# Table of Contents

To the Student ................................................................. iv
Laboratory and Safety Guidelines ........................................ v
Safety Symbols ................................................................. vi
Lab 1 Where did they drown? .............................................. 1
Lab 2 Can fingerprint analysis connect a suspect to a crime scene? 7
Lab 3 The Importance of Trace Evidence in Forensic Science .... 11
Lab 4 Can insect evidence establish time of death? ................. 15
Lab 5 Forensic Odontology at Work ....................................... 19
Lab 6 Crime Scene Investigation .......................................... 23
Lab 7 When did she die? .................................................... 25
Lab 8 A Sweet Season ...................................................... 29
Lab 9 Use Blood Types to Help Solve a Crime ....................... 33
Lab 10 The Missing Restaurant Owner ................................. 37
To the Student

In the real world, biology is often used to solve problems—sometimes even to solve mysteries. Biologists may examine problems in order to improve human life, such as: “How can a rice crop be made more disease resistant?” and “How can a genetic disease in humans be detected?” Biology can also be used to solve mysteries by answering questions like: “When and how did a person die?” and “To whom does the blood or other biological evidence at a crime scene belong?” Biologists work in the fields of forensics to find the answers to these and many other questions.

In *Glencoe’s Forensics Lab Manual*, you will be presented with in-depth investigations that deal with DNA, collecting and analyzing data, or interpreting evidence found at a crime or accident scene. You will use your knowledge of scientific inquiry and your problem-solving skills as you learn current forensics procedures. You will then apply these techniques and procedures to real-world scenarios.

Each lab begins with *The Problem*, a section that describes the discovery of a crime or accident. Information in the *Background* section will help you understand the science involved in the problem or case. The *Procedure* section provides step-by-step instructions for learning a technique or procedure for solving the problem presented. Finally, the *Conclude and Apply* and *Analyze and Conclude* sections allow you to interpret your data and demonstrate your problem-solving skills and understanding of the scientific processes involved.
Laboratory and Safety Guidelines

Emergencies
- Inform the teacher immediately of any mishap—fire, injury, glassware breakage, chemical spills, and so forth.
- Know the location of the fire extinguisher, safety shower, eyewash, fire blanket, and first-aid kit. Know how to use this equipment.
- If chemicals come into contact with your eyes or skin, flush with large quantities of water and notify your teacher immediately.

Preventing Accidents
- Do NOT wear clothing that is loose enough to catch on anything. Do NOT wear sandals or open-toed shoes. Remove loose jewelry—chains or bracelets—while doing lab work.
- Wear protective safety gloves, goggles, and aprons as instructed.
- Always wear safety goggles (not glasses) in the laboratory.
- Wear goggles throughout the entire activity, cleanup, and handwashing.
- Keep your hands away from your face while working in the laboratory.
- Remove synthetic fingernails before working in the lab (these are highly flammable).
- Do NOT use hair spray, mousse, or other flammable hair products just before or during laboratory work where an open flame is used (they can ignite easily).
- Tie back long hair and loose clothing to keep them away from flames and equipment.
- Eating, drinking, chewing gum, applying makeup, and smoking are prohibited in the laboratory.
- Do NOT inhale vapors or taste, touch, or smell any chemical or substance unless instructed to do so by your teacher.

Working in the Laboratory
- Study all instructions before you begin a laboratory or field activity. Ask questions if you do not understand any part of the activity.
- Work ONLY on activities assigned by your teacher. NEVER work alone in the laboratory.
- Do NOT substitute other chemicals/substances for those listed in your activity.
- Do NOT begin any activity until directed to do so by your teacher.
- Do NOT handle any equipment without specific permission.
- Remain in your own work area unless given permission by your teacher to leave it.
- Do NOT point heated containers—test tubes, flasks, and so forth—at yourself or anyone else.
- Do NOT take any materials or chemicals out of the classroom.
- Stay out of storage areas unless you are instructed to be there and are supervised by your teacher.

Laboratory Cleanup
- Keep work, lab, and balance areas clean, limiting the amount of easily ignitable materials.
- Turn off all burners, water faucets, probeware, and calculators before leaving the lab.
- Carefully dispose of waste materials as instructed by your teacher.
- With your goggles on, wash your hands thoroughly with soap and warm water after each activity.
# Safety Symbols

These safety symbols are used in laboratory and field investigations in this book to indicate possible hazards. Learn the meaning of each symbol and refer to this page often. **Remember to wash your hands thoroughly after completing lab procedures.**

## Safety Symbols Table

<table>
<thead>
<tr>
<th>Safety Symbol</th>
<th>Hazard</th>
<th>Examples</th>
<th>Precaution</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISPOSAL</td>
<td>Special disposal procedures need to be followed.</td>
<td>certain chemicals, living organisms</td>
<td>Do not dispose of these materials in the sink or trash can.</td>
<td>Dispose of wastes as directed by your teacher.</td>
</tr>
<tr>
<td>BIOLOGICAL</td>
<td>Organisms or other biological materials that might be harmful to humans</td>
<td>bacteria, fungi, blood, unpreserved tissues, plant materials</td>
<td>Avoid skin contact with these materials. Wear mask or gloves.</td>
<td>Notify your teacher if you suspect contact with material. Wash hands thoroughly.</td>
</tr>
<tr>
<td>EXTREME TEMPERATURE</td>
<td>Objects that can burn skin by being too cold or too hot</td>
<td>boiling liquids, hot plates, dry ice, liquid nitrogen</td>
<td>Use proper protection when handling.</td>
<td>Go to your teacher for first aid.</td>
</tr>
<tr>
<td>SHARP OBJECT</td>
<td>Use of tools or glassware that can easily puncture or slice skin</td>
<td>razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass</td>
<td>Practice common-sense behavior and follow guidelines for use of the tool.</td>
<td>Go to your teacher for first aid.</td>
</tr>
<tr>
<td>FUME</td>
<td>Possible danger to respiratory tract from fumes</td>
<td>ammonia, acetone, nail polish remover, heated sulfur, moth balls</td>
<td>Make sure there is good ventilation. Never smell fumes directly. Wear a mask.</td>
<td>Leave foul area and notify your teacher immediately.</td>
</tr>
<tr>
<td>ELECTRICAL</td>
<td>Possible danger from electrical shock or burn</td>
<td>improper grounding, liquid spills, short circuits, exposed wires</td>
<td>Double-check setup with teacher. Check condition of wires and apparatus.</td>
<td>Do not attempt to fix electrical problems. Notify your teacher immediately.</td>
</tr>
<tr>
<td>IRRITANT</td>
<td>Substances that can irritate the skin or mucous membranes of the respiratory tract</td>
<td>pollen, moth balls, steel wool, fiberglass, potassium permanganate</td>
<td>Wear dust mask and gloves. Practice extra care when handling these materials.</td>
<td>Go to your teacher for first aid.</td>
</tr>
<tr>
<td>CHEMICAL</td>
<td>Chemicals that can react with and destroy tissue and other materials</td>
<td>bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide</td>
<td>Wear goggles, gloves, and an apron.</td>
<td>Immediately flush the affected area with water and notify your teacher.</td>
</tr>
<tr>
<td>TOXIC</td>
<td>Substance may be poisonous if touched, inhaled, or swallowed</td>
<td>mercury, many metal compounds, iodine, poinsettia plant parts</td>
<td>Follow your teacher’s instructions.</td>
<td>Always wash hands thoroughly after use. Go to your teacher for first aid.</td>
</tr>
<tr>
<td>FLAMMABLE</td>
<td>Open flame may ignite flammable chemicals, loose clothing, or hair.</td>
<td>alcohol, kerosene, potassium permanganate, hair, clothing</td>
<td>Avoid open flames and heat when using flammable chemicals.</td>
<td>Notify your teacher immediately. Use fire safety equipment if applicable.</td>
</tr>
<tr>
<td>OPEN FLAME</td>
<td>Open flame in use, may cause fire.</td>
<td>hair, clothing, paper, synthetic materials</td>
<td>Tie back hair and loose clothing. Follow teacher’s instructions on lighting and extinguishing flames.</td>
<td>Always wash hands thoroughly after use. Go to your teacher for first aid.</td>
</tr>
</tbody>
</table>

**Eye Safety** Proper eye protection should be worn at all times by anyone performing or observing science activities.

**Clothing Protection** This symbol appears when substances could stain or burn clothing.

**Animal Safety** This symbol appears when safety of animals and students must be ensured.

**Radioactivity** This symbol appears when radioactive materials are used.

**Handwashing** After the lab, wash hands with soap and water before removing goggles.

---

**Copyright © by Glencoe/McGraw-Hill, a division of The McGraw-Hill Companies, Inc.**
Where did they drown?

The Problem
The Coast Guard discovered two bodies, a man and a woman, in the salt water of the San Francisco Bay. Both victims apparently drowned; their lungs were filled with water, and a frothy mixture of water, air, and mucus was found in their mouths and airways. Your job as the coroner will be to determine where the victims drowned and whether the victims died of accidental drowning or were victims of murder. To help you in your determination, you have taken blood samples from both victims. You must interpret the findings from these blood samples to solve the mystery.

Background
Our bodies contain many compartments of liquid water, such as blood, tissues, and fluids between tissues. This water is composed of many substances, including salts, sugars, and proteins which have dissolved in the water. The concentration of any given substance is the amount of that substance per unit volume of water. Cells, such as those found in the walls of blood vessels and tissues, separate the various compartments of water. The membranes of these cells control which molecules can move between the compartments by allowing some molecules to pass through while limiting others. This is known as selective permeability.

Diffusion How do you know which way substances will move through a membrane? Generally, substances move from an area of high concentration to an area of low concentration. This movement is called diffusion. Diffusion occurs in solids, liquids, and gases. For example, if you cut an onion at the back of your classroom, people at the front of the room will eventually be able to smell it because molecules from the onion are transmitted (diffused) from an area of high concentration (the back of the room) to an area of low concentration (the front of the room). Diffusion continues until the concentration of molecules from the onion in the air is equal in all areas of the room.

All substances, including water, can diffuse. However, the diffusion of water across a selectively permeable membrane has a different name, osmosis. Suppose you have two solutions of sugar of different concentrations (high and low) in a clear box. A membrane that is permeable to water but not to sugar separates the two solutions. High concentration is on the left side, and low concentration is on the right side, as shown in Part A of Figure 1. The solution on the left has a higher sugar concentration relative to the one on the right and is said to be hypertonic to the one on the right. The solution on the right has a lower sugar concentration compared to the one on the left and is said to be hypotonic to the solution on the left.

Figure 1
The more sugar that is dissolved in water, the less concentrated the water becomes; in other words, pure water is 100% water, and the concentration of water decreases as you add sugar. Therefore, the concentration of water on the left side is less than that on the right side. As a result, water will diffuse from the right to the left until the concentrations of water on both sides of the membrane are equal, as shown in Part B of Figure 1. At that time, the concentrations of sugar on both sides of the membrane will also be equal, or isotonic. Solutions in your body behave the same way.

**Diffusion in the Lungs** Your lungs form a compartment of air separated from a compartment of water (your blood) by cells that make up the air sacs called alveoli. When you breathe, gases diffuse from one compartment to another. Oxygen diffuses from the air into the blood, and carbon dioxide from the blood diffuses into the air. When a person drowns, the lungs fill with freshwater or salt water, depending on the type of water in which he or she drowned. The blood and lungs become two water-filled compartments (similar to Figure 1) in which water can move across the membranes separating the blood and the lungs. Salts in the compartments do not move across the membranes.

In this lab, you will simulate what happens in the human body when a person drowns. You will use sugar solutions to represent the solutions of water, salt, and other substances found in the lungs and blood. Solutions in beakers represent the blood; dialysis tubes, which are selectively permeable membranes, represent the alveoli of the lungs; and solutions in the dialysis tubes represent water in the lungs. You will first experiment with several beakers and dialysis tubes containing different concentrations of sugar representing hypertonic, hypotonic, and isotonic solutions. These will help you understand the movement of water that occurs with the differing solutions. Finally, two solution combinations will represent what happens when a person drowns in freshwater and in salt water.

### Safety

- Never eat or drink anything in the lab.

### Procedure

1. Label the beakers A through G.
2. Take each section of dialysis tubing and tie one end using the tube itself or string. Be careful not to tear the bag.
3. Fill each dialysis tube with 25 mL of sucrose solution, according to the table on the next page. The tubes should be about \( \frac{1}{3} \) full. Fill each beaker with 150 mL of sucrose solution according to the table.
4. Once you fill a dialysis bag, squeeze the air out and tie the remaining end a few centimeters above the top of the liquid without tearing the bag. Rinse the bag with distilled water, blot it dry with a tissue, and weigh it on the balance. Record the mass in the table on the next page (initial bag mass) and place the bag in the appropriate beaker. Repeat this procedure for each bag.
5. Allow each bag to stay in the beaker for 30 minutes.
Where did they drown? continued

6. After 30 minutes, remove each bag, rinse with distilled water, blot dry, and determine its mass. Record the mass in the table (final bag mass). Measure the amount of liquid that remains in the beaker after the bag is removed. Discard the bags and empty the beakers.

7. Calculate the change in each bag’s mass (final mass – initial mass) and the percent change \(\frac{\text{mass change}}{\text{initial mass}} \times 100\). Record the values in the table below and use the data to answer the questions.

Table 1

<table>
<thead>
<tr>
<th>Beaker</th>
<th>Bag Sol</th>
<th>Beaker Sol</th>
<th>Initial Bag Mass</th>
<th>Final Bag Mass</th>
<th>Mass Change</th>
<th>%Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10%</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10%</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>10%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>10%</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>10%</td>
<td>40%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>40%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclude and Apply

1. What happened to the mass of Bags A and B during the experiment?

2. Were the concentrations of the solutions in Beakers A and B more than or less than the concentrations of the solutions inside the bags? Would you classify the solutions in the beakers as hypertonic, hypotonic, or isotonic relative to the solution inside the bag? (Refer to the Background section for more information.)

3. Explain the changes observed in Bags A and B in terms of the concentrations of solutions inside and outside the bags and the movement of water.

4. What happened to the mass of Bag C?
5. How did the solution in Beaker C compare to the solution inside the bag? Would you classify it as hypertonic, hypotonic, or isotonic relative to the solution inside the bag?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

6. Explain any changes observed in Bag C in terms of the concentrations of solutions inside and outside the bag and the movement of water.

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

7. What happened to the masses of Bags D and E during the experiment?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

8. Were the concentrations of the solutions in Beakers D and E more than or less than the concentrations of the solutions inside the bags? Would you classify the solutions in the beakers as hypertonic, hypotonic, or isotonic relative to the solution inside the bag? (Refer to the Background section for more information.)

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
9. Explain the changes observed in Bags D and E in terms of the concentrations of solutions inside and outside the bags and the movement of water.

10. Beaker F represents a person who drowned in freshwater. The bag represents the lungs, and the solution in the beaker represents the blood. The 1% sucrose inside the bag approximates the total salt concentration in freshwater, while the 10% sucrose in the beaker approximates the total salt concentration in the blood. What happened to the mass of the bag? Did water move out of the bag or into the bag? What happened to the concentration of sucrose in the beaker? Explain.

11. Beaker G represents a person who drowned in salt water. The 40% sucrose inside the bag approximates the total salt concentration in salt water, while the 10% sucrose in the beaker approximates the total salt concentration in the blood. What happened to the mass of the bag? Did water move out of the bag or into the bag? What happened to the concentration of sucrose in the beaker? Explain.
Analyze and Conclude

12. The following table contains the concentrations (in millimoles per liter) of various substances in the blood of the two drowning victims. Just as the term *dozen* refers to a specific number of things (12), the term *mole* refers to a specific number of particles \(6.02 \times 10^{23}\). A millimole is \(\frac{1}{1000}\)th of a mole. When concentration is given in millimoles (or moles) per liter, higher numbers indicate more particles dissolved in the water—in the table below, higher concentrations of sodium, potassium, or chloride.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Concentration (mmole/L)</th>
<th>Man</th>
<th>Woman</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>200</td>
<td>100</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>125</td>
<td>75</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

Where do you think each victim drowned? Explain your answer.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

13. Should you look for murderers or did the victims drown accidentally? Explain your answer.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Can fingerprint analysis connect a suspect to a crime scene?

The Problem
A computer hard drive has been taken from a tenth-floor office in a government building. Files on the drive include personal information about specific government employees. Federal Bureau of Investigation agents are concerned the data might be used by imposters to access secure sites or information. The investigation is focused on two men. The first is employed by a company that frequently caters early breakfast meetings in the conference rooms, which are located on the second floor. The second man works for a pest control company that services the building. Both suspects claim that they have never been above the second floor of the building.

Multiple fingerprints have been obtained from the office. Most of them match those of government workers, whose fingerprints were recorded when they were hired. However, one fingerprint found on a countertop in the office does not match any employee working in the building. The Integrated Automated Fingerprint Identification System, the national fingerprint and criminal history system maintained by the FBI, also shows no match. If the fingerprints of either suspect match the unidentified fingerprint found in the office, a suspect can be placed at the crime scene. In this lab, you will analyze and compare fingerprints to determine if either of the suspects’ fingerprints match the unidentified impression.

Background
Friction Ridges and Fingerprints Friction ridges are raised ridges of skin on human fingers, palms, and soles of the feet. This hairless skin provides a gripping surface, much like tire treads. Because friction ridges are lined with small sweat pores, a layer of perspiration forms along the tops of the ridges. This sweat can mix with body oils and dirt, producing impressions when fingertips contact surfaces. Fingerprints are often visible on metal, glass, or plastic. When invisible, fingerprints can be detected and developed using special lighting, X rays, or various chemical processes. Impressions are then photographed to create a visible record.

Friction Ridge Characteristics Friction ridge characteristics can be grouped. Refer to Figure 1 as you read each description.

- ridge ending – a ridge that ends suddenly
- bifurcation – a ridge that divides into two ridges
- lake – a ridge that divides, comes together again close to the bifurcation, and continues on as a single ridge
- short ridge – a ridge that travels a small distance
- dot – a short ridge with approximately equal width and length
- spur – a bifurcation with a short ridge branching off a longer ridge
- crossover – a ridge that runs between two parallel ridges

![Figure 1](image-url)
Using Fingerprints for Identification  
Two principles make it possible to use fingerprints to identify individuals.

1. Friction ridge patterns do not change over time. Friction ridge patterns develop between the third and fourth months of pregnancy. While patterns can be altered by an accident or skin disease, aging has no effect on friction ridge patterns.

2. No two people have the same pattern of friction ridges. There is enough variability in friction ridge characteristics to ensure that no two people have identical fingerprints. Humans have different ridge patterns on each finger, and identical twins can be differentiated by their fingerprints.

Materials
- photocopies of suspects’ fingerprints
- photocopy of fingerprint obtained from the office

Procedure
1. Using Figure 1 as a guide, label 15 characteristics of Suspect A’s fingerprint on the photocopies provided. Assign a number to each characteristic labeled.
2. Repeat step 1 with Suspect B’s fingerprint and the unidentified fingerprint.
3. Compare Suspect A’s fingerprint to the unidentified fingerprint. Think about these questions as you look at the two impressions.
   - Are the same characteristics present in both fingerprints?
   - Do the characteristics of both fingerprints flow in the same direction?
   - Do the characteristics occupy the same relative positions to each other in both fingerprints?
4. Focus on a single characteristic of Suspect A’s fingerprint. Compare it to the unidentified fingerprint by answering the questions in the data chart. If the answer to all three questions is “yes,” the characteristic is called a point of similarity. If the answer to any of the questions is “no,” the characteristic is called a point of dissimilarity. Note: When a single unexplainable point of dissimilarity is found, it is assumed there is no match between the fingerprints.
5. Examine characteristics until ten points of similarity are established, or a single point of dissimilarity is found.
6. Repeat step 4 using Suspect B’s fingerprint.

<table>
<thead>
<tr>
<th>Fingerprint Comparison: Suspect A and Unidentified Fingerprint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fingerprint Characteristics</strong></td>
</tr>
<tr>
<td>Characteristic present in both prints?</td>
</tr>
<tr>
<td>Characteristic flows in the same direction in each print?</td>
</tr>
<tr>
<td>Characteristic in the same relative position in each print?</td>
</tr>
<tr>
<td>Point of similarity or point of dissimilarity?</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>X</td>
</tr>
</tbody>
</table>
Conclude and Apply

1. Compare the number of points of similarity and points of dissimilarity identified in the two fingerprint comparisons you conducted.

2. Based on the data, decide among the following choices: there is a match between two fingerprints, there is no match between two fingerprints, or the comparison is inconclusive. Justify your decision.

3. Were either of the suspects lying about having been at the crime scene? On a scale of 1–5 (1 being lowest, 5 being highest), rank your level of confidence in your answer, and explain why you feel this way.
Analyze and Conclude

4. Fingerprint analyses do not rely on numerical measurements of things like the angle formed by a bifurcation, or the precise distance between two given characteristics. Why do fingerprint examiners use a comparison approach rather than a quantifiable approach when studying and comparing impressions?

5. There is currently no international standard for the number of points of similarity required to determine a fingerprint match. Some countries require as many as 20; others require from 8 to 12. In your opinion, are 10 points of similarity adequate to determine a fingerprint match? Explain your answer.
The Problem

At 2 A.M. on a Wednesday morning, university police received a call from a student worried about his roommate. He reported that the young man left his dormitory room to go running at 8 P.M. Tuesday evening and had not returned. The student told police that his roommate was typically back at the dorm within one to two hours after leaving for a run. In the past several months, three university students had been robbed at knifepoint while walking on the campus after dark. While a suspect had been identified by police, the assailant had not been arrested, and many students were concerned.

Within 24 hours, search dogs assisting an investigation team alerted to the young man's scent. His body was discovered in a lightly wooded area off a secondary road roughly two miles from his dormitory. The victim, identified by his roommate, was wearing the running clothes and shoes he was last seen alive in two days before. Based on evidence found at the scene, the man suspected of the local armed robberies was brought in for questioning. No witnesses were found, and no weapons were uncovered at the scene. Police confiscated the suspect's car for further investigation.

As a pathologist assigned to the investigation, you determine the cause of death as asphyxiation resulting from strangulation. You recover a number of fiber samples from the victim's clothing, and find numerous hair strands between the fingers of his right hand and on his sweatshirt. Your job is to determine if properties of the trace evidence found on the victim are consistent with samples taken from the suspect and his car.

Background

When a person is physically involved in a crime, some trace of his or her presence is generally left behind. This concept, called Locard's Principle of Exchange, forms the primary basis for forensic investigations. The term trace evidence is used to describe objects found in small amounts at a crime scene that may hold clues about what took place. Trace evidence can place a suspect at a crime scene, or connect a victim to a suspect in some way. While there are many types of trace evidence, including paint chips, gunshot residue particles, dirt, pollen, and glass fragments, investigations often focus on textile fibers and hair.

Fiber Evidence

Fibers make up materials like clothing, carpeting, furniture, bedding, and wigs. Natural fibers include cotton, linen, and wool. Polyester, nylon, and rayon are artificial fibers. Materials shed fibers, and when there is contact between two people or a person and a fabric-covered object, fibers can be transferred. Fibers are gathered at a crime scene using tweezers, tape, or a specially adapted vacuum cleaner. In most cases, there are a limited number of fibers available for examination; sometimes there is only one. In general, the more fibers present, the greater the likelihood that contact occurred. Whether or not fibers are ultimately found on the victim or the suspect is affected by various factors, including the specific fabrics involved and the type of contact that occurs.
**Fiber Analysis**  Fiber analysts compare the color and diameter of fibers to determine a possible match. They analyze fiber dye content and chemical composition, and look for characteristics like unusual shape and striations or pits on the fiber surface. Fiber analysis alone cannot form the basis for a case against a suspect. Unlike fingerprints or DNA, fibers are not unique. A gray wool fiber that comes from a sweater will have similar characteristics to a gray wool fiber that comes from a blanket. However, while it is impossible to prove that a fiber came from a specific piece of clothing or other specific source, the presence of similar fibers can support other evidence or even prompt a confession.

**Hair Evidence**  Like fibers, hair evidence has limitations. While a hair from a crime scene may have properties that make it consistent with a sample from a suspect, hair is rarely used to make a definitive identification. Only hair shafts attached to a follicle are relevant for DNA testing. Despite limitations, hair characteristics can identify the source as human or some other animal, establish the source’s race, determine if the hair was dyed, cut in a certain way, or pulled out, and identify the body location from which the hair came.

**Examples of Hair Characteristics**  Study Figure 1 as you read each description.

**Hair A:**  Human head hair, Caucasian origin. General characteristics: fine to medium in coarseness; straight or wavy; shafts are round to oval in cross section; color pigments are fine to medium-sized and evenly distributed through the shaft.

**Hair B:**  Human head hair, Afro-Caribbean origin. General characteristics: curly or kinky; flattened cross section; pigment particles are large and grouped in dense clumps of different sizes and shapes; may be opaque.

**Hair C:**  Human head hair, Asian origin. General characteristics: coarse; straight and circular in cross section; compared to hair of other racial groups, the cuticle, or outer layer, is thicker and the diameter is wider; medulla is continuous and wide, large pigment particles grouped in patchy areas; reddish appearance.

**Hair D:**  Cat hair. General characteristics: fibrous roots; pigment particles do not run down to the root; the medulla, or inner layer of cells, is thicker than that of dog hair relative to the overall width of the hair.

**Hair E:**  Dog hair. General characteristics: spade-like roots; pigmentation runs through the shaft to the root; medulla is thinner than that of cat hair relative to the overall width of the hair.

---

**Figure 1**
Safety

- Always wear gloves, goggles, and apron.
- Handle forceps and glass slides carefully. Alert your teacher to broken glass, and dispose of in designated location.
- Keep your hands away from your eyes and face in science lab.
- Wash hands thoroughly after handling samples.
- Follow your teacher’s instructions for disposal of lab materials.

Procedure

Part A: Investigating Known Fiber and Hair Samples

1. Create a data table with the headings shown below. Make the table wide enough to accommodate your observations.

<table>
<thead>
<tr>
<th>Source of Fiber/Source of Hair Shaft</th>
<th>Sketch/Notes</th>
<th>Sketch/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Make a wet mount slide of each known fiber sample provided.

3. Use the microscope to examine each fiber under different magnifications. Make a sketch.

Note features like color, pits, striations, amount of twist, fineness/coarseness, shape, and relative diameter.

4. Make a wet mount slide of each hair sample provided.

5. Use the microscope to examine each hair sample. Make a sketch. Note characteristics of the cuticle, cortex, and/or medulla. Compare samples to the information in Figure 1.

Part B: Comparison of Fiber and Hair Samples

1. Use the microscope to examine the prepared slides of Fiber A and Fiber B found on the victim’s clothing. Make a sketch. Note fiber features, and identify the fiber type if possible. Note similarities and differences between the two fibers.

2. Use the microscope to examine Fiber C taken from a floor mat of the suspect’s car, and Fiber D taken from carpet in the trunk of the suspect’s car. Sketch both fibers. Your notes should include similarities and differences between these two fibers and those found on the victim’s clothing.

3. Use the microscope to examine Hair A found between the victim’s fingers and Hair B found on the victim’s sweatshirt. Sketch both hairs, and note characteristics of each hair layer.

4. Use the microscope to examine Hair C taken from the suspect’s head and Hair D taken from the victim’s head. Sketch both hairs. Your notes should include similarities and differences between these two hairs and the hairs found on the victim.
Conclude and Apply

1. Do either of the fibers taken from the suspect’s car (Fiber C and Fiber D) share characteristics with fibers found on the victim’s clothing (Fiber A and Fiber B)? Describe similarities between these fibers.

2. Based on fiber evidence alone, if the victim was in the suspect’s car at some point during the night he went running, where in the car might he have been?

3. Is there any consistency between the hair samples you examined? Explain.

4. Based on hair evidence alone, is it possible that there was contact between the victim and the suspect on the night of the murder? Explain.

Analyze and Conclude

5. Does the presence of trace evidence on the victim’s clothes and in his fingers prove that he was with the suspect or in the suspect’s car on the night he was murdered? Explain.

6. Based on your review of trace evidence, list a series of events that might have taken place on the night of the murder.

7. Fiber and hair evidence might be used in this case to support other evidence. Describe other things investigators should uncover to establish a case against the suspect.

8. What sources of error could occur while obtaining the evidence?
Can insect evidence establish time of death?

The Problem

During the morning commute on October 9, a driver reported seeing a body in a wooded area beside a major road in a large city. The deceased was an adult female, approximately 55 kg in mass and 160 cm in height (120 pounds and 5’3”). On the day the body was discovered, investigators matched the victim’s description to a current missing person report, and the deceased was identified as a 21-year-old woman who lived with her parents in an apartment complex close to the wooded area. The victim was last seen alive seven days prior to the discovery of the body in the apartment of the prime suspect, an acquaintance with a history of violent criminal behavior. The medical examiner, who was called to the scene, noted these conditions at the site before the body was removed for autopsy:

- rigor mortis absent
- body cold, decomposition in initial stages
- multiple stab wounds present in chest area
- several large maggots, roughly 15 millimeters in length, observed migrating away from the corpse; maggots captured for further investigation

Additional evidence pointed to the suspect. Hair from the victim’s head shared characteristics with hair found on a chair in the suspect’s apartment, blood and hair samples taken from the suspect’s car showed a possible match to the victim, and carpet fibers removed from the victim’s clothing matched fibers from the suspect’s car. However, to build a case and establish a sequence of events surrounding the death, investigators need to determine time of death as accurately as possible.

As a forensic entomologist, you have been asked to apply your knowledge of insects and other forensic evidence to estimate when the victim died. You identify the maggots observed in and around the body as *Lucilia sericata*, a species of blow fly. While the maggots captured at the scene had since died, you determine the stage of development as third instar—the larva stage after the second molting—based on the length of the larvae, the size of their mouth parts, and other physical features.

Because temperature affects the rate of blow fly development, you secure climatological data for the dates surrounding the murder and discovery of the body.

<table>
<thead>
<tr>
<th>Date</th>
<th>Minimum Temperature (°C)</th>
<th>Maximum Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/2</td>
<td>15.0</td>
<td>26.5</td>
</tr>
<tr>
<td>10/3</td>
<td>13.0</td>
<td>26.0</td>
</tr>
<tr>
<td>10/4</td>
<td>11.0</td>
<td>26.0</td>
</tr>
<tr>
<td>10/5</td>
<td>7.5</td>
<td>23.5</td>
</tr>
<tr>
<td>10/6</td>
<td>7.0</td>
<td>23.5</td>
</tr>
<tr>
<td>10/7</td>
<td>6.5</td>
<td>22.0</td>
</tr>
<tr>
<td>10/8</td>
<td>9.5</td>
<td>22.0</td>
</tr>
<tr>
<td>10/9</td>
<td>9.0</td>
<td>20.5</td>
</tr>
</tbody>
</table>
Background

A key component in any forensic examination is establishing time of death. An examiner is trained to interpret body changes, translating them into a timeline of postmortem events. For example, body temperature decreases at a somewhat predictable rate after death. The rate of decrease and temperature of the corpse can help estimate time of death. While body temperature changes are affected by factors like body fat, air temperature, and clothing, other changes occur independently. For example, relaxed muscles begin to stiffen within one to two hours after death, producing a condition called rigor mortis. Muscles remain stiff up to 12 hours after death, then begin to relax again. Between 24 and 48 after death, muscles are again completely relaxed. Body changes are particularly useful within one to two days after death.

Forensic Entomology

How can time of death be established if a body is found more than two or three days after death occurred? At this point, insects can provide vital information. Within minutes after death, certain insects are attracted to a corpse, especially if blood or other body fluids are present. The corpse supports an evolving ecosystem, as other insects arrive and begin to feed, grow, and lay eggs. A forensic entomologist can be called on to interpret this evidence.

Forensic entomology is based on several key principles.

1. Forensically important insects proceed through predictable developmental stages.
Blow flies are typically one of the first insects to arrive on a corpse. The blow fly life cycle is shown in Figure 1. The female lays eggs in body cavities and wounds. The first instar stage occurs when an egg hatches into a small larva. The larva feeds on dead tissue and grows quickly. When the larva grows to a certain size, it discards the exoskeleton and grows a larger one, a process called molting. Now at the second instar stage, the larva continues to feed and grow. The blow fly larva molts a third time, still feeding and growing. At this point, the fully developed third instar larva wanders away from the corpse to find a suitable site to form the puparium, in which final development occurs. When the adult blow fly emerges, one end of the puparium appears cut off, revealing the hollow interior.

2. Forensically important insects lay eggs on a corpse relatively quickly.
Under favorable climate conditions, blow flies lay eggs within the first hours of body exposure. This fact allows entomologists to establish time of death. If the age of blow fly larvae on a corpse can be determined, the entomologist can estimate when death occurred.

3. Insect development depends on temperature.
While the time required for blow flies to complete each developmental stage is known, scientists also know that development proceeds fastest in warm temperatures. For a body discovered in a temperature-controlled environment, it is easier to determine the time between stages of development. For a body left outside, however, temperature fluctuation is a factor the forensic entomologist must consider.
Procedure

1. Create a time line large enough to accommodate notes. Study the Problem section of this lab, and add data to the time line.

   Body discovered and identified

   October 9

2. Based on the medical examiner's notes, narrow the time of death between October 9 and the last date the victim was seen alive. Note these dates on the time line.

3. Calculate the average temperature the body might have been exposed to during the dates on the time line. Calculate the average daily temperature for each date, then find the average temperature for the time period. Record these numbers on or beside the time line.

4. Use the average temperature for the period, the developmental stage of the larvae, and Figure 2 to further narrow the range of time of death. Note this range on the time line.

5. Finally, use information about the length of the larvae, the average temperature, your knowledge of the larval developmental stage, and Figure 3 to estimate when the victim's body was placed at the scene. Note the date on your time line.
Can insect evidence establish time of death? continued

Conclude and Apply

1. Explain how knowing the developmental stage of the oldest blow fly larvae helped narrow the range of time of death in step 4 of the procedure.

2. Based on your calculations, what is your best estimate of the approximate date that the victim’s body was left at the scene? Explain how you reached this conclusion.

3. Based on your time line and the estimate of the date the body was left at the scene, when was the victim murdered? Explain your answer.

Analyze and Conclude

4. Could circumstances in this crime have delayed the time between the victim’s death and when the first blow fly eggs were laid? Could this affect your estimate of the time of death? Explain.

5. Could other climatological factors have affected the growth and development of larvae found on the body in this case? Explain.

6. In your opinion, how valuable is the entomological evidence in this case? Justify your answer.
The Problem

At 9:10 A.M. on December 6, police responded to a call from the owner of a delicatessen. The manager reported that cash and electronic equipment had been stolen from the shop. The crime occurred sometime between 7 P.M. on December 5 after the owner locked the shop for the evening and 7 A.M. the following morning. Investigators found one unusual piece of evidence at the scene: an unwrapped hunk of cheese was discovered in a refrigerated case with a large bite removed from it. A clear impression of teeth marks was preserved in the cheese.

Police had identified a suspect in several robberies that had occurred recently in the neighborhood of the delicatessen. Until this point, however, no evidence at any of the crime scenes had been found to link the suspect to the crimes. Investigators hope an analysis of the bite mark in the cheese might provide a way to link the suspect to this particular robbery, and perhaps to the others as well.

Background

Forensic odontology is an established branch of forensic science in which the principles of dental science are applied to legal matters. Forensic odontologists frequently assist investigators in identifying human remains, particularly in mass disaster situations like the New York City World Trade Center disaster in 2001. While their work in identifying unknown victims is perhaps most well known, forensic odontologists also use their expertise to analyze bite mark evidence on victims or inanimate objects present at crime scenes.

The theory underlying forensic odontology is that no two mouths are alike; an individual's dentition—the type, number, and arrangement of teeth—is believed to be unique. This makes a bite mark a valuable piece of evidence. A forensic odontologist can use teeth impressions left in foods like apples, cheese, chocolate, and even chewing gum to link a suspect to a victim or crime scene. When saliva is present in the impression, the potential for DNA analysis exists. Even when this is not possible, a dental impression alone can provide crucial information about the person who left it behind.

Value of Bite Marks in Food

Teeth impressions in food are forensically important for several reasons.

1. A bite mark left in food is three-dimensional. A three-dimensional image provides information about multiple teeth surfaces, increasing the data available for analysis and comparison.

2. Food evidence can be preserved. Preserving agents like glycerol and formaldehyde make it possible to retain a dental impression for extended periods.

3. There are up to 32 teeth in an adult human mouth. A food impression rarely includes all teeth. However, the more teeth available for comparison between a suspect's mouth and an impression, the greater the level of confidence in the analysis.
Forensic Odontology at Work continued

Teeth in the Human Mouth  Refer to Figure 1 and Figure 2 as you read each definition.

- *incisors* – Teeth 7–10 and 23–26. Generally chisel-shaped; function in nipping—the mouth action taken when biting into an apple.
- *canines* – Teeth 6, 11, 22, 27. Usually long with a pointed cusp; function in piercing and stabbing food.
- *premolars* – Teeth 4, 5, 12, 13. Have two cusps, or points, and can be called bicuspids.
- *molars* – Teeth 1–3, 14–16, 17–19, 30–32. Generally have the greatest surface area; function in crushing.

Matching a Suspect’s Dentition to Bite Mark Evidence  A forensic odontologist follows a general procedure to determine the possibility of a match between a dental impression and a suspect’s dentition.

1. Make a record of the suspect’s dentition. Characteristics including the distance between canines, the shape of the mouth arch, tooth alignment, thickness, width and spacing, missing teeth, and any other unique features are recorded using written records and photography.

2. Create a permanent impression. The suspect makes a dental impression in a soft, silicon-based material. A permanent plaster cast of teeth and gums is made from this impression.

3. Compare the dental impression in the food item to the cast. In comparing the two impressions, the forensic odontologist looks for similar characteristics in teeth shape, size, and position, as well as any unique dental features that are present.
Safety

- Never taste anything in the lab.
- Keep your hands away from your eyes and face in the science lab.
- Wear gloves when handling the food item and dental impressions in this lab.
- Wash your hands thoroughly after each lab activity.

Procedure

1. Study the human teeth model. Number a list from 1–32, then use Figure 1 and Figure 2 to identify and write the name of each tooth in the model. Describe characteristics of each tooth on the list. Note similarities and differences among tooth types.
2. Compare both sections of the suspect’s polystyrene dental impression with the human teeth model. Identify the type and location of each tooth represented by the impression.
3. Examine the suspect’s top impression. Record the number of teeth in the impression. Record characteristics including spaces between teeth, rotated teeth or teeth out of alignment, the distances between specific teeth, and any other unusual features you notice.
4. Repeat step 3 with the suspect’s bottom impression.
5. Next, study the impression in the food item. Note similarities and differences between the food item impression and the polystyrene impression.
6. Based on your observations, choose from the following descriptions:
   - **Positive Identification**
     The suspect’s dental impression matches the impression in the food item.
   - **Possible Identification**
     While consistencies exist between impressions, there is not enough evidence to establish a match.
   - **Insufficient Evidence**
     There is not enough information to reach a conclusion.
   - **Exclusion**
     The suspect’s dental impression does not match the impression in the food item.

Materials

- model of human teeth
- crime scene food item
- ruler
Conclude and Apply

1. Were you able to establish a match between the suspect’s dental impression and the impression in the food item? Explain.

2. What characteristics of the suspect’s dentition did you focus on when attempting to establish a match? Were certain teeth or some specific teeth characteristics more helpful than others? Explain.

Analyze and Conclude

3. How confident do you feel about your comparison of the two dental impressions? Explain.

4. Imagine you are the defense attorney for the suspect. What arguments could you use to damage the credibility of the evidence presented by the forensic odontologist regarding the dental impression comparison?

5. In most cases, a dental impression found in a food item at a crime scene does not show a full complement of teeth. What other types of evidence might a forensic scientist look for to provide additional information about the person who left the impression?
**The Problem**

On May 9, Colorado State Police are contacted by a woman living in Texas whose brother lives in a remote area north of Denver. Though she speaks with her brother by phone about once a month, she has not been able to reach him for a week. She is concerned; the phone conversations occur regularly, and she and her brother have not spoken for roughly five weeks. Officers sent to investigate the brother’s home discover two bodies at the scene.

The body of a man is discovered on the right side of the back yard, about halfway between the house and a car parked in the driveway to the right rear of the house. This body carries no wallet and no identifying records. Another male victim is found on the kitchen floor. The driver’s license in his wallet identifies him as the woman’s brother and owner of the home. The kitchen is located in the right rear of the house. Two steps lead from the kitchen to the back yard, and one window in the kitchen is unscreened and open. An interior doorway leads from the kitchen to the den at the right front of the home.

The ground and floor around both bodies is stained with dried blood, and footprints are evident in the kitchen. A hand gun is located 5 cm from the hand of the man in the kitchen, but no other weapons are recovered inside or outside of the house. Signs of struggle in the house are evident. In the kitchen, two chairs are overturned, and a mug, plate, and fork are on the floor. In the den, several items appear to have been knocked off a bookshelf and a lamp lies broken on its side. A small clump of hair is lying on the carpet near the couch.

You are part of the investigative team assigned to examine and collect evidence at the scene. In this lab, you will design a plan for assessing and collecting evidence at the crime scene using appropriate techniques and tools. Your plan should stress the importance of using precise collecting and handling techniques, and should focus on pieces of evidence you view as crucial in determining events at the scene.

**Background**

Investigators collect as much relevant evidence as possible at a crime scene. In general, the more evidence collected, the better the odds that some evidence may ultimately be used by prosecutors to make a case. Mistakes made during collection, packaging, and storage can compromise evidence integrity and significance. Procedures and guidelines like the ones given next are followed by crime scene investigators to prevent evidence contamination and loss, increasing evidence value.

**General Principles for Evidence Collection and Preservation at the Crime Scene**

1. Minimize traffic at the site. Trace evidence can be easily disturbed or contaminated. Contact between investigative personnel and the crime scene should be limited until evidence is secured.
2. Wear protective clothing. Lab coats and disposable gloves can prevent evidence contamination. Change protective gear as necessary to avoid transfer of evidence from one location or piece of evidence to another at a crime scene.

3. Handle evidence sparingly. Handle items as little as possible to minimize loss and contamination.

4. Package items individually. When possible, keep evidence items separated.

5. Use clean equipment and work surfaces. A dirty work surface or tool can contaminate evidence, lessening its potential value.

6. Document evidence. Each item should be tagged with the date/time of collection, name of person who collected it, item description and unique number, and item location.

**Collecting Evidence**  Investigators use various tools and techniques to collect evidence. Once retrieved, it is packaged in clean, dry containers, then sealed to prevent tampering, contamination, or loss.

**Procedure**

1. Create a master layout of the crime scene on graph paper. Make it large enough to add the location of key evidence, as well as other notes.

2. Develop a plan for assessing and collecting evidence from the scene. As you work through the plan, think about the following elements:
   - *What items or pieces of evidence should be collected and how?*
   - *What unknown factors must be determined by the evidence?*
   - *Which tasks at the scene have the highest priority?*
   - *How can tasks be divided among team members?*
   - *What learning from previous forensics labs can be applied here?*

3. Share your plan with your teacher and other groups. Based on feedback provided, revise your plan to increase its effectiveness.
Lab 7  

When did she die?

Your medical examiner team has been given the following case to review. It is your job to determine whether the victim died accidentally and what the time of death was. Study the details and complete the medical examiner’s report that follows.

The Problem

The victim was found in her home at 10:00 A.M. on Saturday morning by her sister, with whom she was supposed to go jogging. The sister promptly called the police who then notified you, the medical examiner. You noted the following:

- The victim was lying facedown at the bottom of the stairs, facing away from the stairs. The sister indicated the victim was dressed in the clothes she had worn to dinner the night before.
- The victim had no pulse.
- The body was cold to the touch, but the internal temperature, which was measured at 10:30 A.M., was 27°C (room temperature was 20°C).
- Her neck was apparently fractured, and she appeared to have sustained head injuries.
- There were purplish marks on the front of her shoulders and neck; the marks did not change color when touched.
- Her entire body was stiff.
- The victim’s eyes were open and cloudy with a thin film.

Additional Police Notes  The victim had eaten dinner with her sister at 5:00 P.M. the night before (Friday evening). At dinner, they had agreed to meet at the victim’s townhouse at 10:00 A.M. Saturday morning to go jogging. The sister returned to her own home at 11:00 P.M., but she was not sure when the victim returned to her townhouse after dinner. Neighbors did not recall seeing the victim return to her townhouse.

When you performed an autopsy on the victim later that day, you noted that she died of a broken neck and subsequent asphyxiation. The victim was 5 feet 8 inches tall and weighed 130 pounds, her stomach was empty, and her small intestine was full. Your job is to provide police with the time of death.
Background

When a body is discovered, one of the first things that a medical examiner must do is determine the time of death. The medical examiner uses several indicators to help establish the time of death, including body temperature, rigor mortis, discoloration (livor mortis or lividity), and the appearance of the eyes.

Body Temperature

When a person dies, the body immediately begins to cool. On average, the body temperature drops at a rate of 0.75°C per hour for the first 12 hours. After 12 hours, the rate of cooling slows by about one half (approximately 0.4°C per hour) until the body reaches ambient temperature, the temperature of the environment. The rate of cooling is also affected by the following factors:

- **Air temperature** – A body will cool faster on a cold winter night than on a warm summer night.
- **Body fat** – Fat tends to insulate the body, so the more fat a person has, the slower the body cools after death.
- **Clothing** – Clothing also insulates the body, so heavy clothing will slow the rate of cooling.
- **Water** – A body in water cools much faster than one in air. Therefore, it is difficult to use body temperature to estimate the time of death for a victim found in the water.

Rigor Mortis

At the time of death, the body’s muscles are relaxed. However, within 1–2 hours, the muscles begin to stiffen as their stores of adenosine triphosphate (ATP) become exhausted. This stiffening is known as rigor mortis. Rigor mortis begins with the muscles of the face, jaws, and neck, proceeds down the body through the upper arms and torso, and ends with the legs. This process is complete within 8–12 hours after death. As the muscles begin to break down, they begin to relax in the same order as they stiffened. By 24–48 hours after death, the body is totally relaxed again.

Livor Mortis (Lividity)

Within 1–2 hours after death, the blood settles into the lowest parts of the body (parts that are closest to or resting on the ground) due to gravity. The red blood cells settle out and break down into the tissues, leaving purplish marks that later become yellow (due to the breakdown of hemoglobin). The color (lividity) becomes fixed in the tissue within 6–8 hours after death. If a body is moved after this time, then the position of the purplish marks may not agree with the position in which the body is found. Finally, if skin appears discolored, but turns white when touched, then lividity has not been fixed and death probably occurred more than 2 hours, but less than 10 hours ago.

Appearance of the Eyes

If the eyes remain open at the time of death, then a thin film will appear on them as they begin to dry out. As the blood cells within the body break down, they release potassium. Potassium enters the eyes and causes them to appear cloudy. This process takes approximately 2–3 hours after death; however, if the eyes remain closed after death, then the process takes much longer (approximately 24 hours).

Stomach Contents

After you eat, the process of digestion takes place. Digestion begins in the stomach. It takes about 4–6 hours for the stomach to empty its contents into the small intestine. Finally, it takes approximately 12 hours for the food to leave the small intestine. As a rule of thumb:

- Undigested stomach contents—death occurred 0–2 hours after the meal
- Stomach empty—death occurred 4–6 hours after the meal
- Small intestines empty—death occurred 12 hours or more after the meal
Conclude and Apply

1. What is the normal body temperature in degrees Celsius?

2. What biological process allows humans, mammals, and birds to maintain high body temperatures?

3. Research and explain briefly the role of ATP in muscle contraction.

4. Explain the path that food takes through the digestive system in your body.

5. Based on the background information about the average temperature decrease after death, calculate the body temperature for each hour up to 24 hours after death.

<table>
<thead>
<tr>
<th>Hour</th>
<th>Body Temp. (°C)</th>
<th>Hour</th>
<th>Body Temp. (°C)</th>
<th>Hour</th>
<th>Body Temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>9</td>
<td>17</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>10</td>
<td>18</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>11</td>
<td>19</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>12</td>
<td>20</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>13</td>
<td>21</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>61</td>
<td>14</td>
<td>22</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>71</td>
<td>15</td>
<td>23</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>81</td>
<td>16</td>
<td>24</td>
<td>24</td>
<td>1</td>
</tr>
</tbody>
</table>
6. Plot the data for temperature versus time after death on graph paper.
7. Based on the body temperature of the victim, how long has it been since the victim died?

8. Estimate the time of death using body temperature.

9. Based on the observations of rigor mortis, how long has the victim been dead?

10. Where was lividity observed on the body? Was it fixed? How long ago did she die? Was the victim found in the position that she died or was her body moved? Explain your answer.

11. Based on the appearance of her eyes, how long ago did she die? Explain your answer.

12. Based on the examination of her digestive system, how long after a meal did the victim die? Explain.

**Analyze and Conclude**

13. Based on all of the evidence available, estimate the time of death for the victim. Explain your answer.

14. Was the victim’s death an accident? Explain your answer.
The Problem

The boys’ basketball team has been practicing long hours and playing exhausting games all season. Their hard work has paid off. They will be playing in the state championship in two weeks. However, two of the starting players, Jorge and Kyle, have reported to the team doctor. Both boys (age 17) have been complaining about fatigue and muscle weakness and are worried about being able to play their best in the championship.

Listed below are the symptoms the players shared with the doctor.

**Jorge**: sleepy in classes; muscle weakness; increased appetite; drinks plenty of fluids; occasional dizzy spells after heavy exertion; increased urination (not excessive)

**Kyle**: sleepy in classes, especially after lunch; muscle weakness; increased appetite, almost excessive; drinks plenty of fluids, but always feels thirsty; frequent dizzy spells after long practices or heavy exertion; urinates frequently; 15 pound weight loss

Both boys had pre-season physical exams and were healthy. However, both boys have a family history of diabetes, a disease in which the body does not effectively respond to the levels of glucose, a very important type of sugar, in the blood. The result is dangerously high concentrations of glucose in the blood. Jorge’s father developed diabetes at age 50 and is currently managing it by dieting. Kyle’s grandfather had diabetes all of his life. He had to inject insulin daily, developed complications from diabetes, and died at age 55.

Because the symptoms and histories indicate that one or both boys may have diabetes, a glucose tolerance test is ordered to diagnose the disease.

**Glucose Tolerance Test** On the day of the test, each boy does not eat breakfast. During the test, each boy drinks a concentrated glucose solution (50–100 g glucose) and has blood drawn every 30 minutes for 2.5 hours. The blood samples are spun in a centrifuge to separate plasma from blood cells. A portion of each sample is sent to an outside lab, where the insulin and glucose contents in each plasma sample will be measured.

You are a technician in the lab that will measure the blood glucose by using a glucose test strip. The strip contains an absorbent pad that contains two enzymes, *glucose oxidase* and *peroxidase*, and a color indicator. When a blood sample is applied to the pad, glucose oxidase converts glucose to gluconic acid and hydrogen peroxide. Peroxidase then reacts the hydrogen peroxide with the color indicator, which varies in color from light green to brown depending upon the amount of glucose in the sample. Light green indicates lower glucose concentrations, while dark brown indicates higher concentrations. You will compare the color of the strip to a color scale on the bottle to determine the glucose concentration in the sample. You will then graph and analyze the data to make a preliminary diagnosis.
**Everyday Materials**
- tissues
- watch with a second hand display or stopwatch
- ruler
- graph paper

**Lab Materials**
- labeled tubes (12) containing simulated plasma samples (5 mL) from each boy (before, 0.5, 1, 1.5, 2, 2.5 h)
- glucose test strips (12)
- copy of the test strip color chart (if you do not have a copy, see the description in the Procedure)

**Safety**
- Never taste or drink anything in the lab.
- Be sure to keep your hands away from your eyes and face in the science lab.
- Wash your hands thoroughly after each lab activity.

**Procedure**
1. To measure glucose in each sample with the test strips, do the following:
   a. Take a strip and hold it by the end opposite the test area.
   b. Dip the strip into the tube containing the sample and remove it immediately (draw the edge of the strip against the rim of the test tube to remove any excess fluid).
   c. Start the stopwatch and compare the color of the strip to the color scale exactly 30 seconds after wetting the strip (ignore any color changes that occur after 30 seconds).
   d. Note the reading on the data table.
   e. Repeat the procedure with the next sample and continue until you have tested all of the samples.

2. On graph paper, plot the data for each boy on the same graph. Plot the plasma glucose concentration on the y-axis and time on the x-axis. Use your data to answer the following questions. You may also wish to have your textbook and some additional information about diabetes available.

**Plasma Glucose Concentration (mg/dL)**

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Jorge</th>
<th>Kyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Color</th>
<th>Glucose (mg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Light Green</td>
<td>100</td>
</tr>
<tr>
<td>Green</td>
<td>250</td>
</tr>
<tr>
<td>Olive</td>
<td>500</td>
</tr>
<tr>
<td>Light Brown</td>
<td>1000</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>≥ 2000</td>
</tr>
</tbody>
</table>

**Test Strip Color Scale**

**Conclude and Apply**

1. Was the blood glucose concentration the same in each boy prior to the test (i.e. fasting blood glucose)? If not, whose blood glucose concentration was higher?
2. Describe the changes in blood glucose that occur over time in each boy.

________________________________________________________________________

________________________________________________________________________

3. How does glucose that you eat get into your bloodstream? In your answer, describe the organs that it must pass through.

________________________________________________________________________

________________________________________________________________________

4. Does the pattern of the changes in blood glucose that you observed in the boys make sense in light of your answer to question 3? Explain why or why not.

________________________________________________________________________

________________________________________________________________________

5. Whose blood glucose concentration is more stable (i.e. controlled), Jorge’s or Kyle’s?

________________________________________________________________________

________________________________________________________________________

**Analyze and Conclude**

6. Based on the information that you have so far, do either of the boys have diabetes? If so, which boy and how did you make that conclusion?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

7. Obtain a copy of the insulin report from your teacher and look over the data. Describe how insulin levels change with time during the test for each boy.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

8. How do the changes in plasma insulin concentration correlate with the changes in blood glucose?

________________________________________________________________________

________________________________________________________________________
9. Based on the information that you now have, do either of the boys have diabetes? Support your conclusion.

10. Based on your data, what does insulin do to blood glucose levels?

11. Which boy might be better able to withstand a long period without food? Why?

12. If either of the boys has diabetes, explain how the disease accounts for his symptoms. If neither of the boys has diabetes, then what might cause their symptoms? (You will need to obtain information about diabetes.)

13. What treatment might you recommend for each boy? Why?
Use Blood Types to Help Solve a Crime

The Problem

Some school property was vandalized, and a few drops of blood were found at the scene of the crime. The detectives investigating the incident think that the blood came from the perpetrator of the crime, who apparently was slightly injured during the vandalism. The detectives have gathered a group of suspects who were all on school property when the crime was committed. However, the only hard evidence is the blood found at the scene. In this lab, you will act as a lab technician, analyzing a sample of blood from a suspect to determine the blood type. Each one of your classmates will analyze a sample from a different suspect. Then, you and your classmates will compare the blood types of your samples with the type of blood found at the crime scene in order to narrow down the field of suspects.

Background

Using Blood Typing in Forensics

Blood typing is frequently used in forensic investigations. A very small quantity of blood can easily be tested for dozens of genetically controlled traits that have little, if any, environmental influences on their expression. This means that if you know a person’s phenotype for these traits, you also know his or her genotype, or genetic identity.

There are hundreds of known human blood-group systems in addition to the familiar ABO and Rh, or rhesus, blood groups. Each system is based on classes of antigenic molecules on the surface of the red blood cells. An antigenic molecule is recognized by the body’s immune system as a foreign substance, to which it reacts by producing an antibody. Classification, or typing, of a person’s blood to determine which molecular forms are present on the red blood cell depends on antigen-antibody reactions.

Agglutination Reaction

If you take serum from a person of known blood type and add it to a drop of blood to be typed, one of two things will happen. The serum may mix freely with the red cells with no noticeable change, or the mixture may agglutinate, that is, the red blood cells clump together, producing a readily observable change as shown in Figure 1.

ABO Blood Type

There are two common antigenic substances in the ABO blood group, A and B. The O type is not associated with an antigen, which means it is not recognized as a foreign substance by anyone’s immune system—even people who do not have O type blood. Antibodies to type A antigen normally are found in the serum of people without the A antigen (that is, in people with type B or type O blood). These anti-A antibodies cause type A cells to agglutinate if they are mixed together. If a blood sample is agglutinated only by anti-A antibodies and not by anti-B antibodies, then the sample is type A, as shown in Table 1. Agglutination reactions that identify blood types B, AB, and O also are shown in Table 1.

<table>
<thead>
<tr>
<th>ABO Blood Type</th>
<th>Anti-A Reaction (+/−)</th>
<th>Anti-B Reaction (+/−)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>B</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>AB</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>O</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>
Rhesus Blood Type  Rhesus blood types have only one common antigen associated with them. It is often referred to as antigen D. Blood from people with the D antigen (Rh\(^+\)) is agglutinated by anti-D antibodies, which may be found in the blood of people without the antigen (Rh\(^-\)). Agglutination reactions that identify Rhesus blood types are shown in Table 2.

<table>
<thead>
<tr>
<th>Rhesus Blood Type</th>
<th>Anti-D Reaction (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rh(^+)</td>
<td>+</td>
</tr>
<tr>
<td>Rh(^-)</td>
<td>-</td>
</tr>
</tbody>
</table>

### Everyday Materials
- 10% bleach solution
- paper towels

### Lab Materials
- ABO/Rh blood-typing test kit (with artificial or aseptic blood samples)
- protective gloves

### Safety
- In this lab, you will work with artificial or aseptic blood samples obtained from your teacher. Handle and dispose of the samples as instructed by the testing kit or your teacher.
- Be sure to keep your hands away from your eyes and face in the science lab.
- Remember to wash your hands thoroughly before and after completing the lab procedure.

### Procedure
1. Obtain an ABO/Rh blood-typing test kit from your teacher. Open the kit and assemble the contents for the procedure. Read the kit’s instructions.
2. Obtain the blood sample from your teacher. Perform the ABO/Rh test as instructed by the kit. Pay close attention to the amount of time you need to wait for the samples to react.
3. After waiting the time specified in the kit instructions, observe the samples and compare them with Figure 1. Record the results, positive or negative for each reaction, in columns 1–3 of Table 3 under Data and Observations.
4. Refer to Tables 1 and 2 to determine ABO and Rh blood types based on the agglutination reactions. Record the ABO and Rh blood types in column 4 of Table 3. Notify your teacher of your results.
5. Dispose of anything with blood on it immediately after use, according to your teacher’s instructions.
6. Wipe down your work surface with the bleach solution and paper towels.
Conclude and Apply

1. Your teacher will tell you the number of suspects of each blood type. The type of blood found at the crime scene is A+. Based on this information, how many suspects can be ruled out as possible perpetrators of the crime?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

2. Explain why blood types can be used only to rule out potential suspects and not to prove conclusively who committed a crime.

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

3. If you could test for other blood-group types in addition to ABO and Rh, how might this affect the investigation?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Table 3

<table>
<thead>
<tr>
<th>1 Anti-A Reaction (+/−)</th>
<th>2 Anti-B Reaction (+/−)</th>
<th>3 Anti-D Reaction (+/−)</th>
<th>4 ABO/Rh Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analyze and Conclude

4. All of the ABO/Rh blood types are relatively common in the United States. The most common, O+, occurs in 38 percent of people; the least common, AB−, occurs in 1 percent of people. A+, which was found at the crime scene, occurs in 34 percent of people. Some blood-group systems do not show as much variation, and only a small percentage of people do not have the same blood type. How useful would a less variable blood-group system be for forensic analysis?
The Missing Restaurant Owner

The Problem

The following is a description of a fictitious murder case. The victim is a restaurant owner who was last known to be at a bus stop approximately 800 meters from his home. He vanished and was never seen again.

Witnesses testified that they heard yelling from the office of the victim’s restaurant about the time the victim usually left work for home. Using this testimony, police established the identity of the man the victim was arguing with, and they questioned him as a suspect. The suspect had scratches on his face, which he claimed were from a fight he had the previous evening, and soil particles in his ring and bracelet. The suspect had no explanation for the soil particles or for the reports of yelling from the restaurant office. After arresting the suspect, the police searched his car, the restaurant office, and the surrounding countryside and gathered the following evidence:

List of Evidence

From the suspect’s car (trunk):
- Bloodstained watch with the clasp missing (identified as the victim’s)
- Strands of hair

From the restaurant office:
- Clasp matching the watch from the suspect’s trunk
- Blood samples from the floor

Countryside:
- Bloodstained clothes wrapped in trash bags similar to those used by the restaurant; samples of hair from one of the suspect’s dogs and thread from the suspect’s sweater found on the clothes
- Knotted electrical cord with hairs that matched those found in the suspect’s trunk

The hairs found in the car and on the electrical cord matched samples of the victim’s hair taken from his home. Neither the murder weapon nor the body have been found. Your job is to evaluate the forensics evidence and come to a decision about the guilt or innocence of the suspect.
Part 1

Blood Type Analysis This case is peculiar because there is no body, only hair samples and bloodstains. Whose blood was found? The first thing to do is type the blood samples and then try to identify them.

Three genes ($i^A$, $i^B$, $i$) determine human blood type. Two genes ($i^A$ and $i^B$) code for two proteins, A and B, that are found on the surface of red blood cells. The $i$ gene does not code for a protein.

Because you inherit one gene from your mother and one from your father, there are several possible genotypes and phenotypes (i.e. blood types). If you have one copy of $i^A$ ($i^A i^A$ or $i^A i$), then your red blood cells will have the A protein (blood type A). If you have one copy of $i^B$ ($i^B i^B$ or $i^B i$), then your cells will express the B protein (type B). If you have a copy of $i^A$ and $i^B$ ($i^A i^B$), then your cells will express both proteins (type AB). If you only have $i$ genes ($i i$), then your blood cells will express no protein (type O).

Blood typing is a fast, inexpensive, and easy procedure. To determine blood type, two drops or samples of blood are placed side by side on a glass slide. To one side, a drop of an antibody (anti-A) raised against the A protein is added, while to the other side, a drop of an antibody (anti-B) raised against the B protein is added.

If A protein is present on the blood cells, then anti-A will cause them to clump together; likewise anti-B will cause the cells to clump if B protein is present. If no clumping is observed, then neither protein is present.

Procedure

1. Blood type slides from several of the pieces of bloodstained evidence are shown below (anti-A is on the left side and anti-B is on the right side of each slide). The blood-type slide from the suspect is also shown. Because police did not have a blood type for the missing restaurant owner, blood samples were drawn from his parents and are shown as well. Analyze the slides and determine all of the blood types.

Blood Types:

Father ______ Mother ______ Suspect ______

Clothing _____ Restaurant office _____ Watch _____

The Missing Restaurant Owner continued
The blood-typing evidence did not clearly reveal whether the bloodstains belonged to the missing victim. So, investigators turned to a newer technique called DNA fingerprinting or DNA typing. The DNA sequence of human genes (DNA that codes for proteins) follows fairly regular patterns; however, the DNA sequences between genes (i.e. non-coding DNA) differ greatly among individuals. Scientists understand how to identify and analyze these special sequences, so they can tell if two DNA samples probably came from the same person. Since DNA is inherited from each parent, an individual shares patterns within these sequences with his or her parents. Therefore, scientists can also tell whether or not two samples came from individuals who are related.

To conduct a DNA typing experiment, traces of DNA are collected from an individual or crime scene. Then, a technique called polymerase chain reaction (PCR) is used to make copies of the DNA to increase the amount. PCR enables analyzable DNA to be obtained from extremely small samples. The DNA is then cut into fragments using specific enzymes called restriction enzymes. The fragments, which are of different sizes, are separated using a technique called gel electrophoresis. The pattern of separated DNA fragments are transferred from the gel to a piece of filter paper and mixed with radioactive segments of DNA that correspond to an individual’s unique sequences. After exposing the filter paper to the radioactive compounds, it is dried and exposed to X-ray film; the fragments containing an individual’s unique sequences will show up as dark bands on the film. Now you have a DNA fingerprint. In practice, many DNA samples are loaded on the gel for comparison. DNA typing compares the bands from a known sample to those of suspects. The bands from two different samples will match only if the same individual donated both samples. Even though an individual’s pattern of bands is unique, children will share bands with both parents.

To verify the identity of the victim, DNA typing was done using samples of DNA from his mother (A), father (B), the suspect (C), the watch (D), the restaurant office (E), and the clothing (F). Read the gels on the next page from top to bottom and compare the columns.

Conclude and Apply

1. Is it possible that the blood found in the office and on the clothing was the missing restaurant owner’s blood? What was his blood type? Use your knowledge of genetic crosses (i.e., Punnett squares) to determine the victim’s possible blood types from the information that you have. Show your work in the space below.

Part 2

DNA-Typing Analysis  The blood-typing evidence did not clearly reveal whether the bloodstains belonged to the missing victim. So, investigators turned to a newer technique called DNA fingerprinting or DNA typing. The DNA sequence of human genes (DNA that codes for proteins) follows fairly regular patterns; however, the DNA sequences between genes (i.e. non-coding DNA) differ greatly among individuals. Scientists understand how to identify and analyze these special sequences, so they can tell if two DNA samples probably came from the same person. Since DNA is inherited from each parent, an individual shares patterns within these sequences with his or her parents. Therefore, scientists can also tell whether or not two samples came from individuals who are related.

To conduct a DNA typing experiment, traces of DNA are collected from an individual or crime scene. Then, a technique called polymerase chain reaction (PCR) is used to make copies of the DNA to increase the amount. PCR enables analyzable DNA to be obtained from extremely small samples. The DNA is then cut into fragments using specific enzymes called restriction enzymes.
2. Was the victim genetically related to the mother and father tested in columns A and B? Explain your answer.

_________________________________________________________________________________

_________________________________________________________________________________

3. Given that there was no body or murder weapon found, do you think that the evidence indicates beyond a reasonable doubt that the suspect murdered the victim? Explain your answer.

_________________________________________________________________________________

_________________________________________________________________________________

**Analyze and Conclude**

4. Form groups of four students. Two students should act as prosecutors while the other two act as defense attorneys. Each pair should prepare an argument explaining why the suspect is guilty (prosecution) or innocent (defense). Use the lines below to list ideas you will use in your argument.

_________________________________________________________________________________

_________________________________________________________________________________

_________________________________________________________________________________