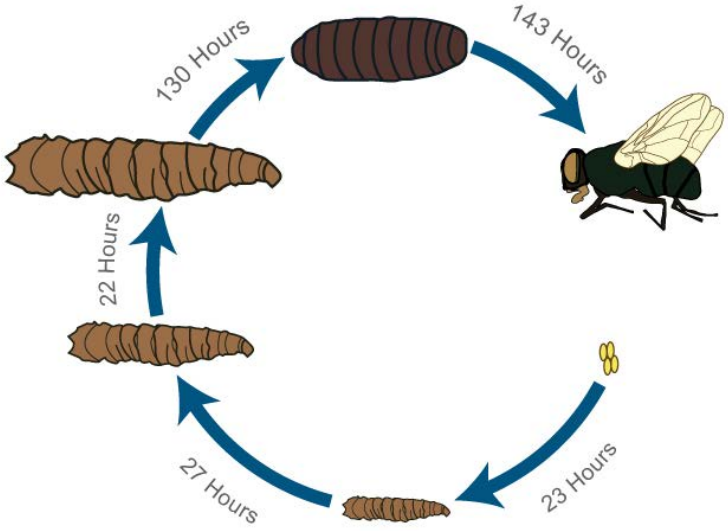


Figure 1: The life cycle of a blowfly is consistent and can be used to estimate time of death.

After 48 hours, determining the time of death may depend on interviews with individuals in contact with the deceased person, circumstantial evidence (evidence not drawn from direct observation but

accumulated to make an inference), and other clues, such as unopened mail.

Knowledge Check

☐ *What is the difference between time of death and post-mortem interval?*

Autopsy

Once the body is initially examined on site, the body is taken to a morgue, where clothing and valuables are identified, searched for relevant evidence, removed, and recorded. The body will be readied for inspection by a **forensic pathologist**, a medical physician trained in the examination of human remains. **Autopsies** - the external and internal examination of a body after death using surgical techniques, microscopy, laboratory analysis, and medical records - are performed to determine the cause and manner of death. Routinely done for suspicious or sudden deaths, autopsies begin with the external inspection of a body, which will be weighed and measured in totality and by organ. X-rays may be taken to evaluate skeletal or other abnormalities, confirm injuries, locate bullets or other objects, or help establish identity.

The internal examination begins with a **Y-shaped incision**, which runs from each shoulder joint, meeting at mid-chest (curving around a female's breasts). The Y's stem continues to the pubic region. Next, a procedure is done to remove the rib cage and access the body's major organs. Organs are examined in place. Then, organs of interest are removed, weighed, examined, and sometimes preserved for later dissection. Samples of blood, tissue, fluids, and stomach contents may be taken and examined. If poisoning is suspected, the liver will be removed for analysis. Upon conclusion, the organs and rib cage are replaced, padding is inserted to compensate for removed parts, and the body is sewn shut. When an autopsy calls for examination of the brain, a cut is made from the bony bump behind one ear to the bump behind the other, and a saw is used to cut around the circumference of the skull.

Virtual Autopsy

Advances in technology have led to a new type of autopsy, the virtopsy. A **virtopsy** consists of 3D virtual imaging of the body using multi-slice computed tomography (MSCT) or magnetic resonance imaging (MRI), and relies on ray trajectory being deflected by bones and organs. These techniques have been particularly revealing for internal bleeding, bullet paths, and hidden fractures, which are difficult to detect using conventional autopsies. An additional benefit to 3D virtual autopsies is that, once the body is

scanned, it can be examined repeatedly in its original condition at the time of death months or years after the body has decomposed or been cremated.

Cause of Death

The cause of death and manner of death are ultimately determined from an autopsy. **Cause of death** is the disease or injury that produced the physiological disruption resulting in death. The **manner of death** is the way in which a person's life ended. Examples include natural death, accident, suicide, homicide, or undetermined. It also might be pending (waiting for more evidence or analysis). For example, the cause of death could be a gunshot wound to the head. From the cause of death, a manner of death is determined. The gunshot wound from the previous example could have been self-inflicted, indicating a suicide, or not, indicating a homicide or accident. After the cause and manner of death are determined, a death certificate is filed.

Lab 8 Autopsy and Time of Death

EXPERIMENT 1: GRASS FROG AUTOPSY

In this experiment, you will perform the basic steps of an autopsy on a grass frog to practice the steps a forensic pathologist or medical examiner uses to determine cause of death.

Materials

- (1) Digital Scale
- (1) Dissection Pad
- (1) Dissection Tools Kit
- (1) Grass Frog
- Safety Equipment
- (1) Underpad (located in the lab safety box)
- (1) Sheet of Weigh Paper
- *Camera/Smart Phone

*You must provide

Procedure

1. While the frog specimen is preserved in Carolina Perfect solution, imagine the specimen is a recently discovered body when performing the autopsy.
2. Record your name and the date in the examiner and exam date rows in Table 1.
3. Put on your safety equipment.
4. To begin, lay an underpad down and place the dissecting tray on top of it. Lay out the dissecting tools.
5. Once prepared, use the dissecting scissors to open the bag that contains the frog.
6. Before performing an internal examination of the tissues and organs, a forensic pathologist will perform an external examination of the deceased.
7. Examine the exterior of the frog, noting the general appearance of the skin, including any marks or discolorations. Record your skin observations in Table 1.
8. Examine the eyes and note the clarity of the lens in Table 1.
9. Use a camera to photograph the dorsal (the back) and ventral (the underside) sides of the frog.

Note: You will need to download, scan, or print the photographs to be included

with your lab report.

10. Use the scalpel to create a Y incision on the ventral side of the frog. The arms of the Y should extend from the shoulders or arm pits and come together at the midline of the frog. The stem of the Y incision should extend down to the pelvis (Figure 2).

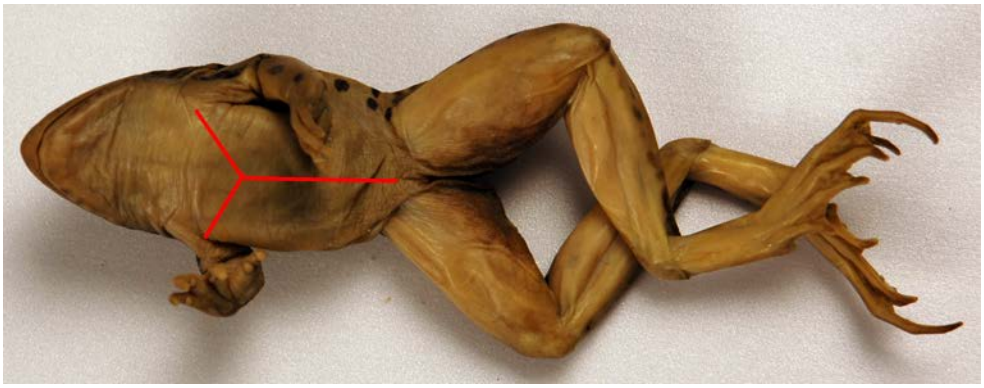


Figure 2: The Y-incision (show as red line) should be cut on the ventral side of the grass frog.

11. Use a camera to photograph the Y incision.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

12. Carefully peel back the layers of the skin to observe the internal organs.
13. Use a camera to photograph the internal organs.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

14. Take time to identify the internal organs of the frog and study their position within the body. Figure 3 identifies the basic internal anatomy of a frog. Record your observations of the internal organs in Table 1.
15. Use a scalpel and probe to cut the internal organs out and remove them as one mass of organs (Figure 3).
16. Turn on the scale by pressing the button labeled “0/T.” If your scale does not turn on, you may have to remove the battery cover and remove a small strip of plastic from the battery housing. Once the scale is on, press the “0/T” button a second time to zero the scale.

Make sure that the units are in grams (g). if not, press the M button until the units are displayed in grams.

17. Place a sheet of weigh paper on the scale and tare the scale.

18. Place the organs on the scale to obtain their mass. Record the mass in Table 1.

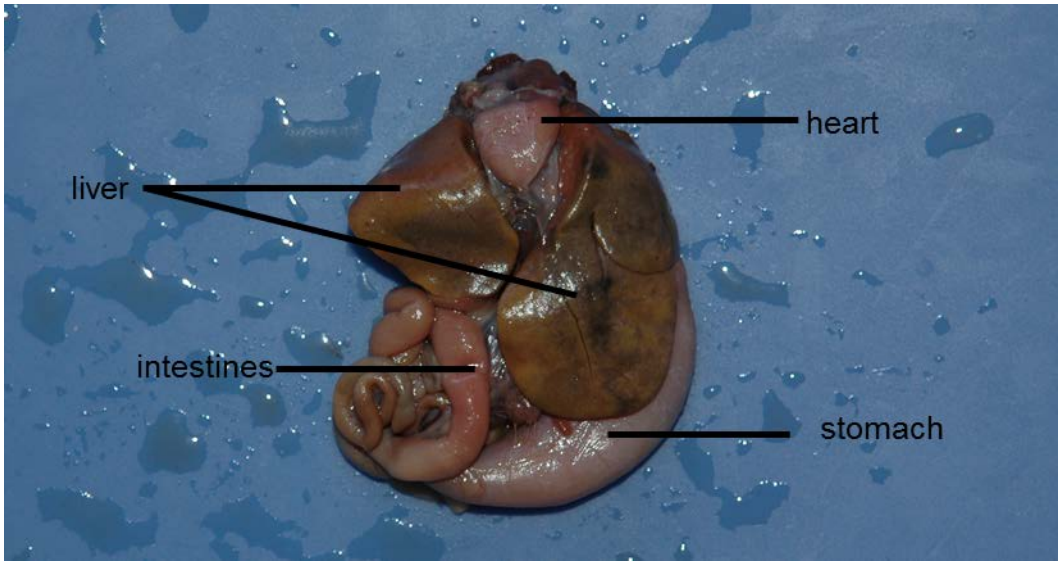


Figure 3: Basic anatomy of the internal organs of a frog. The lungs are not visible in this figure, but are located directly next to each side of the heart and behind the lobes of the liver.

19. Use a camera to photograph the organs on the scale.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

20. Use the dissection scissors to remove the stomach from the mass of organs. To do this, cut the stomach at the top where it meets the esophagus and at the bottom where the stomach meets the small intestines.

21. Use the scissors to cut open the stomach and observe any contents that may be present in the stomach. Record your observations in Table 1.

22. Use a camera to photograph the contents of the stomach.

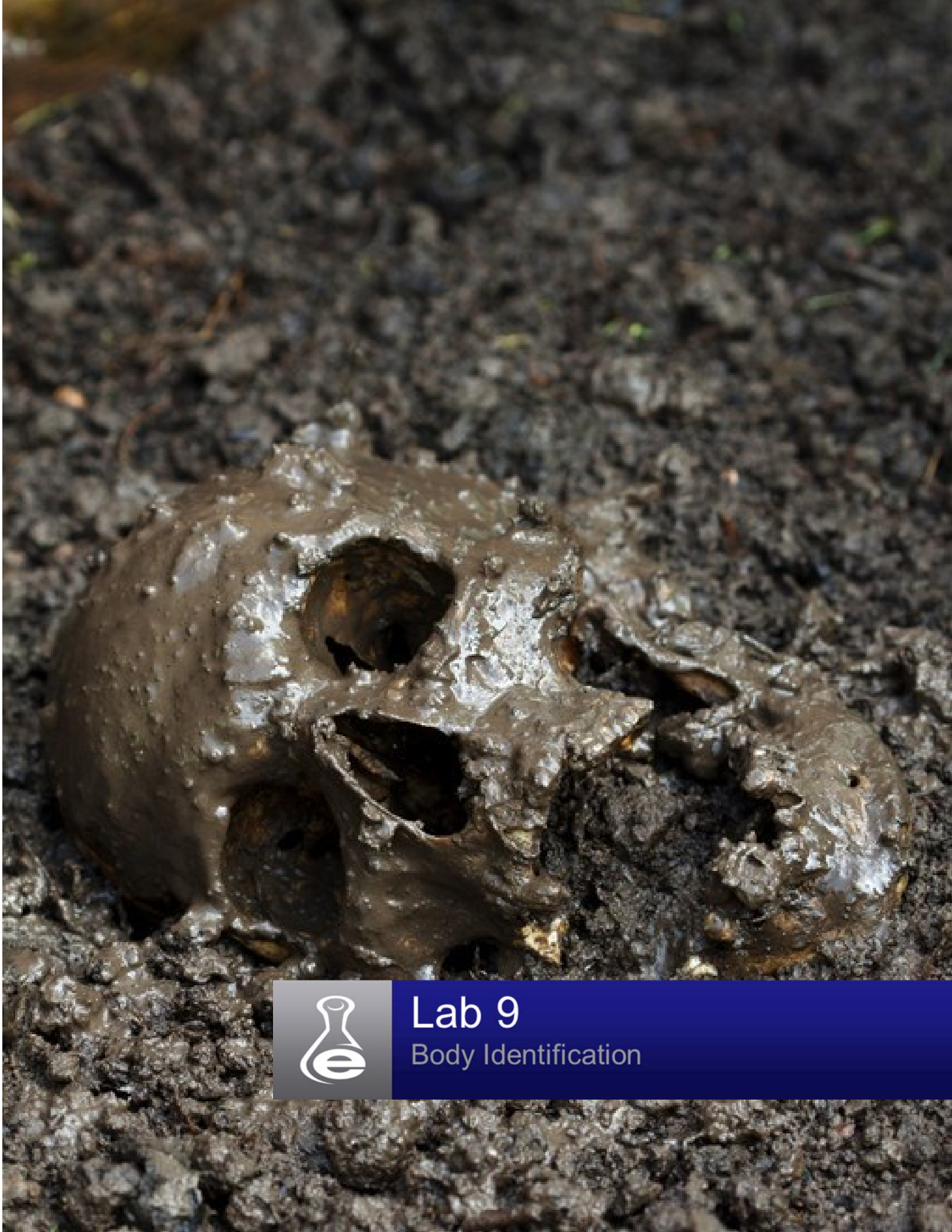
    Note: You will need to download, scan, or print the photographs to be included with your lab report.

23. Replace the mass of organs, including the stomach, back into the frog and fold the skin back into its original position.
24. To dispose of the frog, contact your local waste management organization to determine any specific guidelines for your area. Clean the area in which you worked thoroughly with soap and water.

Results Tables

Table 1: Autopsy Report

Examiner	
Exam Date	
External Examination	
Skin Features	
Eye Features	
Internal Examination	
Internal Features	
Mass of Organs (g)	
Stomach Contents	



Lab 9

Body Identification

Lab 9 Body Identification

LEARNING OBJECTIVES

- Explain the role of anthropology and odontology in forensics
- Differentiate between identifying features of skeletal remains including skull and pelvis anatomy
- Use anthropometry to estimate and compare height
- Create dental impressions to observe identifying features and practice using the universal numbering system

INTRODUCTION

When a body or remains are found at a crime scene, one of the first priorities is to establish the identity of the deceased. **Antemortem data,** information about a person during his or her life that can assist in identification after death, is collected, including a physical description, recent photographs, and medical records. To identify the victim, information about a person's clothing and the personal effects he or she might have been carrying at the time of disappearance are requested.

Other clues that aid in the identification of a deceased individual are scars, birth marks, or tattoos. Body abnormalities, such as evidence of surgical procedures, might prove useful in identification, as well as chest or orthopedic X-rays. Clothing, jewelry, and other artifacts found with or near a body will also be examined. If intact, examiners will collect fingerprints for database comparison and possibly collect DNA for analysis.

If a corpse is found at a site with no identifying items, identification becomes problematic. It becomes more difficult if the remains are badly damaged through disfigurement, submergence in water for long periods of time, burning, decomposition, or skeletal fragmentation.

Knowledge Check

☐ ***List two pieces of information that aid in the identification of a missing individual.***

Skeletal Remains

Examination of skeletal remains can narrow down possible identities. The skull, pelvic bones, and length

of long bones can reveal clues about the sex, race, age, and stature (height) of an individual. An overview of skeletal anatomy can be studied in Figure 1.

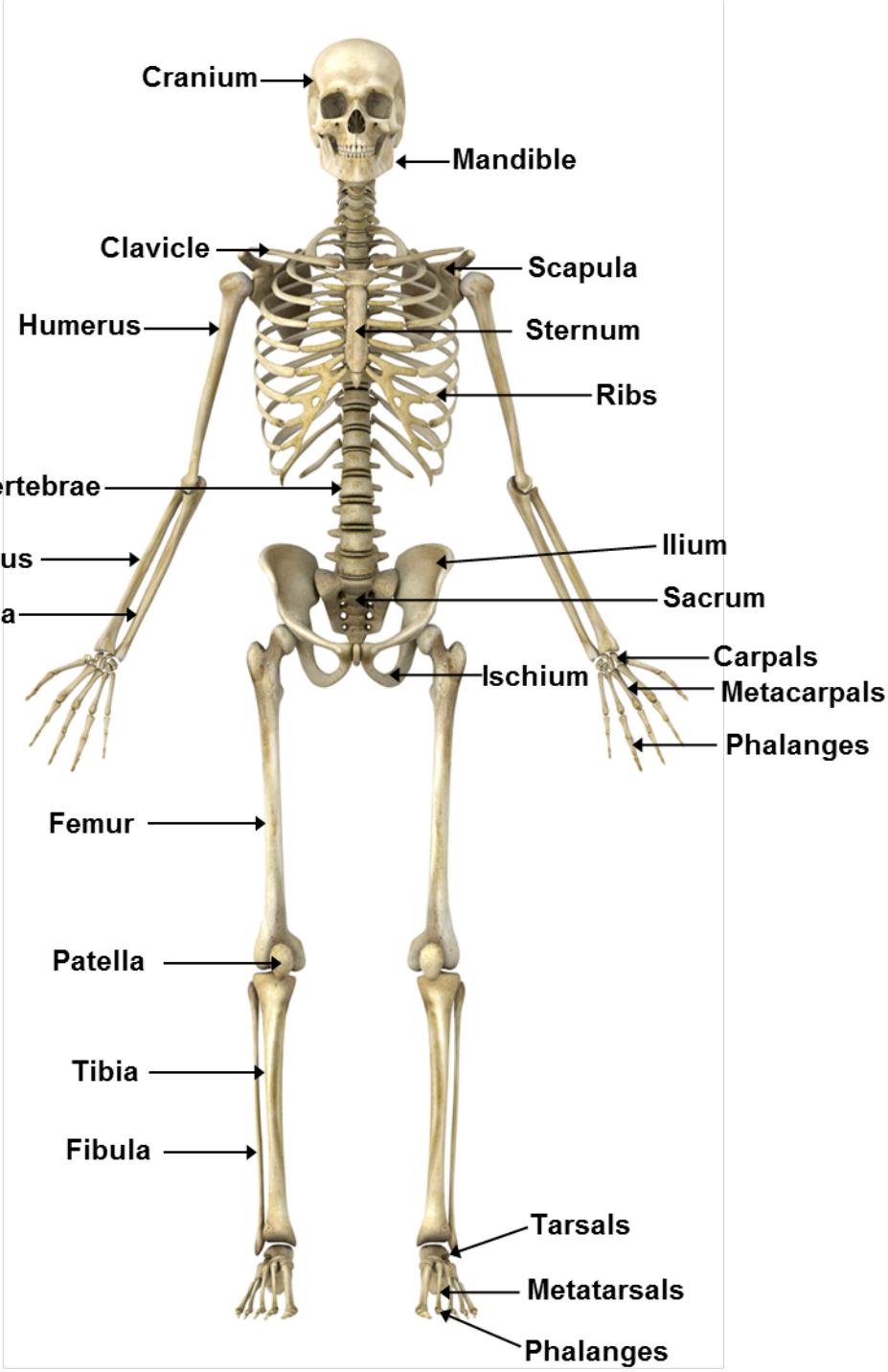


Figure 1: Skeletal anatomy.

On average, male skeletons tend to be taller and larger than female skeletons. Male skeletons are described as robust, while female skeletons are described as gracile, meaning graceful (Figure 2). Table 1 summarizes general distinguishing characteristics between male and female skeletons. The science of physical measurements of a person's size and form is called **anthropometry**. While anthropometry is an older method of human identification, it can be useful in determining an estimated height when only a foot, femur, or other singular bone is discovered.

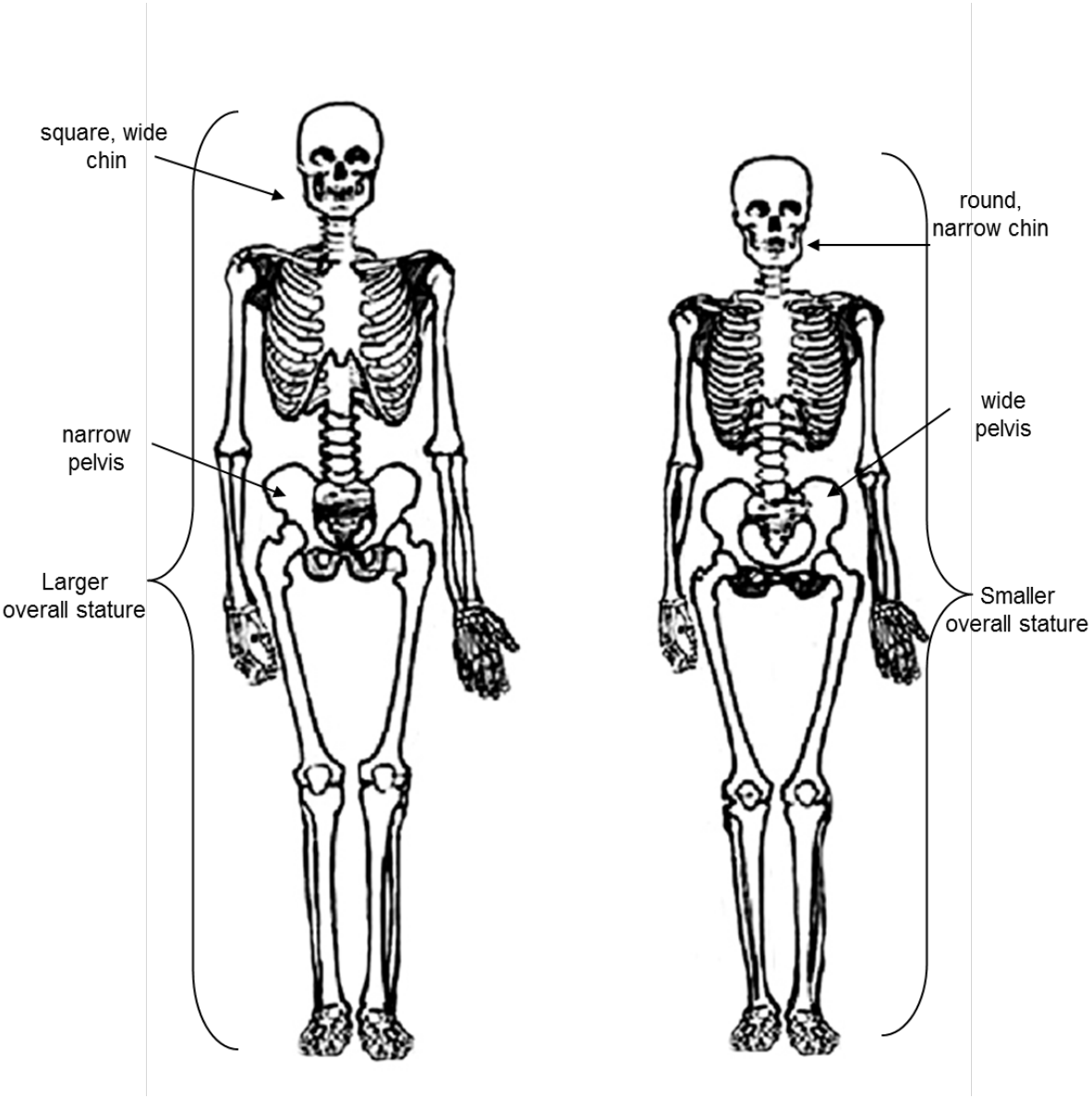


Figure 2: Male (left) and female skeleton (right).

Table 1: Distinguishing Characteristics of Male and Female Skeletons

Landmark	Male Skeleton	Female Skeleton
Overall Anatomy	**Robust**	**Gracile**
Mastoid Process (Behind Ear)	**Larger**	**Smaller**
External Occipital Protuberance (Back of Skull)	**Prominent**	**Not prominent**
Chin	**Square and wide**	**Round and narrow**
Forehead	**Sloping**	**Vertical and smooth**
Brow Ridges (Location of Eyebrows)	**More prominent**	**Less prominent**
Temporal Muscle Lines	**More prominent**	**Less prominent**
Orbital Margins (Edge of Eye Socket)	**Rounded**	**Sharp**
Angle of Ascending Ramus (Back Corner of the Jaw)	**Square (close to 90 degrees)**	**Round (obtuse)**

Skull

The skull can indicate the sex and age range of an individual. Figure 3 summarizes the structural differences between male and female skulls.

The age range of an individual can be estimated based on bone development. At birth, the skeleton is not fully formed, allowing for bone growth into adulthood. Two noticeable age related skeletal features are the cranial bones and the epiphyseal plate of the long bones. Cranial bones compose the cranium of the skull. They are not fused at birth to allow the human head to fit through the birth canal and for growth of the brain during development. Skeletal remains with unfused cranial bones can be indicative of an age range between newborn and 18 months (Figure 4).

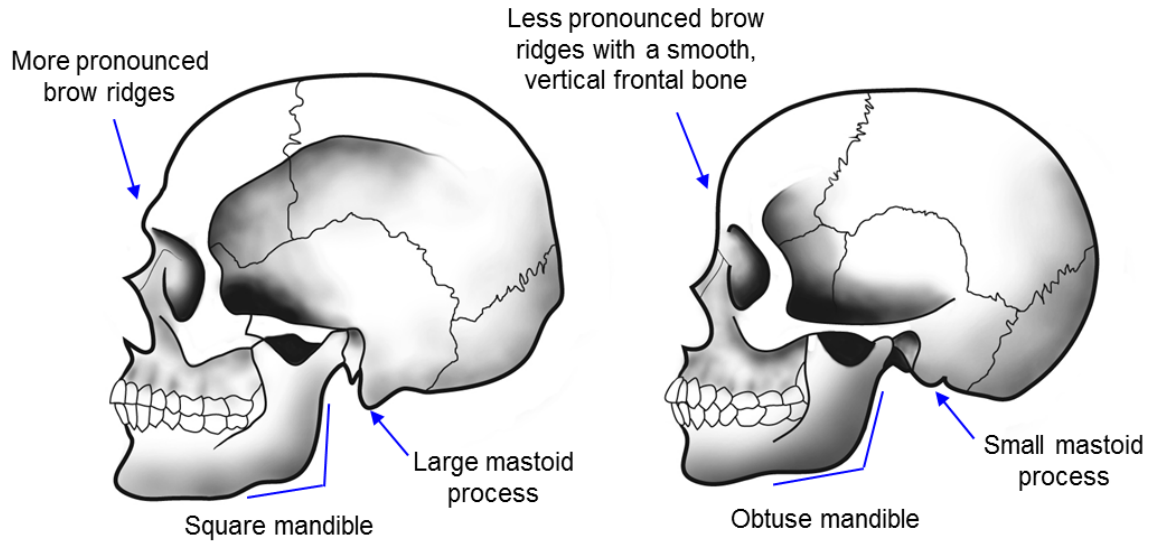


Figure 3: Male skull (left) and female skull (right) with distinguishing features labeled.

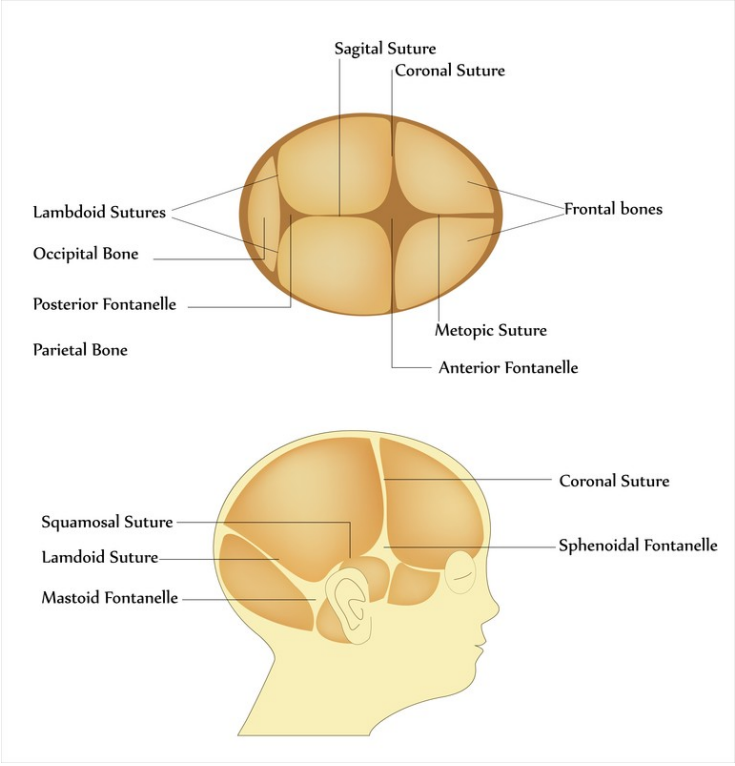


Figure 4: The spaces between three or more cranial plates are called fontanelles, commonly referred to as "soft spots".

The ends of long bones, such as the humerus, are also not fused at birth to allow for growth. Before long bone fuse, the ends are referred to as epiphyses and the middle of the bone is referred to as the diaphysis. Between them is an epiphyseal plate composed of cartilage (Figure 5). While different bones fuse at different times during development, bone fusion is completed by 20 - 28 years of age. Unfused epiphyses are indicative of adolescent age ranges.

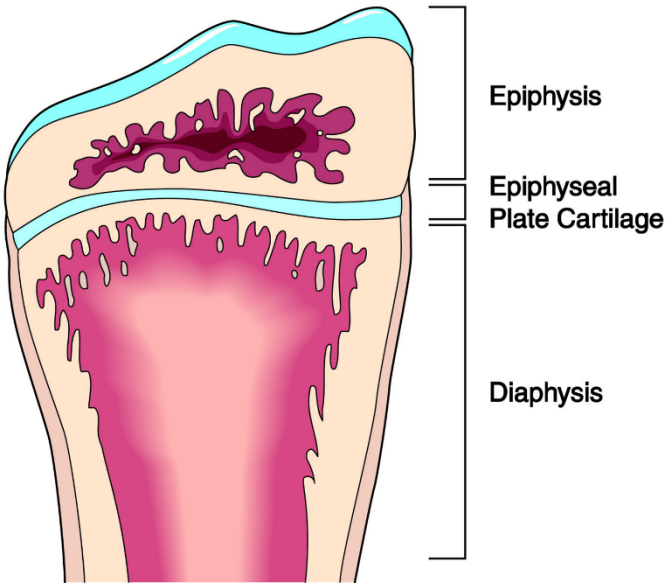


Figure 5: Anatomy of bone development.

Pelvic Bone

The discovery of a pelvic bone can be telling of the sex of an individual. Females tend to have wider, more bowl-shaped pelvic bones than males to accommodate child birth. The female sacrum tends to be shorter and wider than the male sacrum (Figure 6). However, sex isn't reliably determined for pre-pubescent juveniles, due to the absence of sex characteristics that emerge during puberty.

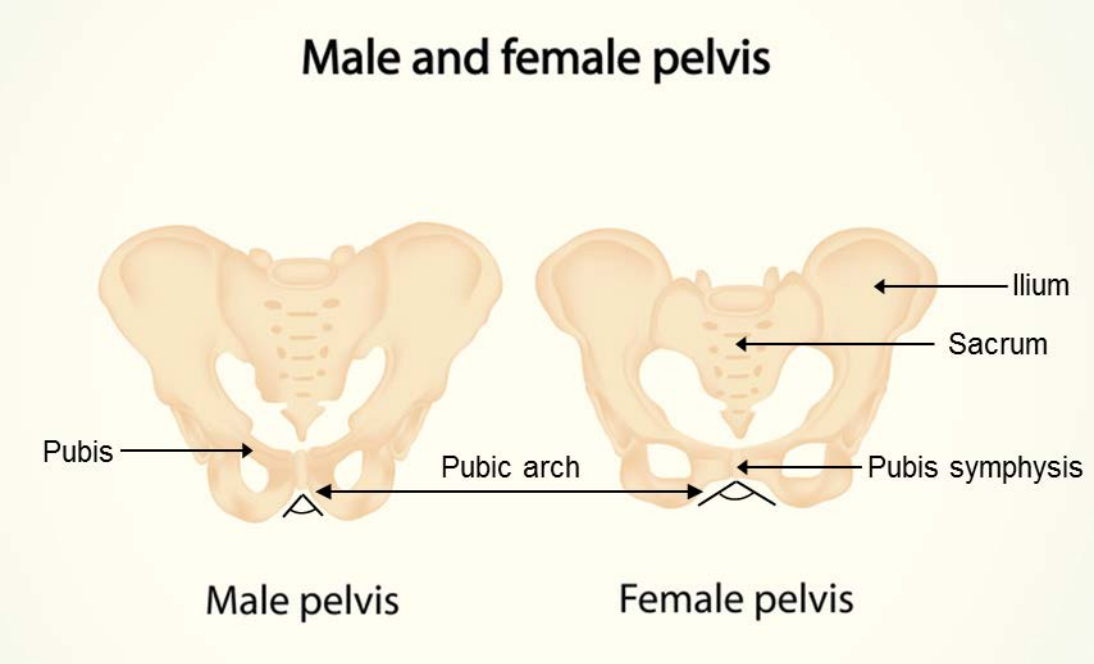


Figure 6: Male pelvis (left) and female pelvis (right). The pubic arch of the male pelvis is typically 90 degrees or less, whereas the female pubic arch is typically wider than 90 degrees.

Odontology

The study of tooth structure is called **odontology**. Odontology is frequently applied in forensics because teeth are durable and remain even after long periods of decomposition. Teeth can vary considerably and are often recorded via x-ray when an individual visits the dentist. However, unlike fingerprints and DNA, dental records are not housed in a national database. Thus, dental x-rays of a corpse are often compared with missing persons' records.

Throughout the world, multiple methods exist to identify teeth. One method is called the **universal numbering system**. This method assigns a number to each of the 32 adult teeth. Numbering starts with the upper right wisdom tooth, and proceeds across the upper row of teeth, down to the lower left wisdom tooth, and across the bottom row, ending with the lower right wisdom tooth (Figure 7). Each quadrant of the mouth contains eight adult teeth: two incisors, one canine, two premolars, and three molars.

Human tooth development is fairly standardized, with teeth emerging at certain ages (Figure 8). This can be useful when estimating the age at which an individual died. By age three, children have 20 baby teeth. Permanent teeth begin to emerge around age six. By age 21, all baby teeth have been lost and 32 adult

teeth are in place. During life, teeth are worn by lifestyle habits, which may result in tooth restorations, fillings, rotations, loss, breakage, injury, or gum disease—all of which aid in identification.

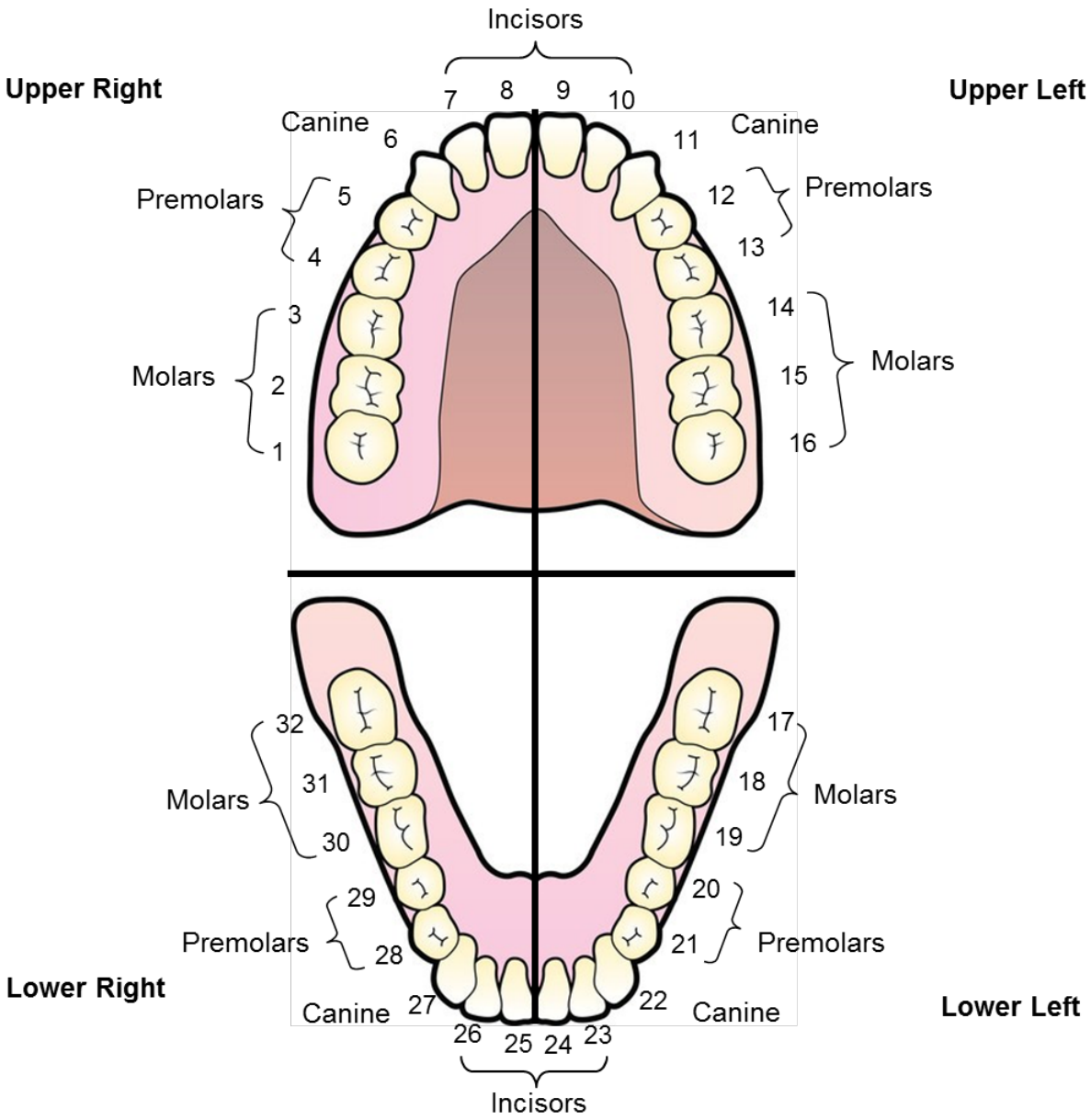


Figure 7: The universal numbering system.

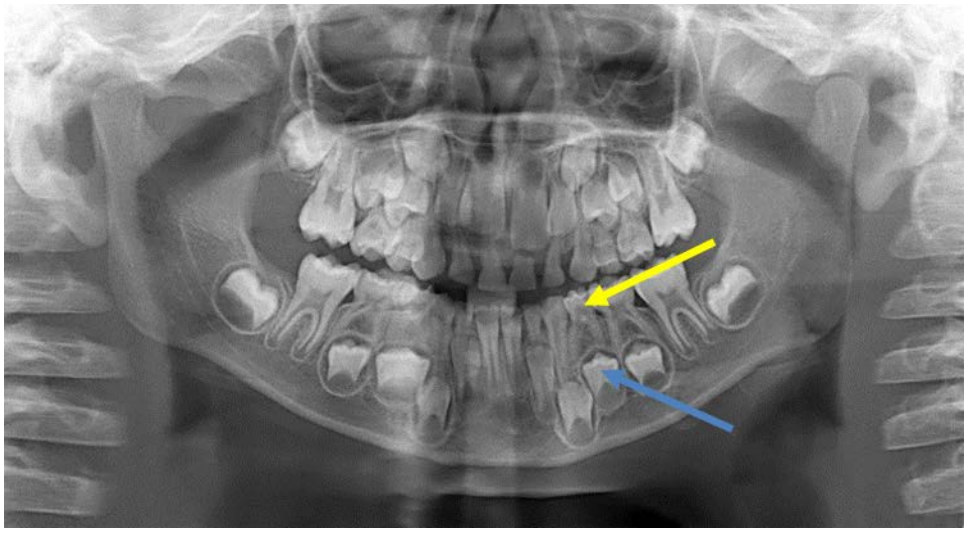


Figure 8: Dental x-ray of a seven year old child. Adult teeth (blue arrow) can be seen developing under the gum line below the baby teeth (yellow arrow).

Mildred Trotter
1899-1991

Figures in Forensics

Mildred Trotter (1899-1991) studied cadavers at Washington University in St. Louis and used that knowledge during World War II to identify the remains of causalities. During her work, she realized that the method being used to identify skeleton height dated to the 1800s and didn't apply to modern Americans. Trotter began studies to more accurately predict height using known measurements of 790 male skeletons. Ultimately, she deduced that a femur or thigh bone was the key to accurate measurement. By multiplying the femur length by 2.38 and adding 24.1771 inches, a person's height could be accurately estimated. Trotter also found that once a person reaches full grown height, height decreases half an inch per 20 years until death.

Image Source: © Acc. 90-105 - Science Service, Records, 1920s-1970s, Smithsonian Institution Archives

EXPERIMENT 1: USING ANTHROPOMETRY TO ESTIMATE HEIGHT

Anthropometry can be helpful to estimate the height of an individual when only partial skeletal remains are discovered. While anthropometric measurements are more accurate when using bones, the intention of this experiment is to introduce the idea that partial remains can hold clues about the stature of an individual. In this experiment, you will use measurements of your foot, ulna, and femur to estimate your height using standard comparison charts and compare them to your actual height by calculating percent error.

Materials

- Masking Tape
- (1) Ruler
- (1) Tape Measure
- *Calculator (optional)
- *Floor
- *Wall
- *Your Bare Foot

*You must provide

Procedure

Part 1: Foot Length and Height

1. Use a piece of masking tape and tape measure to mark the wall 60 inches above the floor, noting whether the top or bottom of the tape marks the 60 inch mark. Proceed to Step 3 if you know that you are no taller than 60". If you are taller than 60", complete Step 2.
2. Place the 0 inch end of the tape measure at the 60 inch tape mark and secure the tape measure to the wall so that an additional 20 inches of the tape measure is vertically positioned on the wall (80 inches total). Use masking tape to secure the rest of the tape measure to the wall so that it is out of the way (Figure 9).

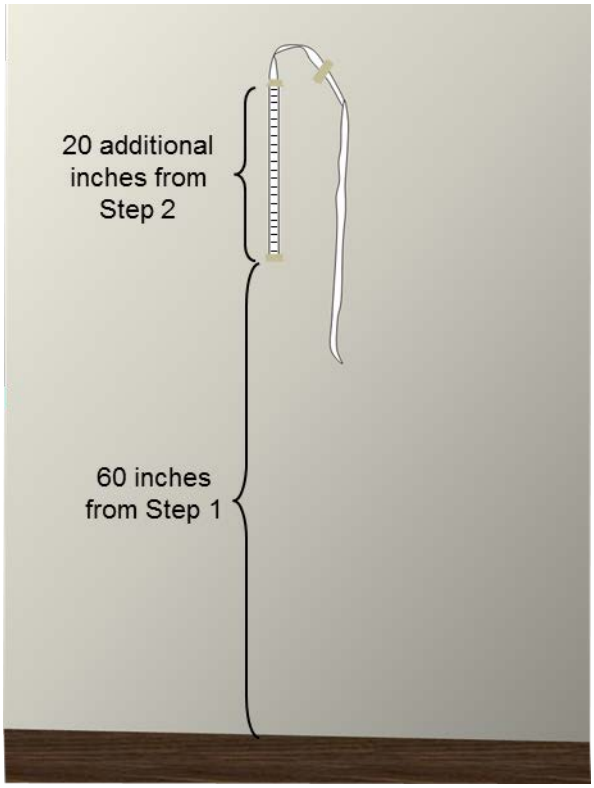


Figure 9: Reference image for tape measure setup.

3. Stand up straight in front of the tape measure with your back touching the wall. Place a ruler level on the top of your head so that it also touches the wall.
4. Keep the ruler still and turn to the wall to determine your height. Record your height in inches in Table 2.
5. Once you have measured your height, remove the tape measure from the wall.
6. Use a piece of masking tape to secure the tape measure to the floor at the 3 inch mark and the 20 inch mark.
7. Remove your shoes and place the edge of the heel of your foot on the tape measure at the 0 inch mark. Measure the length of your foot from the heel to the big toe in inches. You should be standing when you measure your foot. Record the length of your foot in Table 2.
8. Calculate the percent of your foot to height ratio by dividing the length of your foot by your height. Multiply that answer by 100. Record the percent in Table 2.

Part 2: Ulna Length and Height

1. The ulna is the bone that extends from the elbow to the wrist on the outside of the arm (Figure 10).

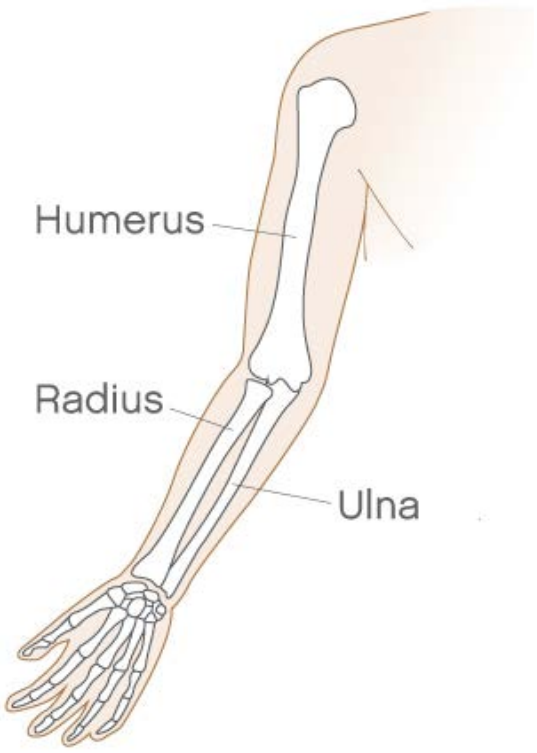


Figure 10: The skeletal anatomy of the arm.

2. If you are wearing long sleeves, roll them up so that your left arm is exposed past the elbow.
3. Use the tape measure to measure between the elbow point (olecranon process) and the midpoint of the prominent bone of the wrist (ulnar styloid process) (Figure 11). To do this, hold the tape measure in your left hand near the 15 inch mark. With the tape measure in your right hand, hold your hand over your heart. Use your left hand to extend the 0 inch end of the tape measure to the point of your right elbow. Record the length of your ulna in Table 3.

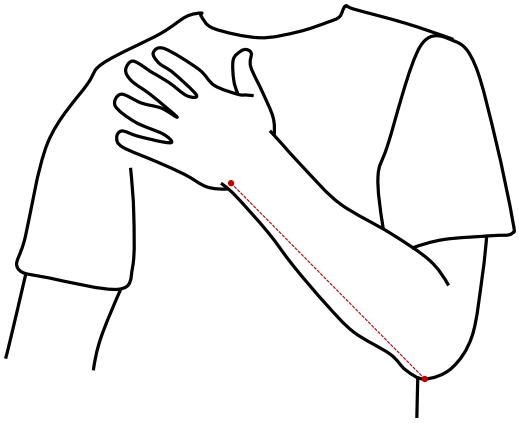


Figure 11: How to measure the ulna.

4. Use the ulna measurement to estimate height with the following formulas:

   Male [3.70 x ulna length in inches + 29.1 inches = height in inches

   Female [4.27 x ulna length in inches] + 22.8 inches = height in inches
5. Record the calculated height in Table 3.
6. Compare the ulna bone measurement to Table 5 to determine estimated height. Record your height according to Table 5 in Table 3.

Part 3: Femur Length and Height

1. Use a tape measure to measure your femur in inches from just below your hip bone to the top of your kneecap. Record the length in Table 4.
2. Use the femur measurement to estimate height with the following formulas:

   Male [1.88 x femur length in inches + 32.0 inches = height in inches

   Female [1.94 x femur length in inches] + 28.7 inches = height in inches

Data Tables

Table 2: Foot to Height Ratio

Measured Height (inches)	
Foot Length (inches)	
Foot to Height Ratio	

Table 3: Height Estimate Based on Ulna Length

Ulna Length (inches)	
Calculated Height (inches)	
Height according to Table 5	

Table 4: Height Estimate Based on Femur Length

Femur Length (inches)	
Calculated Height (inches)	

Table 5: Age and Sex Specific Height Based on Ulna Length (Inches)

Ulna Length	Height			
	Male (<65 years)	Male (≥65 years)	Female (<65 years)	Female (≥65 years)
12.5	76.4	73.6	72.4	72.4
12.4	75.9	73.2	72.0	72.0
12.2	75.2	72.4	71.5	71.5
12.0	74.4	71.7	70.9	70.5
11.8	73.6	71.3	70.5	70.1
11.6	72.8	70.5	69.7	69.3
11.4	72.4	70.1	69.3	68.9
11.2	71.6	69.3	68.9	68.1
11.0	70.9	68.9	68.1	67.3
10.8	70.1	68.1	67.7	66.9
10.6	69.3	67.3	66.9	66.1
10.4	68.9	66.9	66.5	65.4
10.2	68.1	66.1	66.1	65.0
10.0	67.3	65.7	65.4	64.2
9.8	66.5	65.0	65.0	63.4
9.6	65.7	64.2	64.2	63.0
9.4	65.4	63.8	63.8	62.2
9.2	64.6	63.0	63.4	61.4
9.0	63.7	62.6	62.6	61.0
8.8	63.0	61.8	62.2	60.2
8.6	62.2	61.4	61.4	59.8
8.4	61.8	60.6	61.0	59.0
8.2	61.0	59.8	60.6	58.3
8.0	60.2	59.4	59.8	57.9
7.8	59.4	58.6	59.4	57.1
7.6	58.7	58.3	59.1	56.7
7.4	58.3	57.5	58.3	55.9

Ulna Length	Height			
	Male (<65 years)	Male (≥65 years)	Female (<65 years)	Female (≥65 years)
7.2	57.5	57.1	57.9	55.1

EXPERIMENT 2: ODONTOLOGY

Dental records can be a quick, inexpensive way to identify victims, especially when only skeletal remains are recovered. In this experiment, you will examine your dental impressions.

Materials

- Permanent Maker
- Styrofoam® Plate
- Underpad (located in your safety box)
- *Camera/Smart Phone
- *Scissors

*You must provide

Procedure

1. Use scissors to cut a Styrofoam® plate in half.
2. Place the two halves over each other.
3. Use the scissors to cut the halves in half so there are four equal pieces.
4. Overlap two quarters of the Styrofoam® plate.
5. Use the scissors to cut about one inch off the pointed tip of the plate pieces. See Figure 12 for reference.

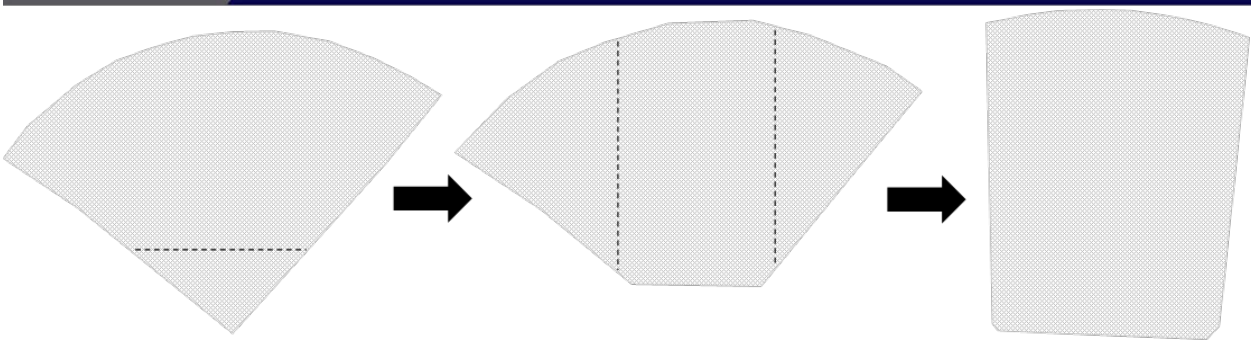


Figure 12: Reference image for cutting the plate. The dotted lines represent the location to be cut with the scissors.

6. Overlap the quarters with cut tips and place them into your mouth to fit them. You will make two more cuts so that the pieces are rectangular and can more easily fit in your mouth, but make sure the pieces are wide enough to get an impression of all of your teeth, including the molars.
7. Remove the pieces, overlap them, and use the scissors to make two more cuts up each side of the triangular pieces to create rectangular pieces. See Figure 12 for reference.
8. Use a permanent marker and Figure 13 (for reference) to label the outer edge of each quarter.

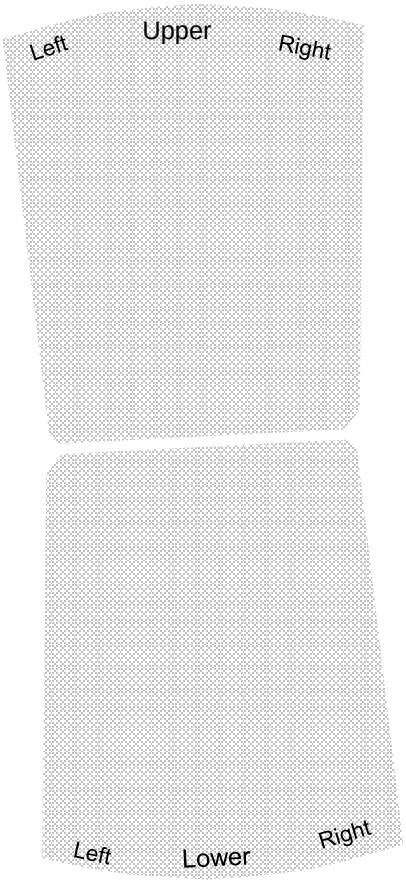


Figure 14: Labeling reference.

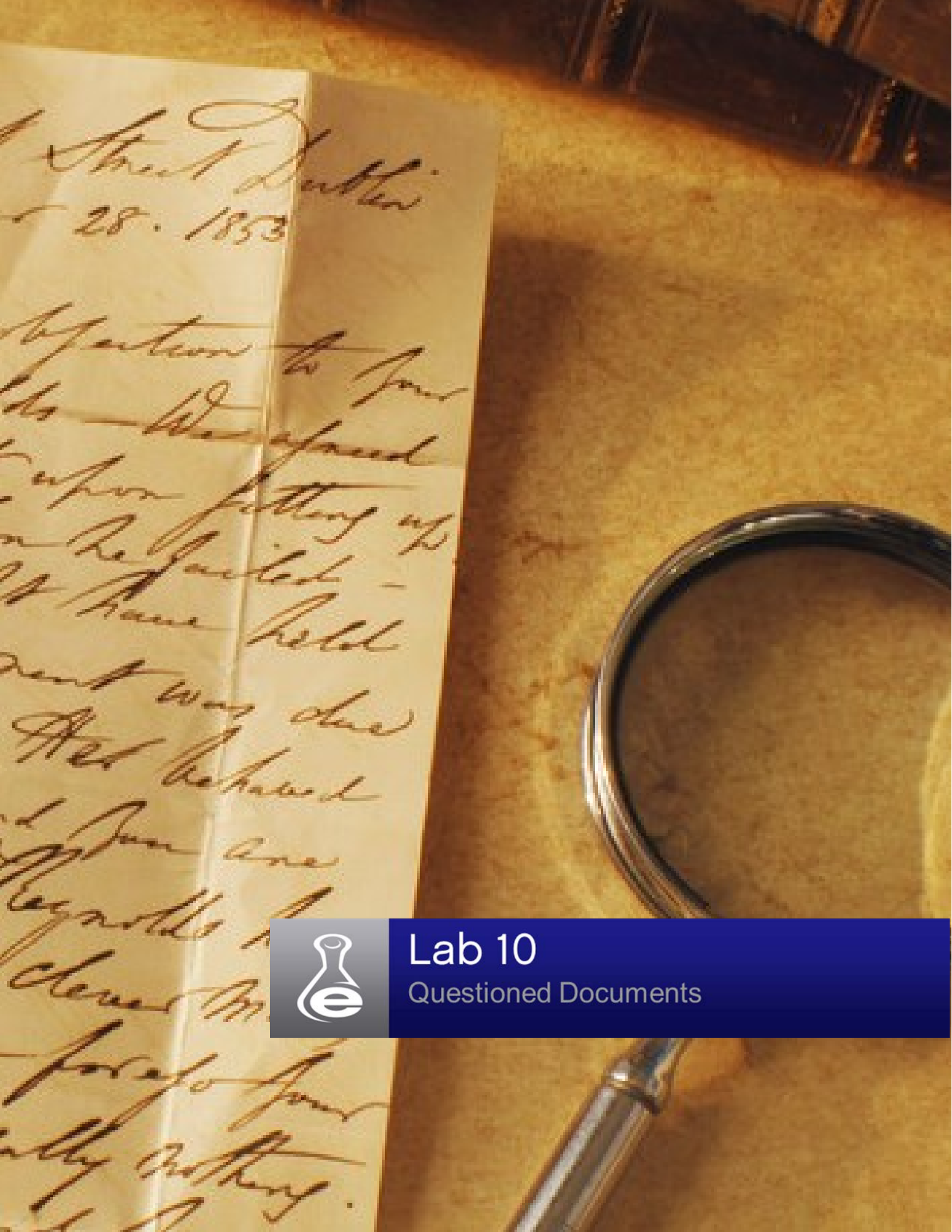
9. Overlap the quarters so that the Left and Right labels are aligned with each other.
10. Place the upper and lower halves in your mouth so that the upper piece contacts the teeth on your upper jaw and the lower piece contacts the teeth on your lower jaw. The left labels should be located on the left side of the mouth and the right labels should be located on the right side of the mouth. You will need open your mouth wide to ensure all of your teeth contact the plate.
11. Bite down with enough force to leave an impression, but not enough to bite through the plate. The goal is to leave a clearly marked impression.
12. Remove the plate from your mouth and place it on an underpad.
13. Use a permanent marker to highlight the impression of each tooth by lightly filling in depressions and dents.
14. Use a permanent marker to label the teeth marks on the plate using the universal

numbering system. Remember that wisdom teeth are included in the universal numbering system.

Note: The dental impression you made is inverted according the universal numbering system. Keep this mind when you are numbering the impression.

15. Use a camera to photograph the dental impression.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.



Lab 10

Questioned Documents

Lab 10 Questioned Documents

LEARNING OBJECTIVES

- Explain properties used to analyze questioned documents
- Perform a handwriting analysis
- Analyze ink samples using paper chromatography

INTRODUCTION

When a written item with handmade or typed markings is involved in a crime, it is referred to as a **questioned document**. A questioned document may be a ransom note, written threat, or an official document, such as a will or contract. In other instances, it may be a check or a will suspected of forgery. **Forgery** is defined as the intentional creation or alteration of a document with the intent to defraud or commit theft. Signing a document, such as a check, without authorization is also considered forgery. Similar to forgery, production of currency is termed **counterfeiting**.

Figure 1: The date and material of this document can be telling of its authenticity.

Questioned Document Analysis

Analysis of questioned documents primarily relies on the fields of history, optics, physics, and chemistry. For example, a document purported to be from an earlier time must be studied in reference to other documents from the same author, in relation to other documents, and available materials during the time period in question (Figure 1). The ownership chain must be verified as best as possible. Analysis of documents is based on finding the answers to questions including:

Is the content valid?

It is hard to prove, but if the dates mentioned in the document make a reference to something that has not occurred, the document is suspect.

Is the document too perfect?

In older, hand-printed documents, each print differs slightly. Forgeries are exactly the same because they are typically machine-produced from a photograph.

Is the document paper consistent with the era?

In previous centuries, a variety of paper sizes were popular, including sheets as wide as several feet and as small as 4 inches by 5 inches. In the United States today, 8 ½ inch by 11 inch is considered standard sized paper. Additional ingredients in the paper-making process might include starches or proteins, such as gelatin, or finish coatings that contribute clues to origin and date. The method of making paper has changed from the hand-made creations of the past to machine-made paper today (Figure 2). Paper made by hand consists of soaked fibers placed in a specialized mold. It often has deckled edges and **watermarks**, a raised design on the mold visible when held to light. During the early 1800s, papermaking became mechanized with distinctive grains and fiber alignment. Materials and production techniques have multiplied as papermaking has advanced to include synthetic papers, use of plastics, and paper brighteners. Properties of paper can be analyzed using microscopy, spectroscopy, and chemical testing.

Figure 2: Hand-made paper (left) and machine-made paper (right).

For past and present documents, questions to ask include:

What ink is used?

Ink is a fluid that contains colorants used in writing or printing. Depending on the fluid, inks dry when the colorless liquid evaporates and the paper absorbs the colorant. Forgers use hypochlorite to remove dye-based inks; however, this will not remove permanent inks. To distinguish between inks, a scientist can use chromatography to separate a sample's components or look at the sample under certain wavelengths of light. Ink databases can also aid in identification of inks.

Chromatography is a technique used in many scientific fields to separate and identify components of compounds. To identify a specific ink, analysts examine color distribution on a chromatography strip, since each color represents a different part of the original ink solution. For example, a black ink may appear black on paper; however, chromatography may reveal it consists of green and yellow ink.

Each separated component of the ink can be given a **retention factor** (Rf), the ratio of the distance the ink area traveled relative to the distance the solvent traveled, and be compared to a certain manufacturer's ink formula.

What writing instrument is used?

Long ago, quills were used that showed up on paper as a double-tracked line, unlike later steel nibs that show changing ink lines. The ballpoint pen, developed in the mid-twentieth century, sometimes can have an indention in the middle of the line, but also can spread ink evenly, as do rollerball and fiber tip pens.

Are there any alterations or additions?

Documents can be altered by abrading the paper surface with a razor, knife, eraser, or through other means, such as chemicals, all of which disturb the paper's surface. Erasures can be seen under microscopes or specialized lights, such as infrared light. If erasures are done with a rubber eraser, minute fragments may be visible using lycopodium, a powder made from the spore of clubmoss and fern plants. However, this method doesn't work well with plastic erasers.

Handwriting Analysis

Handwriting, an individual's unique style of writing characters, should also be considered when examining a questioned document. The study of written or printed symbols is called **graphology**. Experts look for smooth or jagged lines, flourishes, slants to the left or right, and complex letter construction, such as the letter "q" (Figure 3). Each of these depends on **exemplars**, or known examples. Tracing is a forger's most common technique. A forger might copy the general style of the handwriting being reproduced. Surprisingly, if a forged signature did look exactly like an authentic signature, analysts would automatically suspect forgery. A writer doesn't produce the exact signature twice because natural writing is rhythmic and unconsciously made. However, the writer does produce signatures with the same patterns and characteristics as his or her other signatures. Consequently, analysts try to get as many examples of a signature as possible. Ideally, at least 15 known, genuine signatures are gathered for comparison with an unknown or questioned signature. In addition to quantity, quality signatures are needed: a signature written in haste versus one on a formal document may differ significantly. Analysts will look at how the signature is placed on the page, its baseline, its shape as shown by sequence of individual strokes, and other traits. Microscopes also can show pen lifts, tremors, and corrections that evidence forgery.

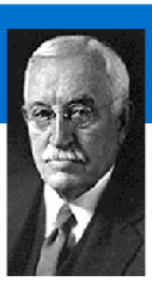
Figure 3: Complicated letters, such as the letter "q," can be useful in identifying the author of questioned handwriting.

Forgery practices also include writing more slowly than regular writing with stops and starts. Forgers may also change their grip on the writing instrument. Even with well-studied practices, forgery identification still depends on the individual forensic analyst. The admission of handwriting analysis as evidence in court has been questioned. However, with advances in computer systems that can more accurately match handwriting, handwriting evidence is becoming more standardized, and in some cases, may be used to corroborate other pieces of evidence.

Lab 10 Questioned Documents

Typed or computer-produced documents have expanded the arsenal of tools for forgers. While typed documents may appear identical upon first inspection, typewriters and computer printers all vary and develop tell-tale variations over time due to inherent flaws or use patterns. When examining a suspect document, finding the printer source is crucial. For instance, photocopiers print with different ink cartridges and can have visible glass scratch marks. Typically, several copies are printed on a suspected printer to obtain representative samples. Points of comparison can be random debris, ink transfer, or mechanical wear. If a source printer is not known, class comparison studies can often identify the make and model of a printer through typeface studies, copy alignment, and other identifiers. Another trait of photocopies is that the clearest copies are made directly from the original. Copies of copies have less distinction and are more obviously reproductions.

Figures in Forensics



Albert Osborn
1858 - 1946

For centuries, legal courts have tried criminals who allegedly forged documents. However, document examination did not become an accepted forensic science until the 20th century, thanks to the work of Albert Osborn. After studying and teaching penmanship, Osborn became skilled in questioned documents. To gain validity, he wrote articles in legal publications and researched paper, ink, and typewriters. He also designed instruments for document inspection and incorporated scientific reasoning in his 1910 publication *Questioned Documents*, which became a classic text.

Image Source: ©2014 http://www.nndb.com/

Lab 10 Questioned Documents

EXPERIMENT 1: HANDWRITING ANALYSIS

In this exercise, you will use tracing paper to analyze and compare exemplar signatures to forged signatures.

Materials

- (1) 8.5'' X 11'' Tracing Paper Sheet
- (1) Exemplar Signatures
- (1) Hand Lens
- Masking Tape
- (2) Paperclips
- (1) Pen
- (1) Ruler
- *Camera/Smart Phone
- *Pencil

*You must provide

Procedure

1. Use a pen to forge the three exemplar signatures. Write the forgeries in the forgery column in Table 1.
2. Use a camera to photograph Table 1 with the forgeries.

   Note: You will need to download, scan, or print the photographs to be included with your lab report.
3. Place a piece of tracing paper over Table 1.
4. Use masking tape to secure the top edge of the paper containing Table 1 and the tracing paper together.
5. Use one paperclip to secure each side of the papers together.
6. Use a pencil to draw a dot on the tracing paper at the high point of each letter in Exemplar 1.
7. Use a ruler and pencil to connect the high point dots. This will form a pattern.
8. Use a pencil to draw dots on the low point of each letter in Exemplar 1.

9. Use the ruler and pencil to connect the dots to make a pattern.
10. Use a pencil and ruler to draw a line over each letter in the direction that the letter slants. This may be at an angle to the left, at an angle to the right, or vertical. Each word then will be represented by a series of slants.
11. Use a ruler and pencil to connect the low point dot of the first letter in the signature's first name and the low point dot of the last letter in the signature's first name.
12. Repeat Step 11 for the middle and last name (if they are included in the exemplar).
13. Repeat Steps 1 – 12 on the forged signature.
14. Repeat Steps 1 – 13 for Exemplar 2 and Exemplar 3.

Results Tables

Table 1: Handwriting Exemplars and Forgeries

Exemplar	Forgery
 **Ellis H. Roberts**	
 **John Burke**	
 **Charles Francis Adams**	

EXPERIMENT 2: CHROMATOGRAPHY OF INKS

In this experiment, you will perform paper chromatography to compare a sample of ink from a possible forged signature on a will to ink from pens that may have been used to commit the forgery.

Materials

- 5 mL Acetone, C_3H_6O
- (1) 100 mL Beaker
- (1) 11 x 11 cm Chromatography Paper
- (1) 10 mL Graduated Cylinder
- (1) Paper Mate® Pen
- (1) Ruler
- (1) Underpad (located in your lab safety kit)
- (1) uni-ball® Onyx Fine Point Pen
- (1) Will Signature Ink Sample
- (1) Pair of Disposable Gloves
- (1) Pair of Safety Glasses
- *Camera/Smart Phone
- *(1) Pencil
- *(2) Sample Pens
- *Scissors
- *Timer or Clock

*You must provide

Lab Safety

Wear safety glasses, gloves, and an apron when working with acetone. Keep pets and children away from acetone.

Procedure

1. Use a ruler and pencil to measure and draw a line 1 cm from the edge of one of the sides of the chromatography paper (Figure 4).
2. Fold the chromatography paper in half so that the pencil line overlaps itself.
3. Repeat Step 2 to create four sections of identical size (Figure 4).
4. Use the scissors to cut along the folds to create four evenly sized pieces, each with a

pencil line across the bottom.

Note: You will use two of the four pieces now and the remaining two later. You may need to further cut down the papers so that they comfortably fit in the 100 mL beaker without touching one another.

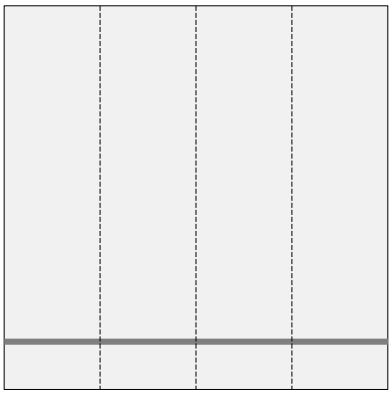


Figure 4: Steps 1 and 3 reference. The gray line represents the pencil line and the dotted lines represent folds.

5. Use a pencil to label the top (the end opposite the pencil line) of one of the chromatography pieces "uni-ball®" (Figure 5).

Figure 5: Steps 5 and 9 reference. The black line represents an ink sample.

6. Repeat Step 5 for one additional piece of chromatography paper using the label "Paper Mate."
7. Remove the piece of chromatography paper from the bag labeled "Will Signature Ink

Sample."

8. Use a pencil to label the top of the crime scene ink sample "will."
9. Remove the cap of the uni-ball® pen and place a sample of the ink on the pencil line of the corresponding piece of chromatography paper (Figure 5).
10. Repeat Step 9 with the Paper Mate pen on its respective piece of chromatography paper (the will sample is already complete).
11. Use a 10 mL graduated cylinder to measure and pour 5 mL of acetone into a 100 mL beaker.
12. Place each piece of chromatography paper into the beaker so that the bottom (side with ink sample) is submerged in the acetone and none of the pieces of chromatography paper touch (Figure 6). The ink lines should not touch the acetone (this will only happen if more than 5 mL is present in the beaker). Each piece of paper should lean vertically on different areas of the beaker walls so that they are facing each other.

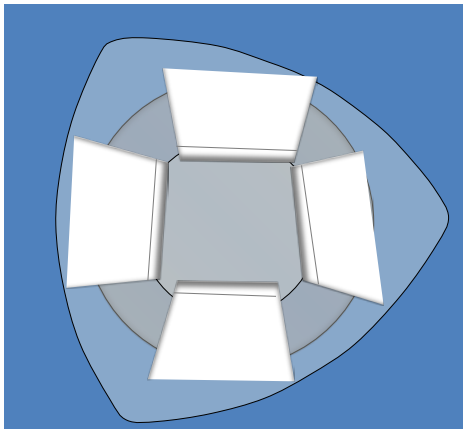


Figure 6: Step 12 reference. Top view of chromatography set up. The strips of paper rest, sitting up vertically without touching each other, inside the beaker. The end with the ink sample rests in the acetone, but the samples of ink are not submerged in the acetone.

13. Using a timer or clock, allow the ink samples to rest in the acetone for 10 minutes.
14. After 10 minutes have elapsed, remove the pieces of chromatography paper from the acetone and set them on an underpad. Allow approximately 5 minutes for the paper to dry.
15. Observe the samples for banding and the different colored inks that compose the black ink. Record the number of bands, colors present, and any differentiating description (see

Figure 7 for chromatography terms) for each sample in Table 2. Do not include the original ink spot in your data.

16. Use a camera to photograph your results.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.

17. Use the extra pieces of chromatography paper to run a chromatography test on ink from two pens (any color) of your choice.

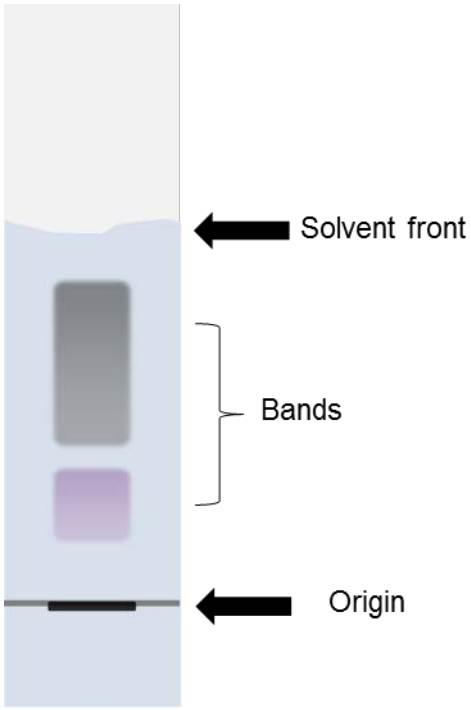


Figure 7: Chromatography terms.

Results Tables

Table 2: Ink Chromatography Results

Ink Sample	Number of Bands	Color and Description of Bands
uni-ball®		
Paper Mate®		
Will Signature		
Pen Sample (Student Chooses)		
Pen Sample (Student Chooses):		

Lab 11

Fire Investigation and Arson

Lab 11 Fire Investigation and Arson

LEARNING OBJECTIVES

- Describe fire behavior, including combustion, backdraft, and flashover
- Identify methods used in fire investigation to determine if a fire is accidental or arson
- Test the tetrahedron fire theory

INTRODUCTION

Accident or arson? Investigators seek to answer this difficult question about fire, which causes devastating damage to structures and claims lives every year. **Accidental fires** may result from faulty electrical wiring or a campfire that is not completely extinguished after use (Figure 1). When a fire is intentionally set for criminal purposes, it is referred to as **arson**.

Figure 1: Sometimes forest fires are accidentally set when campers do not completely extinguish a campfire. Even though a flame may not be present, the wood may still smolder and, if conditions are right, start back up after the campers have left.

Arson is a crime that may be committed for many reasons, including destruction of evidence of another crime, as a strategy to terrorize or intimidate, or to reap the financial payout of a fraudulent insurance claim. Arson involves a person tampering with one or more of the following factors: increasing the fuel load of a fire by introducing flammable material, adding an **accelerant**, a combustible material used to make fire burn hotter and spread quicker than usual, or introducing a heat source, such a match. The most commonly used accelerants are gasoline (Figure 2), kerosene, turpentine, and diesel fuel. Each is an organic compound containing a mixture of hydrocarbon molecules.

Figure 2: Gasoline is a common accelerant.

Arsonists often pour or place accelerants in several places, using more than necessary to ensure the fire successfully damages property. However, this may cause accelerants to pool or soak into a surface with insufficient oxygen to burn, leaving behind evidence. Accelerant residue can be collected and analyzed in a laboratory. Accelerants are also absorbed by porous materials, such as carpet, flow downward, and may be found under **charring,** the chemical process of incomplete combustion when subjected to high heat.

Arson and the Scientific Method

It is important to note that forensic fire investigation of fire is a relatively new science. Previously, fire investigators gained knowledge passed down from fire investigators before them. Often, this knowledge was not tested using the scientific method (Figure 3). There have been numerous cases of people convicted of arson, even sentenced to death, on false knowledge about fire behavior. Therefore, fire knowledge supported by scientific study is important as an investigator searches a scene damaged by fire.

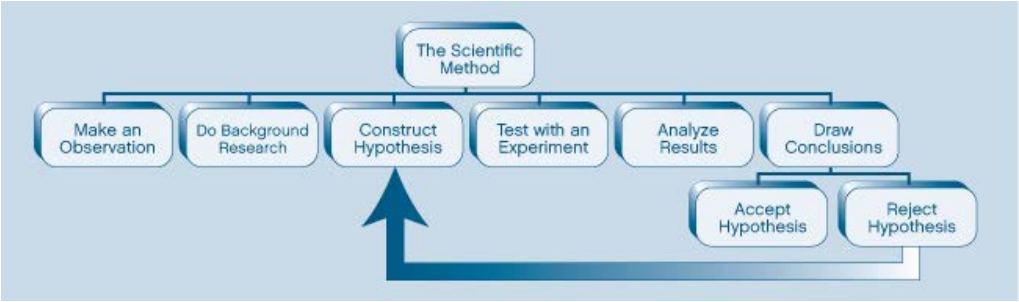


Figure 3: The scientific method helps ensure data and results are replicable and valid.

Fire Theory

Combustion is the exothermic (heat releasing), self-sustaining process of oxygen oxidation (losing electrons) and fuel reduction (gaining electrons). **Fire** is a product of substances rapidly combining with oxygen from the air that typically produces bright light, heat, and often smoke.

The combination of elements required to produce fire or burning is referred to as the **fire tetrahedron** (Figure 4). It consists of oxygen, heat, fuel, and an uninhibited chain reaction. If any of the elements are reduced or removed, the fire decays or does not burn at all. For example, the wood in a campfire is the fuel. Once all of the fuel is used and additional fuel is not added, the fire will decay until it goes out. Similarly, if a campfire is smothered by sand causing a lack of oxygen, the fire will also decay or die out.

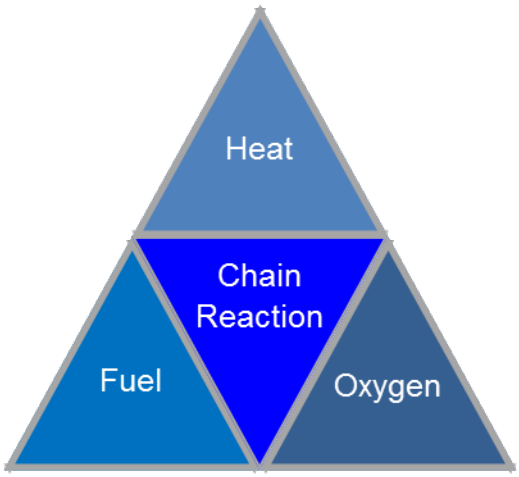


Figure 4: Four essential elements are required for fire to occur.

Fuel exist in solid, liquid, and gaseous states. While some solids do burn, fire generally does not burn solids or liquids. It burns the gases formed when heat vaporizes solid or liquid fuels. Before a solid fuel source burns, it vaporizes. As a solid or liquid fuel is heated, the molecules at the surface of the fuel will gain energy, and at a certain temperature, escape the surface as a gas. It is this gas that is flammable. This is why a piece of wood does not immediately catch fire when a match is held up to it. The wood has to reach a certain temperature before it decomposes to a gas that will ignite.

Fire Behavior

Fire does not behave the same way in every situation. Rather, it tends to cause common patterns and effects that can aid in determining information useful to a fire investigation. The development of a fire is categorized into stages, characterized by differences in temperature and atmospheric composition over time (Figure 5).

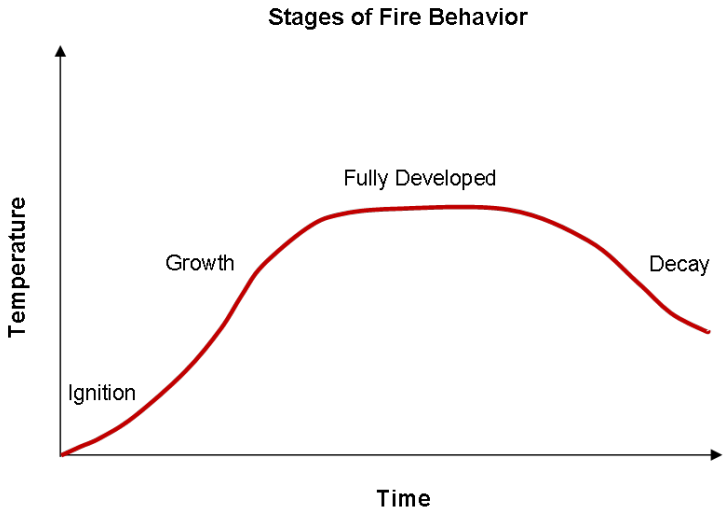


Figure 5: Stages of fire behavior. Source: http://www.nist.gov/fire/fire_behavior.cfm

- **Ignition**: The necessary elements for a fire come together and combustion occurs.
- **Growth**: With adequate oxygen, more fuel will become involved and the heat release rate will increase.
- **Fully Developed**: Heated gases rise upward and spread out laterally. This forces the cooler air down and consumption of most of the oxygen available. The fully developed stage occurs when all combustible materials are burning.
- **Decay**: Insufficient oxygen and fuel cannot support the fire. Burning is reduced to flameless, smoldering embers and interior structures fill with dense smoke and gases.

As soon as a fire has been extinguished, investigators at a fire scene determine where the fire began, called the **origin**. Fire tends to burn upward and outward, producing V-shaped burn patterns on walls. While it used to be thought that multiple V-patterns indicated multiple origins and hence arson, it is now known that a phenomenon called **flashover** can cause combustible objects enclosed in a space with a developed fire to ignite. As a fire grows from an origin, heat rises to the ceiling of a structure and begins to spread out across the ceiling. As time goes on, the heat becomes so intense that objects not originally

on fire can vaporize and ignite. The buildup of heat and gases in an enclosed space can also result in a phenomenon known as backdraft. **Backdraft** occurs when oxygen is cut off from a fire and is then reintroduced after the fire has decayed and created large amounts of smoke and gases trapped in an enclosed space. Once oxygen is reintroduced, the smoke, which is partially combusted material and gases, rapidly oxidizes and ignites. This rapid ignition is often manifested as an explosion. For example, if a fire originates in a room with closed doors and windows, eventually the oxygen in the room will be used up. If a door or window is then opened, oxygen rushes back into the room, igniting the trapped smoke and gases.

Laboratory Analysis of Fire Debris

While it is difficult to determine if a fire is the result of arson, laboratory analysis can aid in the detection of accelerants. Crime scene investigators obtain samples of liquids suspected of being used as an accelerant, as well as furniture and surfaces suspected of containing accelerants. Laboratory tests, such as gas chromatography (GC) and mass spectrometry (MS), can be used to detect accelerants in fire debris. **Gas chromatography** is used to detect and identify an accelerant. This method separates mixtures of compounds based on the differences in their physical or chemical properties. **Mass spectrometry** is used to separate ionized components of molecules in an electromagnetic field.

EXPERIMENT 1: TESTING THE TETRAHEDRON THEORY OF FIRE

In this experiment, you will observe the elements that are required for fire to occur and how fire is affected when any one of these elements is changed.

Materials

- (1) 12'' by 12'' Sheet of Aluminum Foil
- (1) Butane Lighter
- (1) 3'' by 3'' Cylindrical Candle
- (1) Glass Test Tube
- (1) Pair of Safety Glasses
- Masking Tape
- (1) 4'' by 3'' Metal Mesh
- Metal Tweezers (located in your dissection tools kit)
- (1) Test Tube Clamp

Lab Safety

Use caution when working with flames. The foil will protect the surface you are working on. Wear safety glasses, secure long sleeves by rolling them up, and tie back long hair. Do not wear gloves or an apron when working with flames. They are flammable and will cause more injury to your hands than a burn to bare skin. If you follow the procedure as written, your hands and clothes will never be near a flame, but accidents can still happen. Have an emergency plan to extinguish flames, such as a fire extinguisher or container of water, easily accessible. The mesh may produce black smoke when heated. Be sure to perform the lab in a well-ventilated area.

Procedure

1. Clear your work space of flammable materials and place a 12" by 12" sheet of aluminum foil on your work surface.
2. Use masking tape to secure the edges of the foil to the work surface.
3. Place a 3" by 3" cylindrical candle on the aluminum foil work surface. If the candle is packaged in plastic, be sure to remove all packaging before proceeding.

   Note: You should be wearing safety glasses. All long hair and loose clothing should

also be secured. If not, please take proper precautions before proceeding to the next step.

4. Use the butane lighter to light the candle. Allow the flame to rest for 30 seconds or until the flame is stable.
5. Use metal tweezers to pick up the metal mesh by an edge.
6. Hold the metal mesh parallel to the work surface and above the flame. Slowly move the metal mesh down towards the flame until it touches the candle wick.
7. Slowly raise the metal mesh back up.

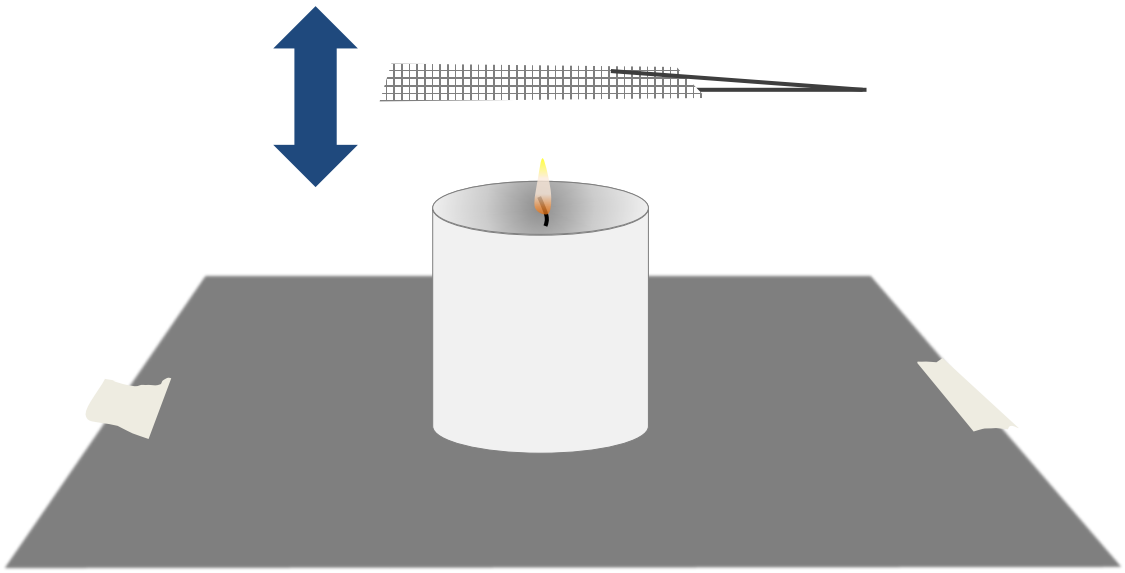


Figure 6: Steps 6 – 8 reference. Side view of work surface.

8. Repeat Step 6 and 7 three more times noting the behavior and shape of the flame (Figure 6).
9. Place the metal mesh on the foil work surface, blow out the candle flame, and note your observations.
10. Use the butane lighter to light the candle. Allow the flame to rest for 30 seconds, or until the flame is stable.
11. Use metal tweezers to pick up the metal mesh by an edge.
12. Place the metal mesh close (nearly touching) the wick of the candle to reduce the flame. To keep the flame from extinguishing, move the metal mesh back and forth and side to

side to constantly expose the flame to a new part of the metal mesh (Figure 7). This should create a consistent amount of smoke.

13. Use your free hand to light the butane lighter and hold it above the metal mesh (that you are still keeping in motion) just over the wick. If the lighter goes out, relight it.
14. Observe the interaction between the lighter's flame and the smoke.

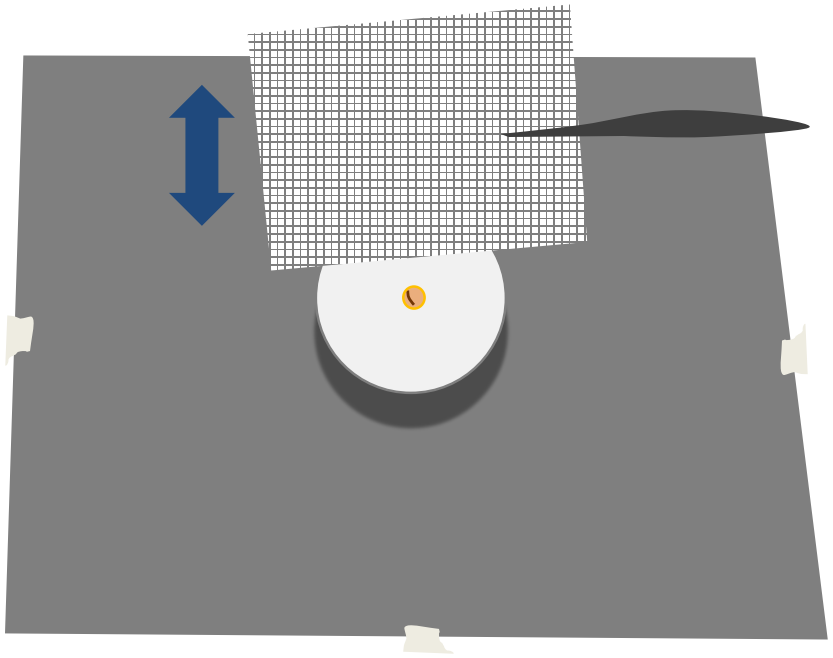


Figure 7: Step 12 reference. Top view of work surface.

15. Turn off the butane lighter, place the metal mesh on the foil work surface, blow out the candle flame, and note your observations.
16. Use the butane lighter to light the candle. Allow the flame to rest for 30 seconds or until the flame is stable.
17. Use the test tube clamp to hold a glass test tube upside down.
18. Hold the inverted test tube over the candle flame and lower it onto the flame until the opening of the test tube touches the candle wax (Figure 8).
19. Place the test tube on the foil work surface and extinguish the flame.

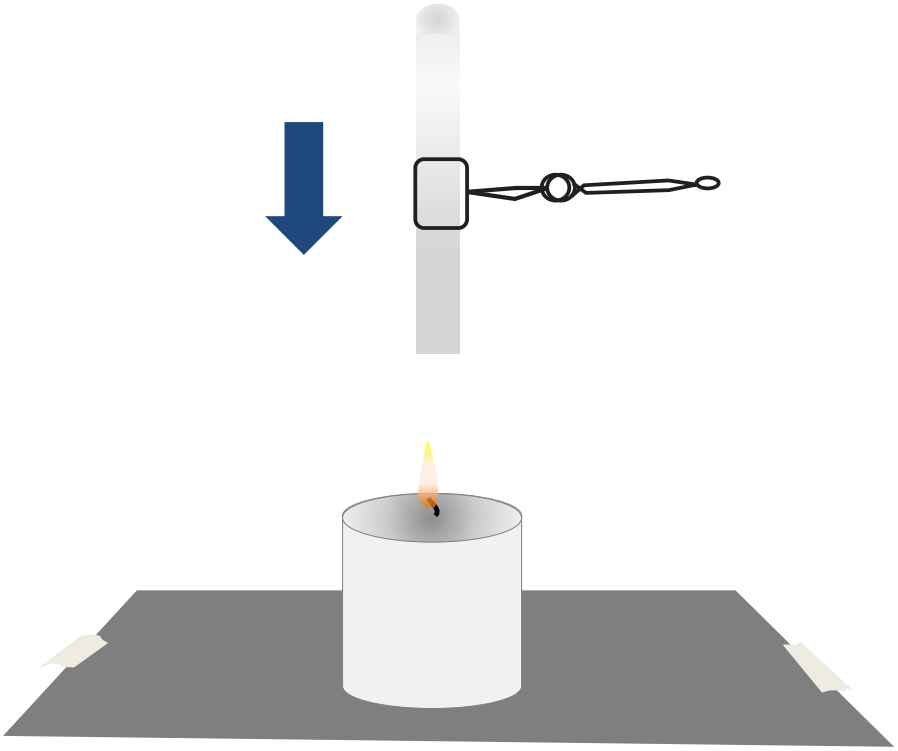


Figure 8: Step 18 reference. Side view of work surface.

Lab 12

Toxicology

Lab 12 Toxicology

LEARNING OBJECTIVES

- Explain the role of toxicology in forensics
- Apply physical and chemical properties of substances to identify unknown substances

INTRODUCTION

Forensic toxicology is the analysis of samples, such as bodily fluids and tissues, for the presence of toxins. This includes prescription medications, illegal drugs, and poisons. Toxicologists perform tests on collected samples to find what substances are present and whether the amount exceeds a harmful level. Collected samples are then compared to standards, which allow scientifically supported determinations to be made on the substance's possible effect on an individual.

Did You Know ?

According to the National Capitol Poison Center (http://www.poison.org/stats/), the most common poisons among adults are:

- Pain medicine
- Sedatives, hypnotics, and antipsychotics
- Cleaning substances
- Antidepressants
- Bites and envenomation
- Alcohols
- Food products and food poisoning
- Cosmetics and personal care products
- Pesticides
- Cardiovascular drugs
- Fumes, gases, vapors
- Antihistamines
- Anticonvulsants
- Cough and cold preparations

Lab 12 Toxicology

Poisons

Any substance in the right amount can be a **poison**, a substance capable of causing illness or death when absorbed through the skin, respiratory system, or digestive tract. Historically, minerals and plants with harmful or toxic properties were used as poisons. For example, hemlock and monkshood are plants that, when consumed in small amounts, can cause death. Since they produce hard-to-trace symptoms, they were poisons of choice by murderers before testing became commonplace. Another poison of note is the mineral thallium, which dissolves in water, is invisible to the eye, and is tasteless. Victims who drink thallium weaken and die from cumulative internal damage.

Today, intentional poisonings are far less frequent, but accidental poisonings still occur. For example, prescription medicine mix-ups, ingestion of toxic organisms, or ingestion of deadly household products by children can lead to injury or death. Carbon monoxide is a common gaseous product generated by automobile exhaust and faulty gas appliances. Victims of carbon monoxide poisoning display a bright red outward appearance caused by inhaled carbon monoxide combining with hemoglobin in the red blood cells. A victim of carbon monoxide suffocates because oxygen cannot bind to the occupied hemoglobin. Cyanide, composed of carbon triple bonded to nitrogen, also starves the blood of oxygen; however, it is more potent, exerting an effect within minutes.

Did You Know ?

Safety seals and packaging on over the counter medications, which are commonplace today, were added after a mass poisoning of TYLENOL® pills that left seven people dead. In 1982 the Chicago area was terrorized by an anonymous suspect that allegedly removed Extra Strength TYLENOL® from grocery and drug store shelves, tampered with the capsules by placing cyanide in them, and returned the tainted bottles to the stores where unsuspecting consumers purchased them. The first victim was a 12 year old girl, followed by a postal worker the same day. It was only after the postal worker's brother and sister-in-law also died unexpectedly after taking Tylenol® from the postal worker's home that it was discovered that the pain relieving medicine was poisoned. To this day, no one has been found guilty.

Drugs

Accidental and intentional death can also result from an overdose of **drugs**, chemical substances that biologically affect organisms (Figure 1). Drugs may be prescribed by a doctor for medical reasons. When drugs are ingested for reasons other than medical purposes, they are referred to as **recreational drugs**. Figure 2 outlines different types of drugs and their effects on the human body. People who use drugs for recreational purposes are at risk of accidentally overdosing on drugs or having an accident due to impaired judgment while under the influence. Morphine and heroin, derivatives of a nineteenth century drug called opium, can cause a drug overdose because users keep increasing their intake as their body becomes more dependent on the opiates.

Figure 1: Drugs can be produced in pill, powder, or liquid form. Pills and powders may be further prepared and injected with a hypodermic needle or inhaled through the nose.

Knowledge Check

☐ ***When is a substance considered a recreational drug?***

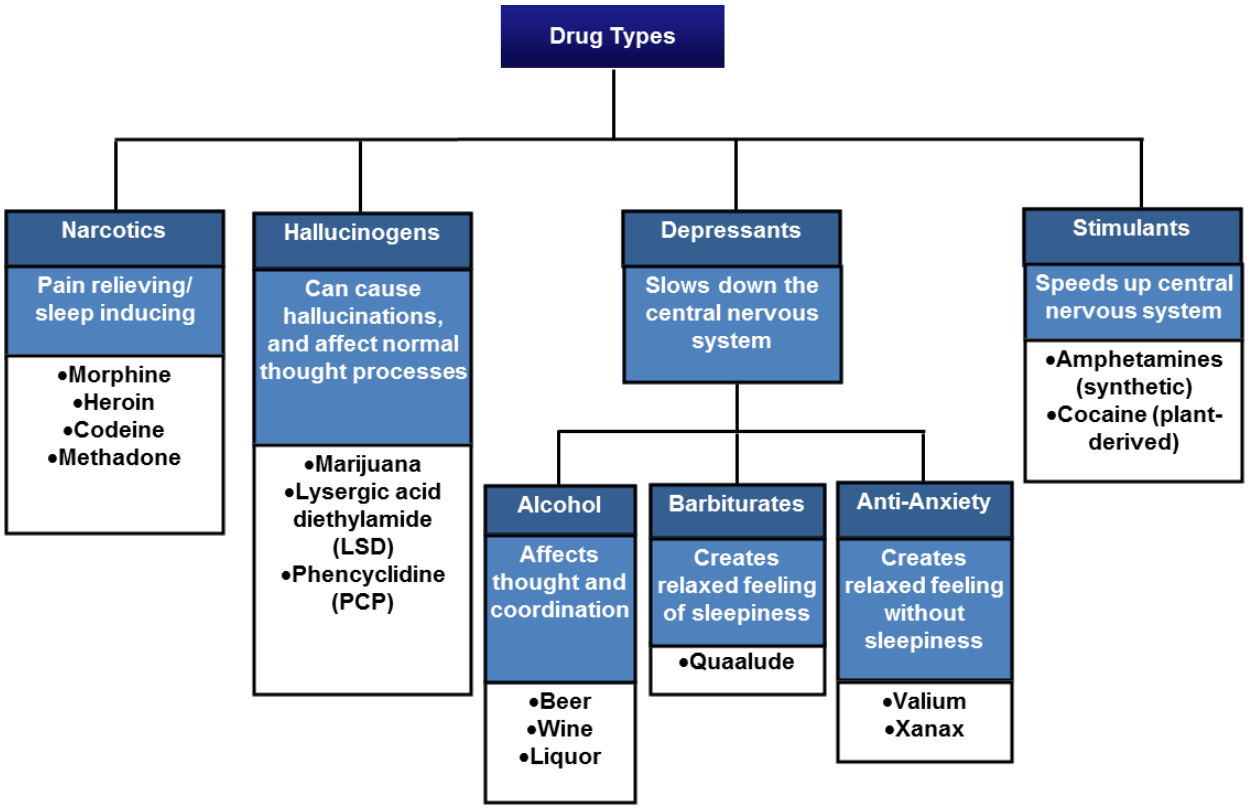


Figure 2: Organizational chart of drug types. Not all drugs are listed as examples.

Toxicology

Toxicology relies on several procedures that can be carried out in the field or in a laboratory. One example of a field test is a breathalyzer test used to detect blood alcohol level (Figure 3). A police officer who pulls over a driver may administer this test if there is evidence suggesting the driver is under the influence of alcohol. Many toxicology procedures take place in laboratories where forensic lab screening targets several thousand organic and inorganic substances.

Test results can take months because a final toxicology report often draws from multiple test results and conclusions. This is especially true for **postmortem drug testing,** testing done after a person's death, which relies on blood, urine, and tissue samples obtained during an autopsy. Multiple blood samples may be collected from different areas of the body as drug concentrations may differ from area to area. Tissue samples are typically collected from the liver, brain, kidney, and a liquid layer in the eye called the vitreous humor. Stomach contents may also be collected and tested. Pills that are not fully digested in the stomach may provide evidence of the amount or type of drug ingested. Hair follicles are useful for drug testing because they can store drugs for long periods of time (up to 90 days).

Figure 3: A breathalyzer.

Presumptive Tests

A **presumptive test or screening** can initially include or exclude common substances. These tests help narrow down the wide range of possible substances present in a sample. Many presumptive tests rely on **color tests**, which use indicators that turn certain colors when reacting to certain chemicals. For example, the **Marquis test** for heroin, morphine, and other drugs is composed of formaldehyde and sulfuric acid. The colorless indicator produces a variety of different colors when in contact with drugs (Table 1). Toxicology screenings commonly utilize uses **immunoassays**, which use specific antibodies to detect drug classes. Another screening test is the **microcrystalline test,** which produces a crystal pattern of a certain size and shape when the suspected substance reacts to the chemical on a slide. Interpretation of presumptive tests must be done with caution to avoid false positive results.

Table 1: Marquis Reactions for Various Drugs

Drug Name	Color Results Over Time
	0 sec 30 60
MDMA/MDA/MDE	
Amphetamine	
Methamphetamine	
Heroin	
Morphine	
Oxycodone	
Aspirin	
Sugar	

Confirmatory Tests

Once a presumptive test narrows down the possible substances in a sample, **confirmatory tests** can be performed to verify the identity of the substance and the amount present. **Gas chromatography** is a technique used to sort molecules by their size and is often coupled with mass spectrometry, which can identify chemicals in substances by their mass and charge. **Ultraviolet spectrophotometry** is a method that analyzes the way substances react to ultraviolet and infrared light. **Thin-layer chromatography** allows for the separation of components in a mixture up a plastic or glass plate placed into a developing chamber containing a solvent (Figure 4). The separated components in an unknown solution (sample of prepared bodily fluid or tissue) can then be compared to known samples or standards (suspected drugs present). Once results are obtained, toxicologists can decide whether the amount of the substance was therapeutic, toxic, or lethal. They may also have to make a judgment about the effect of two or more drugs present in a sample.

Knowledge Check

☐ *Can a presumptive test identify a substance? Why or why not?*

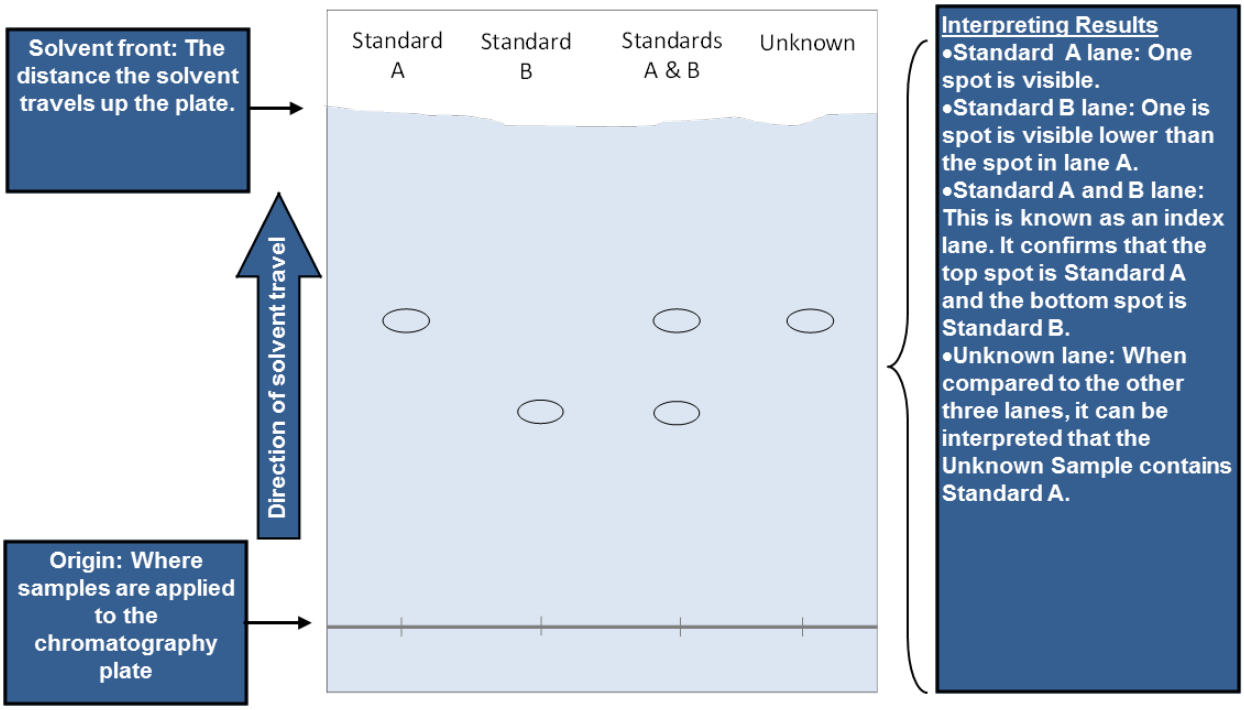


Figure 4: An illustration of thin-layer chromatography results. There are four samples placed onto lanes at the origin of this chromatography plate: Standard A, Standard B, Standard A and B, and the Unknown sample.

Figures in Forensics

James Marsh
1794-1846

James Marsh, invented a method to detect arsenic, a popular poison made of an element found in sulfide or metallic ores. Tasteless, odorless, and fatal in the smallest of doses, arsenic is easy to obtain because of its use to poison rats and kill weeds. Its symptoms, including stomach cramps and vomiting, resemble those of cholera, a common disease before modern sanitation. Marsh tested a victim's stomach contents and a coffee pot suspected of containing arsenic. He mixed the victim's stomach contents with a yellow precipitate, a substance that separates from a solution if arsenic is present. Detecting arsenic, he confirmed his test method and later perfected his testing with an apparatus that would emit arsine gas, an indicator of arsenic and its quantity.

Image Source: http://commons.wikimedia.org/wiki/File:Marsh_James.jpg

EXPERIMENT 1: IDENTIFYING UNKNOWN SUBSTANCES

When an unidentified substance is found at a crime scene or detected in a victim's body, its physical and chemical properties can be tested and compared to known samples, along with the level of the substance present. This can indicate to a forensic scientist if a poison or drug was present in the victim's body at the time of death and if there was enough present to be the cause of death. In this experiment, you will simulate a presumptive test using physical and chemical properties of known substances to identify an unknown substance.

Materials

- 5 mL Acetic Acid (Vinegar), CH_3COOH
- (1) 100 mL Beaker
- 2 g Corn Starch
- (1) Hand Lens
- 5 mL Iodine-Potassium Iodide (IKI) Solution
- (1) Multi-Well Plate
- (1) Permanent Marker
- 2 g Sodium Bicarbonate (Baking Soda), $NaHCO_3$
- 2 g Sodium Hydrogencarbonate (Baking Powder), $NaHCO_3$
- 2 g Unknown Substance
- (4) Weigh Paper Sheets
- (4) Wooden Scoops
- (2) Transfer Pipettes
- *Camera/Smart Phone
- *Hot Water

*You must provide

Procedure

1. Use the permanent marker to label the blank sides of the multi-well plate according to Figure 5.

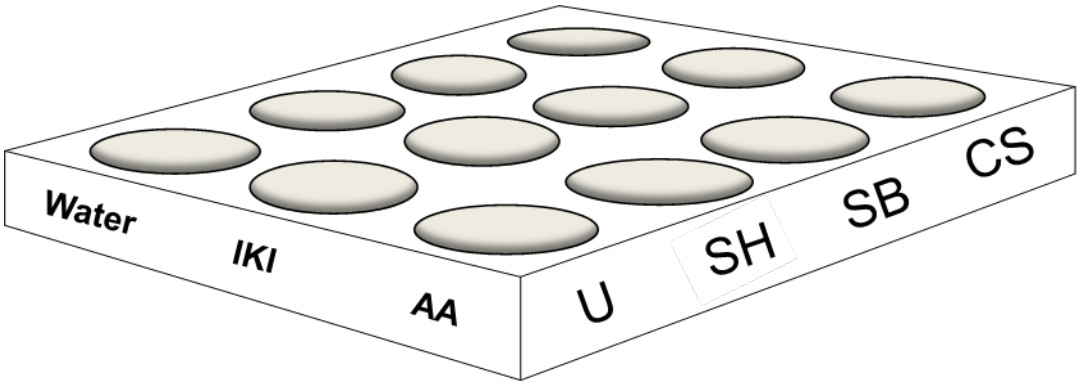


Figure 5: Step 1 reference. IKI = IKI solution, AA = acetic acid, U = unknown substance, SH = sodium hydrogencarbonate, SB = sodium bicarbonate, CS = corn starch.

2. Use the permanent marker to label the bottom edge of four sheets of weigh paper with the following labels: “sodium bicarbonate,” “sodium hydrogencarbonate,” “corn starch,” and “unknown.”
3. Carefully pour each powdered substance onto its corresponding sheet of weigh paper.
4. Use the hand lens to observe the following physical characteristics of each powder. Record your observations in Table 2:

   Color: What color is each powdered substance?

   Visual Texture: What is the visual texture of each powder? Examples include large crystals, smooth and fine, clumped, small crystal-like texture, etc.
5. Use a wooden scoop to transfer a small amount of the unknown sample into the three wells that are in line with the **U** label (Figure 6).

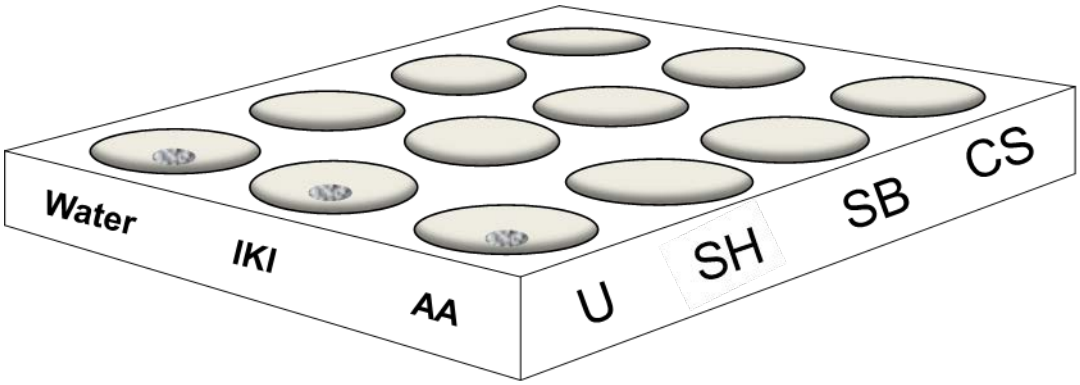


Figure 6: Step 5 reference. The white circles represent a scoop of the unknown sample in each of the three wells lined up with the U label.

6. Use a new wooden scoop to transfer a small amount of the sodium hydrogencarbonate (baking powder) sample into the three wells that are in line with the **SH** label.
7. Use a new wooden scoop to transfer a small amount of the sodium bicarbonate (baking soda) sample into the three wells that are in line with the **SB** label.
8. Use a new wooden scoop to transfer a small amount of the corn starch sample into the three wells that are in line with the **CS** label.
9. Remove the lid of the acetic acid (vinegar). Use the drip bottle to place 2 - 3 drops of acetic acid into the four wells that are lined up with the **AA** label (Figure 7).

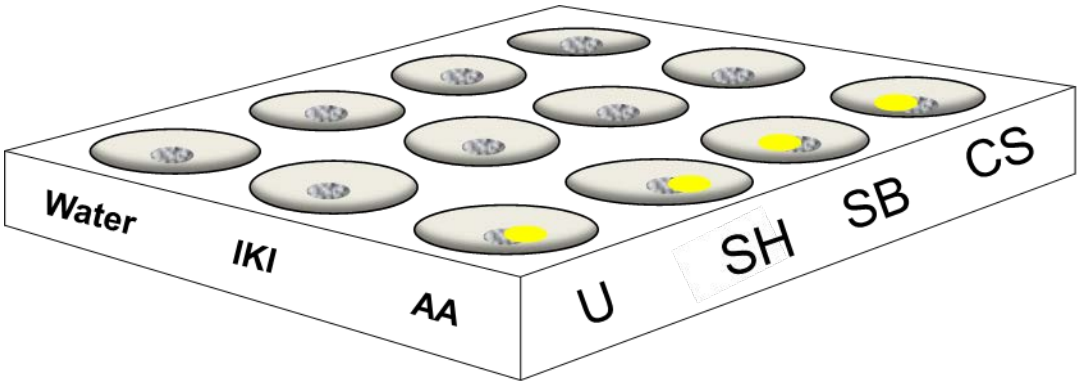


Figure 7: Step 9 reference. The yellow circles represent 2 – 3 drops of acetic acid (vinegar) in each of the four wells lined up with the AA label.

10. Observe each well for the occurrence of effervescence (bubbling or fizzing). Record your observations in Table 2.

11. Remove the lid of the IKI solution. Use a transfer pipette to take up several drops of IKI solution. Place 2 - 3 drops of IKI solution into the four wells that are lined up with the **IKI** label.
12. Observe each well for a color change to a dark purple/black color or a yellow/brown color. Record the color change of each powder in Table 2.
13. Fill a 100 mL beaker with approximately 20 mL of hot water. The water can come from a hot water tap, be heated in a microwave, or be heated on a stove top. It does not need to be boiling, but should be hot.
14. Use a transfer pipette to take up several drops of hot water. Place 2 - 3 drops of hot water into the four wells that are lined up with the **Water** label.
15. Observe each well for the occurrence of effervescence (bubbling or fizzing). Record your observations in Table 2.
16. Use a camera to photograph your results.

    Note: You will need to download, scan, or print the photographs to be included with your lab report.
17. When you have completed the experiment clean up by thoroughly rinsing labware that may be reused, such as the well plate. Discard items that cannot be reused such as the wooden scoops and the weigh papers with powders.

Results Tables

Table 2: Physical and Chemical Property Test Results of Known and Unknown Powders

Powder	Color	Texture	Acetic Acid Effervescence (Yes or No)?	IKI Solution Color Change	Hot Water Effervescence (Yes or No)?
Baking Powder					
Sodium Bicarbonate					
Corn Starch					
Unknown					

Lab 13

Firearms

Lab 13 Firearms

LEARNING OBJECTIVES

- Sequence the expulsion of a bullet from a firearm
- Explain firearm analysis methods
- Analyze a bullet trajectory path

INTRODUCTION

Ballistics is the study of the motion of projectiles. **Firearm investigation** is a subfield of ballistics that focuses on **firearms**, handheld weapons that expel a projectile via an explosive material, such as gun powder. Firearm investigation tries to determine the circumstances surrounding a crime involving a firearm, including the type of firearm used to commit the crime, what specific gun a bullet or multiple bullets came from, and where a shooter was positioned when the bullets were fired. To do this, investigators examine bullet characteristics, gun barrel characteristics, and bullet trajectory.

Basic Firearm Terminology

The object that is loaded into a gun is called a **cartridge**. It consists of a bullet, propellant, casing, and rim (Figure 1). A **bullet** is composed of a heavy metal, such as lead. **Propellants** are chemicals that burn quickly and create gases that expand. This expansion is what causes a bullet to exit a gun at high velocity. Surrounding the bullet and propellant is the **cartridge case**, which is ejected from a gun automatically if it is automatic or manually if it is a manual firearm. Propellants are ignited by a **primer** located in the rim of the cartridge. The rim is also where the caliber is imprinted. **Caliber** refers to the size of a firearm and is determined by measuring the internal diameter of the barrel of the firearm. Caliber can also be determined by measuring the diameter of a cartridge or bullet hole. Caliber is commonly measured in inches or millimeters. For example, a .22 caliber cartridge is 0.22 inches in diameter and a 9 mm cartridge is 9 mm in diameter.

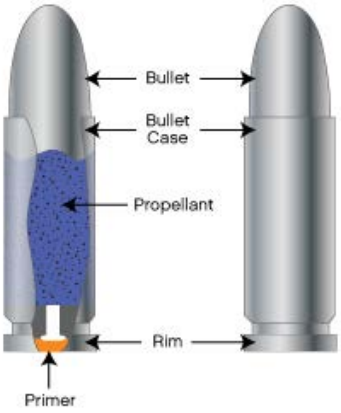


Figure 1: Cartridge anatomy.

Firing Mechanism

Different types of firearms will load and prepare to fire differently. In general, once the hammer (Figure 2) of a gun is cocked and released, it hits the firing pin into the primer of the cartridge, causing a spark. The spark ignites the propellant, which produces gases that start to expand. The force created by the expanding gases expels the bullet out of the barrel of the firearm.

Figure 2: A firearm with basic parts labeled.

Collecting and Documenting Firearm Evidence

When a crime involves a firearm, it is often helpful to reconstruct the crime scene to determine the events that occurred. Forensic investigators will account for every cartridge casing and bullet before removing

them from the scene. They will also photograph the position of bullets, casings, and bullet holes.

In addition to crime scene photographs, digital photographs of firearms can be sent to computerized databases, including the National Integrated Ballistic Information Network (NIBIN), which contains firearm identification evidence and can link crime evidence. Probable matches based on an one hundred item scale may be determined based on land numbers, caliber, and firing pin mark shapes.

When a bullet hole is identified, it will be noted as either an entrance or exit hole. Entrance holes or wounds are typically smaller and smoother than exit wounds. Measurements of the minor axis and major axis of a bullet hole (Figure 3) can be used to compute the angle at which the bullet entered a surface using the equation:

$$\Theta = \sin^{-1}\left(\frac{\text{Minor Axis } (a_{minor})}{\text{Major Axis } (a_{major})}\right)$$

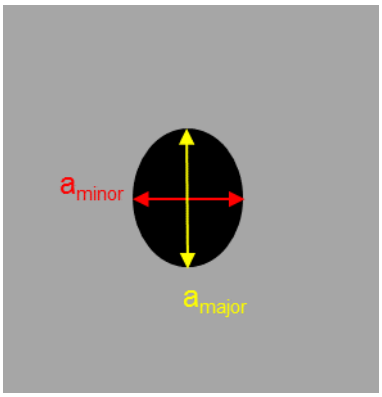


Figure 3: A illustrated bullet hole with the horizontal and vertical diameters labeled.

Once the angle of impact is determined, trigonometry can be applied and a bullet trajectory can be estimated, including factors such as shooter position and shoulder height.

It is important to note that there are many factors that can affect the reconstruction of a crime scene involving a firearm:

- A bullet rarely travels in a straight trajectory, especially when it hits and ricochets off of an obstacle.
- When a bullet hits an obstacle, it can change shape and direction.
- A bullet may become damaged if it hits an obstacle. This can make bullet comparison impossible.

Firearm Analysis

Bullet comparison and gunshot residue analysis are analyses that can be performed when a crime involves a shooting. Firearms used to commit a crime are often not recovered at the crime scene, which makes forensic analysis difficult. There are two basic types of firearms: hand guns and long guns. **Hand guns** are designed to be fired with one hand. **Long guns** are designed to be fired with two hands.

During the manufacturing process, grooves and lands, called **rifling**, are added to the inside of the barrel of handguns (Figure 4). **Lands** are raised areas between grooves. Rifling causes a bullet to spin and maintain a stable trajectory after it leaves the gun. Rifling varies between different gun manufacturers, creating class characteristics that can narrow a suspect firearm to a particular type. Firearm class characteristics include the direction of rifling and the number of grooves and lands. Grooves and lands may spiral to the left or right. Therefore, if a bullet exhibits rifling spiraling to the left, it can be concluded that the bullet could not have come from a firearm with right spiraling rifling. The firearm used to fire a bullet may also have dirt, rust, wear, and other small imperfections. All of these factors create unique striations on a bullet that can be microscopically analyzed and compared to sample bullets test fired from a suspect gun. Shotgun barrels are not manufactured with rifling because a shotgun cartridge contains many small pellets, called **shot**, instead of a bullet. When fired, the pellets are expelled from the barrel and spread out to cover a wider area. Shot can be collected and individually weighed to narrow down suspect weapons to manufacturers.

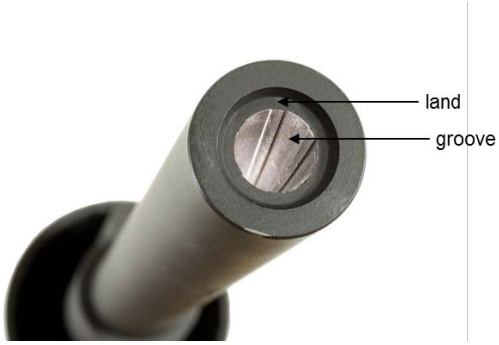


Figure 4: Rifling with grooves and lands labeled.

The barrel of a suspect firearm can also be examined for evidence from **blowback**, the vacuum created when the bullet leaves the barrel. Fibers and other evidence that connect a suspect to a crime may get sucked in by the vacuum.

Gunshot discharge consists of burnt particles that are ejected onto a shooter and surfaces nearby. Residue patterns can reveal the distance from which the firearm was discharged, as well as who and what was near the weapon when it was fired. For example, entrance holes usually show residue, such as a darkened rim around the perimeter of the hole. If any residue is on an exit hole, it will be very light. Residue can be emitted from several areas of a firearm. Other variables, such as the type of gun and distance from target, can influence the amount of gunshot residue. The amount of residue increases as the distance between a firearm and target decreases.

Clothing worn by a gunshot victim is examined visually and microscopically before it is chemically processed for gunshot residue. One test is the Modified Griess Test for the presence of nitrate. One advantage to this test is that it does not interfere with later tests for lead residue. It uses desensitized photographic paper with a chemical mixture of sulfanilic acid in distilled water and alpha-naphthol, which reacts to nitrite residue. Firearms examiners can use these findings to determine the muzzle-to-garment distance, which is the distance it will deposit a similar pattern of gunshot residue. Minimum and maximum distance is determined by firing the firearm into fabric coated panels with ammunition used in the investigation.

EXPERIMENT 1: BULLET TRAJECTORY ANALYSIS

After an attempted bank robbery, you are called to the crime scene. You must interpret the events of the crime. You notice a security camera that has been disabled by gunfire. In addition to the damaged security camera, you find a bullet hole in the wall under the camera. In this experiment, you will analyze bullet trajectory to determine the approximate shoulder height of the suspect.

Materials

- (1) Bullet Hole
- Masking Tape
- (1) Protractor
- (1) Ruler
- (1) String
- (1) Tape Measure

Procedure

1. Use the ruler to measure the major and minor axis of the bullet hole (Figure 5). Record the measurements in Table 1.
2. Use the equation sin θ = minor axis (mm)/ major axis (mm) to determine the angle at which the bullet impacted the wall. Record the angle in Table 1.
3. Use a tape measure and masking tape to hang Figure 5 on a wall so that the bullet hole is located 80” from the floor.
4. Use the masking tape, string, and angle of impact to create a trajectory from the bullet hole to the ground.
5. As your investigation proceeds, a latent shoe print is recovered 45” from the wall with the bullet hole facing the wall.
6. Draw a diagram of the wall, floor, and bullet trajectory.
7. Use trigonometry to calculate the approximate shoulder height of the shooter. Record the approximate shoulder height in Table 1.

8. Check your work by using the measuring tape to determine if the calculated shoulder height falls on the estimated trajectory of the bullet.

Figure 5: Simulated bullet hole.

Data Tables

Table 1: Bullet Trajectory Data

Bullet Hole Minor Axis (mm)	
Bullet Hole Major Axis (mm)	
Angle of Bullet Impact (º)	
Approximate Shoulder Height (inches)	

Appendix

Good Lab Techniques

GOOD LABORATORY PRACTICES

Science labs, whether at universities or in your home, are places of adventure and discovery. One of the first things scientists learn is how exciting experiments can be. However, they must also realize science can be dangerous without some instruction on good laboratory practices.

- Read the protocol thoroughly before starting any new experiment. You should be familiar with the action required every step of the way.
- Keep all work spaces free from clutter and dirty dishes.

Figure 1: An underpad will prevent any spilled liquids from contaminating the surface you work on.

- Read the labels on all chemicals, and note the chemical safety rating on each container. Read all Material Safety Data Sheets (MSDS) prior to each experiment. These are provided on the eScience Labs website.
- Thoroughly rinse labware (test tubes, beakers, etc.) between experiments. To do so, wash with a soap and hot water solution using a bottle brush to scrub. Rinse completely at least four times. Let air dry.
- Use a new pipette for each chemical dispensed.
- Wipe up any chemical spills immediately. Check MSDSs for special handling instructions (provided on the eScience Labs website).
- Use test tube caps or stoppers to cover test tubes when shaking or mixing – not your finger!
- When preparing a solution, refer to a protocol for any specific instructions on preparation.

Weigh out the desired amount of chemicals, and transfer to a beaker or graduated cylinder. Add LESS than the required amount of water. Swirl or stir to dissolve the chemical (you can also pour the solution back and forth between two test tubes), and once dissolved, transfer to a graduated cylinder and add the required amount of liquid to achieve the final volume.

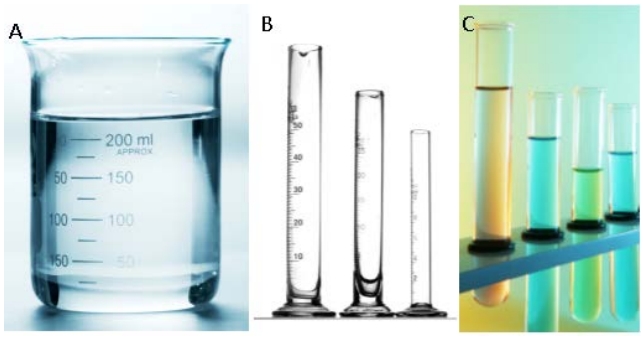


Figure 2: Special measuring tools make experimentation easier and more accurate in the lab. A shows a beaker, B graduated cylinders, and C test tubes in a test tube rack.

- A molar (M) solution is one in which one liter (L) of solution contains the number of grams equal to its molecular weight.

  Ex: 1 M = 110 g CaCl ÷ 1 L

  (The formula weight of CaCl is 110 g/mol)

- A percent solution can be prepared by percentage of weight of chemical to 100 mL of solvent (w/v) , or volume of chemical in 100ml of solvent (v/v).

  Ex: 20 g NaCl ÷ 80 mL H_2O = 20% w/v NaCl solution

- Concentrated solutions, such as 10X, or ten times the normal strength, are diluted such that the final concentration of the solution is 1X.

  Ex: To make a 100 mL solution of 1X TBE from a 10X solution:

  10 mL 10X TBE ÷ 90 mL water = 100 mL 1X TBE

- Always read the MSDS before disposing of a chemical to insure it does not require extra measures (provided on the eScience Labs website).
- Don't pour unused chemical back into the original bottle.
- Avoid prolonged exposure of chemicals to direct sunlight and extreme temperatures.

- Immediately secure the lid of a chemical after use.

Figure 3: Disposable pipettes aid in accurate measuring of small volumes of liquids. It is important to use a new pipet for each chemical to avoid contamination.

- Prepare a dilution using the following equation:

$$c_1V_1 = c_2V_2$$

Where c_1 is the concentration of the original solution, v_1 is the volume of the original solution, and c_2 and v_2 are the corresponding concentration and volume of the final solution. Since you know c_1, c_2, and v_2, you solve or v_1 to figure out how much of the original solution is needed to make a certain volume of a diluted concentration.

- If you are ever required to smell a chemical, always waft a gas toward you, as shown in the image below. This means to wave your hand over the chemical towards you. Never directly smell a chemical. Never smell a gas that is toxic or otherwise dangerous.

Figure 4: An image of a woman wafting.

- Use only the chemicals needed for the activity.
- Keep lids closed when a chemical is not being used.
- When diluting an acid, always pour the acid into the water. Never pour water into an acid.
- Never return excess chemical back to the original bottle. This can contaminate the chemical supply.
- Be careful not to interchange lids between different chemical bottles.
- When pouring a chemical, always hold the lid of the chemical bottle between your fingers. Never lay the lid down on a surface. This can contaminate the chemical supply.
- When using knives or blades, always cut away from yourself.
- Wash your hands after each experiment.

CREDITS

Saferstein, R., (2013). Forensic science from the crime scene to the crime lab. (2nd ed.). San Francisco, California: Pearson Education Inc.

Technical Working Group on Biological Evidence Preservation. The Biological Evidence Preservation Handbook: Best Practices for Evidence Handlers. U.S. Department of Commerce, National Institute of Standards and Technology. 2013.

www.canstockphoto.com

www.eScienceLabs.com - 888.375.5487