

Chapter Overview

Blood is one of the most important kinds of biological evidence. Forensic scientists can test blood evidence for blood type, which would be considered class evidence, and also for a specific DNA profile, which would be individual evidence. Blood is made up of three types of cells—red blood cells, white blood cells, and platelets—all suspended in a liquid called plasma. Each type of cell has a specific function. Scientists determine the blood type of a sample by testing that sample for the presence or absence of certain proteins. By examining blood-spatter patterns left at a crime scene, investigators can tell the direction the blood was traveling, the angle of impact, and the point of origin of the blood.

The Big Ideas

Blood is composed of red blood cells, white blood cells, and platelets. Red blood cells transport oxygen to, and carbon dioxide away from, all parts of the body; white blood cells fight diseases that threaten the body; and platelets help blood clot. Scientists have been analyzing blood-spatter patterns since the late 1800s. When investigators find dark stains at a crime scene, they first confirm whether the stains are blood. They even have methods of finding blood after a scene has been cleaned. Once the presence of blood is confirmed, investigators test to see if the blood is human. Scientists can run tests on blood found at a crime scene to determine the blood type and the DNA fingerprint of the person who shed the blood. By studying blood-spatter patterns, investigators can tell the direction in which the blood was traveling, the angle of impact, and the point of origin.

CHAPTER 8

Blood and Blood Spatter

BLOOD PAINTS A PICTURE

Concerned neighbors called the police after hearing a woman screaming in the upstairs apartment. When the police arrived, they found the woman with a split lip, bruised cheek, and several facial cuts. Her left eye was swollen shut, and it looked like a black eye was developing. Both of her upper arms were bruised. Behind the woman's chair, blood spatter was evident.

When questioned, the woman said she had been climbing the stairs and had fallen on the last step, striking her head as she fell. Her husband had a small cut on his fist and some blood on the cuff of his shirt-sleeve. He told the police that the blood on his shirt was his wife's blood. He explained that the blood must have gotten on his sleeve as he tried to help her wipe the blood from her wound.

The police photographed and noted all of the evidence. However, was the description of the accident consistent with the blood evidence? Did the woman fall on the steps? If the woman had fallen on the steps, then why wasn't any blood



Collecting blood evidence at a crime scene.

found on the steps? The blood-spatter evidence found behind the chair where the woman was sitting indicated that the blood originated from the area of the chair and moved toward the wall. Was the blood on the man's shirt his wife's blood or his own? Were the woman's injuries of the type that would occur by falling on steps, or were they more consistent with a beating from her husband? These are the types of questions a blood-spatter expert tries to answer.

SCENARIO

After reading the scenario, have students discuss these questions:

Why did the police suspect that the wife did not fall and injure herself?

What would they need to find out about the bloodstain on the husband's sleeve to validate their suspicions?

Was there other evidence the police could use to prove or disprove the husband's story?

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CRIME SCENE DO NOT

OBJECTIVES

By the end of this chapter you will be able to

- 8.1 Explain the composition of blood.
- 8.2 Describe the functions of blood cells.
- 8.3 Describe a brief history of the use of blood and blood-spatter analysis in forensics.
- 8.4 Describe how to determine the blood type of a sample of blood.
- 8.5 Describe how to screen for the presence of human blood.
- 8.6 Calculate the probability of certain blood types within a population.
- 8.7 Conduct a blood-spatter analysis.
- 8.8 Examine stab wounds and describe the nature of the weapon.
- 8.9 Use blood-spatter evidence to recreate the events at a crime scene.



VOCABULARY

agglutination the clumping of molecules or cells caused by an antigen-antibody reaction

antibodies proteins secreted by white blood cells that attach to antigens

antigen-antibody response a reaction in which antibodies attach to specific antigens

antigens any foreign substance or cell in the body that reacts with antibodies

cell-surface protein proteins embedded in the cell membrane

lines of convergence a two-dimensional view of the intersection of lines formed by drawing a line through the main axis of at least two drops of blood that indicates the general area of the source of the blood spatter

point of origin a three-dimensional view formed using lines of convergence and angles of impact of at least two different drops of blood to identify the source and location of blood splatter

red blood cells donut-shaped cells that carry oxygen throughout the body

satellite drop of blood secondary drop formed when some blood breaks free from the main contact drop of blood

white blood cells cells that police the body by destroying foreign materials

KEY SCIENCE CONCEPTS

Biology: the main functions of blood in the body

Chemistry: chemical reactions used to discover blood evidence that may not otherwise be visible

Physics: the effects of surface tension, gravity, and other forces on blood droplets

Math: calculating probability

Teaching Tip

Teachers may choose to explore blood spatter at different levels. Much of the math content appears in the activities, rather than the text, and deals with angle of impact and point of origin.

Teaching Resources

- Instructor's Resource CD-ROM includes:
 - PowerPoint Presentation
 - Lesson Plan and extended Objective Sheets
 - Teacher Notes and Activities
 - Activity Forms
 - Rubric
- ExamView CD-ROM
- E-book on CD-ROM

Web site: school.cengage.com/forensicscience

Differentiated Learning



Teaching English-Language Learners

Reinforce the vocabulary used in this chapter by asking students to create flashcards with a vocabulary word on one side and its meaning on the other. Allow students to write the meaning in both their native language and in English. Encourage students to review their flashcards before each class.

Engage

Ask students the following questions:

- What do you think is the role of blood in the human body?
- What is blood made of?
- Do you think all human blood is the same? Explain. Have students view a short segment of CSI dealing with blood at a crime scene.
- Do you think you could determine where the blood originated based upon the blood-spatter stains? (You might show students a picture of blood spatter from a crime scene as you ask the question.)

Explore

Discuss the history of bloodletting and the use of leeches with students. Ask students why they think blood has been studied much longer than DNA. Then ask students why people may have been curious about blood. What do they think ancient peoples hoped to find out by studying blood?

INTRODUCTION

Blood left at a crime scene can be analyzed in several ways by a criminal investigator. Blood typing may provide class evidence because more than one person has the same blood type. Because white blood cells contain DNA, it is possible to determine with a high degree of certainty using DNA profiling whether evidence blood left at a crime scene matches the blood of a suspect (or victim).

Blood-spatter evidence can also be used to help recreate a crime scene to validate the information provided by a witness or suspect. By using blood spatter, it is possible to note the direction from which the blood originated, the angle of impact, and the point of origin of the blood. Further examination of the blood drops might indicate if the blood spatter resulted from a high- or low-velocity impact, indicating the type of weapon used to cause the injury.

In this chapter, we will explore how to analyze blood found at a crime scene. By examining blood types and studying blood-spatter patterns, you will learn how a criminalist is able to use this evidence to help solve crimes.



In 1937, Dr. Bernard Fantus established the first Blood Bank.

BLOOD HISTORY

Blood has been studied in one way or another for thousands of years. The table shown in Figure 8-1 provides a snapshot of the gradual developments in our knowledge of blood.

Figure 8-1. A chronological history of the study of blood.

Date	Who	Contribution
2500 B.C.	Egyptians' bloodletting	Effort to cure disease
500 B.C.	Greeks	Distinguished between arteries and veins
175 A.D.	Galen	Established that circulatory paths exist
1628	Sir William Harvey	Noted continuous circulation within body
1659	Antony Leeuwenhoek	Viewed blood cells with microscope
1795	Philip Syng Physick	Performed first blood transfusion (not recorded)
1874	Sir William Osler	Discovered platelets
1901	Karl Landsteiner	Discovered three blood types: A, B, O
1902	Alfred on Decastello	Discovered blood type AB
1922	Percy Oliver	Established blood donor service
1925	various	Discovered that about 80% of human population "secretors"
1935	Mayo Clinic	Developed a method to store blood for transfusions

Differentiated Learning



Teaching English-Language Learners

Make sure students understand the word "blood," what it is, and its function in the human body. Ask volunteers to explain how the circulatory system works and the functions of blood. You might draw a loop on the board to represent the system and use it to highlight the functions students describe.

Differentiated Learning



Teaching At-Risk Students

At-risk students will benefit from a brief review of the importance and function of blood. While students may be familiar with the concept of tissue, they may have a difficult time believing that a tissue can be a liquid. Explain to students that blood is a tissue made of different kinds of specialized cells and that blood is an important tissue in the cardiopulmonary system in the human body. Blood analysis can also provide an overview of the health of a person. Explain that doctors often test patients' blood to determine their health.

Date	Who	Contribution
1937	Dr. Bernard Fantus	Established Blood Bank
1900s	Kastle	Developed first presumptive blood test
1940	Karl Landsteiner	Discovered Rh protein
1940	Edwin Cohn	Devised a method to fractionate blood for transfusions
1941	American Red Cross	Organized civilian blood banks for WWII
1943	Dr. Paul Beeson	Described transfusion-transmitted hepatitis
1959	Dr. Max Perutz	Described structure of hemoglobin
1959	Belgian Congo	Recorded first case of AIDS
Late 1960s	Dr. Kenneth Brinkhaus	Produced large quantities of Factor VIII
1971	Dr. Blumberg	Developed method of antibody detection
1984	Dr. Robert Gallo	Identified virus causing AIDS
1985	Various	Developed an ELISA test
1987–2002	Various	Development of blood-screening tests for infectious disease

COMPOSITION OF BLOOD

Obj. 8.1

Blood is a circulating tissue consisting of three types of cells: **red blood cells**, **white blood cells**, and platelets (Figure 8-2). These cells are suspended in a liquid known as plasma. Plasma is similar to salt water in composition. It carries dissolved proteins, such as antibodies, hormones, and clotting factors, and nutrients such as glucose, amino acids, salts, and minerals.

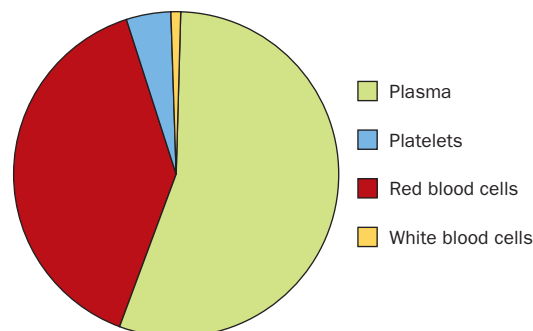


BLOOD CELLS Obj. 8.2

Each blood cell performs a different function. Red blood cells (erythrocytes) carry respiratory gases, mainly oxygen and carbon dioxide. The hemoglobin in red blood cells is an iron-containing protein that binds to oxygen in the lungs and transports the oxygen to cells in all the tissues in the body. Hemoglobin in red blood cells is also responsible for the red color in blood. White blood cells (leukocytes) fight disease and foreign invaders. Platelets (thrombocytes) aid in blood clotting and are involved in repairing damaged blood vessels.

Our bodies have the ability to discriminate between their own cells and molecules (self) and foreign invaders (non-self). The immune system functions to protect our bodies by identifying cells or molecules that are foreign, such as viruses, bacteria, and other parasites. When the immune system recognizes the presence

Figure 8-2. Pie chart showing the distribution of the various components that make up blood.



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Science



Biology

Blood is an important tissue which is responsible for transporting nutrients, water, and oxygen to all of the cells in the body, and transporting carbon dioxide and wastes away from all of the cells in the body. The immune system depends upon the circulating white blood cells to identify and destroy pathogens.

This might also be a good place to discuss the overall importance of blood by asking students if they have heard public service announcements asking people to donate blood.

Science



Biology

In addition to transporting nutrients, water, and oxygen to the cells, blood carries hormones, enzymes, vitamins and minerals to nourish and regulate certain bodily functions.

Science



Biology

Humans could not live without blood. In multi-cellular organisms, blood is responsible for delivering oxygen to all of the body's cells. Blood is also responsible for delivering all of the body's wastes to the appropriate location for disposal. Waste gases, such as carbon dioxide, are delivered to the lungs, where they are exhaled. Other wastes are filtered from the blood in the kidneys, where they are dissolved in water and excreted as urine. Toxins are removed from the blood by the liver. Foreign substances are identified and destroyed through the action of the circulating blood.

Science



Biology

The movement of hormones in the blood enables one organ to control the function of another organ, even though the two organs might be located far apart. In this way, blood acts not just as a means of transportation, but also as a communication system.

Evaluate

To assess students' understanding of the information about blood and DNA, ask them the following questions:

- What part of blood can be used for DNA analysis?
- How long has DNA analysis been possible?
- Why is DNA an important tool for forensic scientists?



of invading foreign molecules, white blood cells, which migrate throughout the body, concentrate in the location of the invading material—whether it is a virus, bacteria, or protein. The white blood cells engulf and digest the invader. Other white blood cells secrete proteins, known as **antibodies**, which assist in the immune response. Because white blood cells are the only type of blood cell that contains a nucleus, they are the only blood cells that can be used as a source of DNA for DNA profiling. Figure 8-3 shows various types of blood cells.

Obj. 8.3 HISTORY OF DNA PROFILING

In 1982, white blood cells were used as a source of DNA by Dr. Alec Jeffreys to produce the first DNA profile. The first legal case involving DNA evidence is described in a novel entitled *The Bloodling* by Joseph Wambaugh. Today, DNA profiling or DNA fingerprinting is widely accepted and is used by such programs as The Innocence Project to help free inmates who have been falsely convicted of crimes (see Chapter 1). The cellular components of blood are shown in Figure 8-4.

Figure 8-3. Types of blood cells.

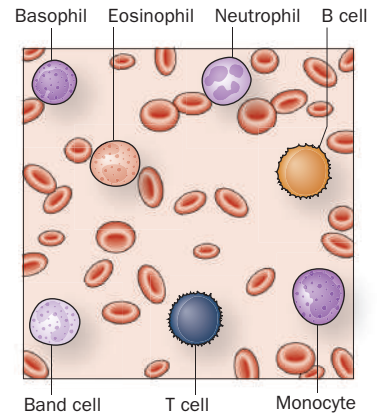



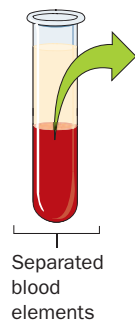


Figure 8-4. The cellular components of blood. (Cells not drawn to scale.)

Cellular elements 45%		
Cell type	Number per μL (mm^3) of blood	Functions
Erythrocytes (red blood cells) 	5–6 million	Transport oxygen and help transport carbon dioxide
Leukocytes (white blood cells) 	5,000–10,000	Defense and immunity
Platelets 	250,000–400,000	Blood clotting



Differentiated Learning

Teaching At-Risk Students

At-risk students will benefit from a brief review of the previous chapter on DNA and DNA profiling.



BLOOD TYPING

Obj. 8.4



Blood typing is less expensive and quicker for analyzing blood evidence than is DNA profiling. Because many different people share the same type, this blood evidence is considered to be class evidence. By typing the blood found at a crime scene, it is possible to link a suspect to a crime scene or to exclude a suspect. However, matching blood types does not prove guilt because many people share the same blood type.

Discovery of Blood Types

In 1900, Karl Landsteiner found that blood from one person did not always freely mix with blood from another person. Instead, clumping might occur, which could result in death. The presence or absence of particular proteins found embedded within the cell or plasma membranes of red blood cells determine a person's blood type. In 1901, Landsteiner described the A and B proteins found on the surface of red blood cells. Other red blood cell proteins, such as the Rh factor, were later identified. The presence or absence of these **cell-surface proteins** gives rise to our present system of blood typing. An antibody reaction test is used to identify each blood type.

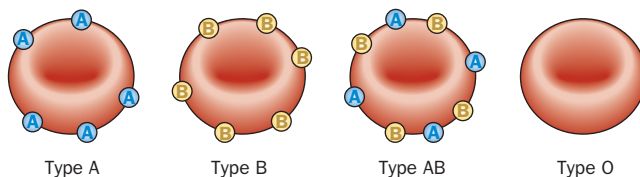
A and B Proteins

A and B proteins are found on the surface of some red blood cells (Figure 8-5). If a person's blood contains only protein A, then he or she has type A blood. If the blood has only protein B, then the person has type B blood. If the person's blood has both the A and the B proteins, then he or she has type AB blood. The blood of some people lacks both the A and the B proteins. This blood type is designated as type O blood.

Four main human blood types using the ABO system and the percentage of the U.S. population with that particular blood type include:

- Type O (43%)
- Type A (42%)
- Type B (12%)
- Type AB (3%)

Figure 8-5. A diagrammatic representation of the cell-surface proteins for the different human ABO blood types.



Rh Factor

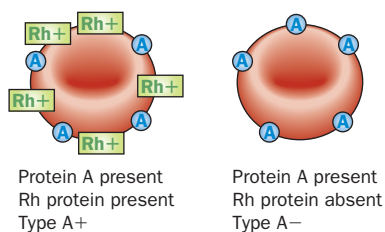
In 1940, Alexander Weiner, working with *Rhesus* monkeys, noticed another type of red cell protein. Eighty-five percent of the human population has a protein called Rh factor on their red blood cells. Blood that has the Rh factor is designated Rh+ (positive), while blood that does not have this factor is designated Rh- (negative) (Figure 8-6).

Naming of Blood Types

A person's blood type is based on the presence or absence of the AB and Rh proteins.

The earliest performed blood transfusions sometimes helped the recipient of the blood, but many times the transfusion killed the person. In the early days of transfusion, doctors were not aware that people have different blood types. The presence of different blood types was not discovered until 1901. When a person receives a blood protein that is foreign to him or her, antibodies will cause the blood to clump and may cause death.

Figure 8-6. Rh factor and ABO blood type examples.



Protein A present
Rh protein present
Type A+

Protein A present
Rh protein absent
Type A-

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Teaching Tip

Many students may not know their own blood types. Encourage students to find out their blood types. Emphasize the importance of knowing your blood type by describing the consequences of receiving a transfusion of the wrong kind of blood. As a class, determine the percentages of students who have each of the four main blood types. How do these percentages compare with the U.S. population?

Evaluate

Help students understand how blood typing is used as evidence by discussing these questions:

- What kind of evidence is a blood type?
- How can a blood type be used to rule out a suspect in a case?
- Is a blood type as precise as a DNA profile? Why or why not?

Science



Biology

Each biological parent contributes one of their two ABO alleles to their child. These genotypes produce these phenotypes (blood types).

Genotype	Blood Type
AA or AO	A
BB or BO	B
AB	AB
OO	O

Science



Biology

- A person with A antigens is type A and can produce antibodies to B antigens.
- A person with B antigens is type B and can produce antibodies to A antigens.
- A person with both antigens is type AB and will not produce any antibodies against the A or B protein.
- A person with none of the antigens is type O and can produce antibodies to both A and B antigens.

Explore

Ask several students to help model antibodies. Have students stand and raise their arms above their head in a Y position to represent an antibody. Ask students to show you their bonding sites (located at the tips of the Y).

Ask another student to enter the room wearing a red cap. This student is considered to be an antigen. When the student with the red cap enters the room, instruct the Y shaped antibodies to surround him or her. Have the antibodies “label” the antigen by placing their hands on the red cap. Note that the antibodies do not destroy the antigen, they merely identify it.

Have another student represent an engulfing white blood cell (phagocyte). Have this student wander around the room. Have the white blood cell notice the antigen surrounded by antibodies. Have it engulf the antigen by putting its arms around the student in the red hat. Explain that the white blood cell will digest the antigen. Have the white blood cell display the red cap. Tell students it does this to alert the other immune cells of the nature of the antigen.

You might want to replay the above scenario. However, this time when the antibodies have identified the red-hatted antigen, have another white blood cell, known as a killer or cytotoxic T-killer cell approach the antigen surrounded with antibodies. The role of the T-killer cell is to secrete digestive enzymes on the antigen. To symbolize this, use a water gun or pipette filled with water. As the killer T cell secretes its enzymes, the antigen is destroyed.

Teaching Tip

Explain to students that there are thousands of binding sites on the surface of a red blood cell.



Antibodies

To help white blood cells identify foreign proteins, B-lymphocytes, specialized type of white blood cells, secrete antibodies. The antibodies are Y-shaped protein molecules that bind to the molecular shape of an **antigen**, fitting like two complementary puzzle pieces. The binding site of the antibody is located on the tip of the Y-shaped molecule (Figures 8-7 and 8-8). The antibody recognizes a foreign substance as an invader and attaches to it.

Figure 8-7. The general structure of an antibody.

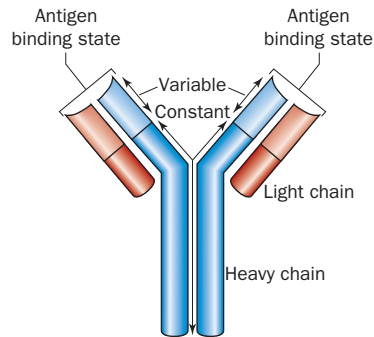
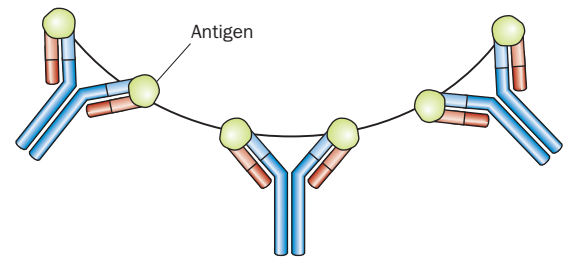


Figure 8-8. The shape of the antibody fits the bonding site on the foreign protein or antigen.



Antigen–Antibody Response

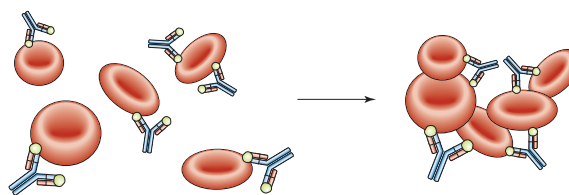
When a foreign invader is recognized by the immune system, an attack is launched against that invader. This is called the **antigen–antibody response**. White blood cells recognize a substance as foreign and try to destroy it. The foreign invaders may be viruses, bacteria, or even the red blood cell proteins from a person with a different blood type.

For example, if a person with type A blood receives a transfusion containing type B blood, foreign type B antigens alert the immune system to the presence of an invader. The body responds in two ways: (1) B lymphocyte makes specific antibodies against that protein; these antibodies are Y-shaped and have specific binding sites that attach to foreign proteins; and (2) phagocytes, a type of white blood cells, engulf the invader.

Agglutination

There are more than 300 known blood group proteins and more than 1 million different protein-binding sites on each red blood cell. Many of these proteins are on the surface of the cell membrane. When one arm of the Y-shaped antibody attaches to the red blood cell, the second arm of the

Figure 8-9. An antibody reaction to surface proteins on red blood cells causes agglutination, or clumping, of the cells.



Y attaches to another red blood cell. The result is **agglutination**, or clumping, of the red blood cells (Figure 8-9).

If this clumping occurs within the circulatory system of a person receiving a blood transfusion, blood could cease to flow. The blood vessels will become obstructed by clumped red blood cells. Without blood circulation,

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Science

Biology



The level of antigens in the blood ebbs and flows with need. They naturally decline over time but rapidly increase following renewed contact with a specific antigen.

the cells of the body cannot receive oxygen or eliminate carbon dioxide, and the person will die.

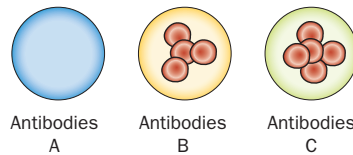
Blood Typing Tests

Blood typing is a way to identify and match blood samples. When a patient needs a blood transfusion, his or her blood needs to be typed to ensure that the transfused blood does not contain any foreign blood proteins. The person's blood is tested for the presence of three red blood cell proteins: A, B, and Rh.

Three separate tests are performed. The patient's blood is mixed with antibodies that bind to the A protein. If the patient's blood clumps or agglutinates, that means that the person's blood contains protein A. If the blood being tested does not react with the antibodies that bind the A protein, then that person's blood does not contain protein A.

Similar testing is done with antibodies to protein B and the Rh factor. If the blood clumps or agglutinates in the presence of these antibodies, it means that those proteins are present in the blood. In the absence of these blood proteins, no clumping will occur (Figure 8-10).

Figure 8-10. Notice that agglutination occurs in only two of the blood tests, indicating that the person has blood type B+ (clumping with anti-B and with anti-Rh antibodies).



Additional Blood Proteins and Probability

Many other blood proteins have been identified. The presence or absence of these proteins is inherited from our parents. In addition to A, B, and Rh protein, people can have M proteins and N proteins.

Approximately 30 percent of the population is pure MM, inheriting a gene for the M protein from each parent. Twenty-two percent of the population is pure NN, inheriting a gene for the N protein from each parent. The remaining 48 percent of the population have MN, inheriting a gene for M from one parent and a gene for N from the other parent (Figure 8-11).



Figure 8-11. A summary of the population percentages having different blood proteins and enzymes in the United States.

ABO			MN			Rh		
Type	Percent	Fraction	Type	Percent	Fraction	Type	Percent	Fraction
A	42%	42/100	MM	30%	30/100	Rh +	85%	85/100
B	12%	12/100	MN	48%	48/100	Rh-	15%	15/100
AB	3%	3/100	NN	22%	22/100			
O	43%	43/100						

Additional enzymes and proteins have been found in the blood, which are important for identification purposes. They include:

1. Phosphoglucomutase (PGM)
2. Adenylate kinase (AK)
3. Adenosine deaminase (ADA)
4. Esterase D (EsD)
5. Glucose-6-phosphate dehydrogenase (G-6-PD)
6. Polymorphic proteins: Group-specific Components (Gc) and haptoglobins (Hp)

Scientists note that antibodies are normally absent at birth. In time, they begin to appear in response to antigens. They are also introduced by immunization with vaccines, or following normal infections.

Science



Math

The M protein is a derivative of an antibody found in unusually large amounts in the blood or urine of patients with multiple myeloma, a form of cancer that arises in plasma cells.

Science



Math

To illustrate how blood types are inherited, show (using a Punnett square) a cross between a mother who has blood type O and a father who has type AB. The mother can contribute only an O allele. The father can contribute either an A or a B allele. So this couple could have children of either blood type A (O from the mother and A from the father) or B (O from the mother and B from the father). Point out that the child would have a probability of 1 in 2 of having type A blood.

Digging Deeper

When new blood proteins are discovered that are prevalent in the general population, a new blood-typing test is developed. Encourage students to research how and why these tests are developed by going to the Gale Forensic Science eCollection at school.cengage.com/forensicscience.

Obj. 8.6 PROBABILITY AND BLOOD TYPES

Given the frequency of different genes within a population, it is possible to determine the probability or chance that a particular blood type will appear within a particular population. To determine the probability of two separate events, it is necessary to multiply their individual probabilities.



Example 1: What is the chance of throwing dice and getting two sixes?

The probability of one die showing a six is $\frac{1}{6}$ (one side out of six).

The probability of the other die showing a six is $\frac{1}{6}$ (one side out of six).

So, the chance of throwing two dice and getting both showing a six is calculated by multiplying the individual probabilities:

$\frac{1}{6} \times \frac{1}{6} = \frac{1}{36}$, or one chance of throwing two sixes out of 36 possible combinations!

Try to estimate the probability that an individual will have a particular blood type. Refer to the preceding charts to determine the individual probability of a particular blood protein. Here are some examples to guide you.

Example 2: What percentage of the population would have A+ blood?

Type A blood = 42% of the population

Rh+ = 85% of the population

Step 1. Convert the percentages to decimals.

Type A blood = 42% = 0.42 of the population

Rh+ = 85% = 0.85 of the population

Step 2. Multiply the decimals.

$0.42 \times 0.85 = 0.357$ of the population should be both A and Rh+.

Step 3. Multiply by 100 to convert the decimal to a percentage.

$0.357 \times 100\% = 35.7\%$ of the population should be both A and Rh+.

Therefore, about 36 out of every 100 people would have Type A+ blood.

Example 3: What percentage of the population would have the following combination of blood-type proteins? Type O-, MN

Step 1. Convert the percentages to decimals.

Type O = 43% = 0.43

Rh- = 15% = 0.15

MN = 48% = 0.48

Step 2. Multiply the decimals.

$0.43 \times 0.15 \times 0.48 = 0.031$

Step 3. Multiply by 100 to convert the decimal to a percentage.

$0.031 \times 100\% = 3.1\%$ of the population are O- MN. Therefore, only 3

out of every 100 people would have Type O- MN blood. This would make the suspect population very small.

By identifying the additional proteins in the blood, we can limit the size of our suspect population and help identify a suspect. For example, analysis of

Digging Deeper

with Forensic Science e-Collection

How are new blood-typing tests developed? What types of new blood-typing tests are being used? How is the accuracy of new blood-typing tests checked? Go to the Gale Forensic Science eCollection on school.cengage.com/forensicscience and enter the search terms "blood typing" and then click on Academic Journals and read about some of the problems and successes associated with new blood-typing tests. Write a brief essay describing your findings, and be sure to cite your resources.



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blood found at a crime scene resulted in data with the following characteristics: Type A, N, Hp-1, Rh-, PGM-2. What is the probability of someone having all of these blood proteins?

The probability of finding another person in the population with the same blood type can be calculated by finding the product of the individual probabilities:

Type A \times N \times Hp-1 \times Rh- \times PGM-2 = occurrence of this combination in the population. Substituting, $0.42 \times 0.22 \times 0.14 \times 0.15 \times 0.06 = 0.000116$, or about 1 in every 8,600 people should have this combination of blood-type proteins. By testing for more blood-type proteins, the probability for uniqueness continues to increase, and the number of other people with the same combination as our suspect decreases.

BLOOD SPATTER

When a wound is inflicted and blood leaves the body, a blood-spatter pattern may be created. A single stain or drop of blood does not constitute a spatter. Instead, a grouping of bloodstains composes a blood-spatter pattern. This pattern can help reconstruct the series of events surrounding a shooting, stabbing, or beating.

HISTORY OF BLOOD-SPATTER ANALYSIS

In 1894, Pitoroski wrote the earliest reference to blood-spatter analysis. In 1939, Balthazard was the first researcher to analyze the meaning of the spatter pattern. In 1955, blood-spatter evidence was used by the defense in the Sam Shepard case, helping to exonerate him. In 1971, Dr. Herbert MacDonnell used blood-spatter analysis as a tool in modern forensic examinations. Today, blood-spatter evidence is used to explain events at a violent scene.

BLOOD-SPATTER ANALYSIS

In the laboratory activities in this chapter, you will study how blood-spatter patterns can be used to recreate a crime scene. Given blood-spatter patterns, it is possible to determine the direction the blood was traveling, the angle of impact, and the point of origin of the blood. Blood-spatter patterns can help determine the manner of death, based on the blood velocity. Instructions on blood-spatter analysis are provided within each activity.

Did you ever wonder why blood forms droplets as it falls from a wound? If blood is a mixture, then why doesn't it separate in the air before it hits the ground or an object? Why does a drop of blood have a curved surface when it lands on a flat surface instead of spreading out flat? The answers to these questions have to do with what happens when the forces of gravity, cohesion, adhesion, and surface tension act on blood.

Recall that blood is a thick mixture of blood cells and plasma. When a person is injured and is bleeding, gravity acts on blood, pulling it downward toward the ground (Figure 8-12). The blood droplet has a tendency to become longer than it is wide as a result of gravity (Figure 8-13). Blood is cohesive. This means that the blood mixture is attracted to similar blood mixtures and tends to stick together and not separate as it falls (Figure 8-14).

Obj. 8.7,
8.8,
and 8.9

Figure 8-12. A falling droplet of blood.



Figure 8-13. The effect of gravity on blood.



Figure 8-14. The cohesive forces in a blood droplet.



Science



Physics

Blood also exhibits the forces of cohesion, adhesion, and surface tension. As a droplet of blood is released from an eyedropper it will be teardrop shaped because of adhesive forces, (Figure 8-12) but as it falls, the droplet's shape becomes spherical because of internal cohesion and surface tension.

Science



Physics

Surface tension is the result of the attraction between like or similar molecules in a substance, such as water molecules being attracted to other water molecules. Water has a relatively high surface tension, which is why some water bugs can seemingly "walk" on top of water.

Science



Physics

Because objects can move in three dimensions, it is important to use Cartesian principles of physics and math when analyzing blood spatter. Cartesian physics, based on the teachings of Rene Descartes, provides mechanistic explanations for natural phenomena. In this case, it applies to the forces acting on the blood. The spatter pattern can give two pieces of information: the direction in which the droplets were traveling and the angle of impact on the surface.

Differentiated Learning



Teaching English-Language Learners

The word *spatter* may be unfamiliar to English-language learners. Help students understand the meaning of spatter by showing them how to make blood spatter patterns with a paintbrush and some washable paint or with a toothbrush and artificial blood.

Differentiated Learning



Teaching At-Risk Students

Have students view a short segment of *CSI* dealing with blood at a crime scene. If students have already viewed a segment, you might stop at critical points and ask them to explain what they see, what the crime scene investigators are doing, and why they are doing it.

Explore

Divide students into small groups. Ask groups to investigate techniques used in early cases in which blood spatter was used in an investigation. Then have the class discuss whether the techniques used have changed over time or remained, more or less, the same.

Teaching Tip

Ask students to investigate cohesion and adhesion by using water droplets and a glass surface such as a glass slide. A water drop will move slowly across a tilted glass slide because of adhesion as the water sticks to the glass. Water will form a rounded drop on a flat surface because of cohesion due to water molecules being attracted to other water molecules. Use a flex cam to project an image of water drops sticking together.

Teaching Tip

Use a water gun filled with colored water or nontoxic, washable paints to recreate blood-spatter patterns. As a class, analyze the patterns left by the water gun. Use a large cardboard refrigerator box to create a corner spatter. Ask students to identify any of the six patterns that Dr. Glaister classified in 1902.

Figure 8-15. Cohesive forces resist droplet flattening.



Figure 8-16.

Note the smaller satellites are not attached to the main drop of blood but have broken free

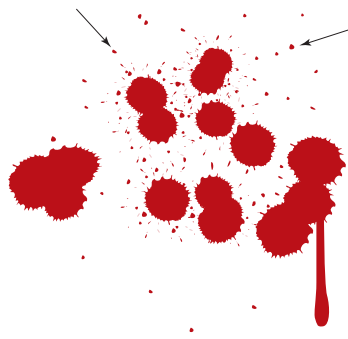
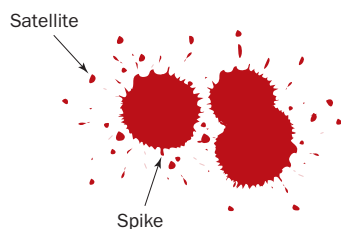


Figure 8-17. Satellites and spikes in a blood drop pattern.



The effect of the downward force of gravity combined with the cohesive force of the blood results in a net effect on the blood droplet as it falls. Thus, the blood maintains a circular or round appearance.

When a drop of blood falls on a flat surface, the blood drop will have a curved surface. The blood drop does not totally flatten out (Figure 8-15). The reason for this shape is the cohesive nature of blood causing the blood to pull together and resist flattening out on a surface. The result is that the surface of the blood is elastic, giving the top of the blood spatter a spherical appearance.

If any of the blood does overcome cohesion and separate from the main droplet of blood, it will form small secondary droplets known as **satellites** (Figure 8-16).

If blood is dropped onto a smooth surface, such as glass or marble, the edge of the blood drop appears smooth and circular. However, if the blood lands on a porous surface, such as wood or ceiling tile, then the edge of the drop of blood may form small spikes or extensions (Figure 8-17). Notice that spikes are still connected to the main droplet of blood, whereas satellites are totally separated.

In 1902, Dr. John Glaister first described the six patterns into which blood spatters could be classified. They include:

1. Blood falling directly to the floor at a 90-degree angle will produce circular drops, with secondary satellites being more produced if the surface hit is textured. This is known as a passive fall.
2. Arterial spurts or gushes typically found on walls or ceilings are caused by the pumping action of the heart.
3. Splashes are shaped like exclamation points. The shape and position of the spatter pattern can help locate the position of the victim at the time of the attack.
4. Smears are left by a bleeding victim depositing blood as he or she touches or brushes against a wall or furniture.
5. Trails of blood can be left by a bleeding victim as he or she moves from one location to another. The droplets could be round or smeared or even appear as spurts.
6. Pools of blood form around a victim who is bleeding heavily and remains in one place. If the bleeding victim moves to another location, there may appear to be droplets or smearing connecting the first location with a second.

The size and shape of blood droplets help identify the direction from which the blood originated. Round droplets, for example, are caused by blood dripping downward at a 90-degree angle. Blood droplets with tails or satellite droplets help us determine the direction from which the blood originated.

Differentiated Learning

Teaching Gifted Students

Gifted students should be challenged to predict what the blood-spatter patterns would look like under certain circumstances. Ask them to create blood-spatter patterns for the following scenarios:

- While slicing onions, the knife slips and cuts a woman's finger. Describe the blood-spatter pattern left as she walks to the bathroom.
- Right before the opposing team hit a fly ball, an outfielder's nose starts to bleed. Describe the blood-spatter patterns left as he runs to catch the ball.



Spatter patterns can help the investigator determine the type of wound. A fine-mist spatter pattern is produced by a high-velocity impact, such as a gunshot wound. A beating with a pipe will produce blood cast off with a lower-velocity pattern. Voids (empty spaces) in the spatter pattern could help determine the presence of a person or object moved after the attack.

By using the spatter pattern to determine the angle of impact of various blood droplets, the examiner can determine the point of impact or convergence, a two-dimensional representation of the location of the victim at the time of the injury.

The **point of origin** can next be determined by the mathematical relationship between the width and length of the blood droplets. These relationships will be addressed in the activities section.

EXAMINATION OF DIRECTIONALITY OF BLOOD

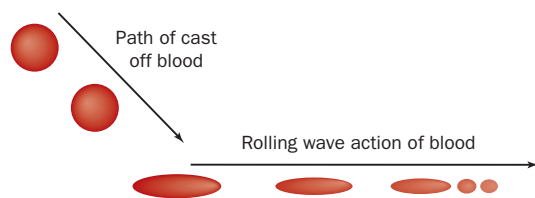
The shape of an individual drop of blood provides clues to the direction from where the blood originated. A circular drop of blood (width and length are equal) indicates that the blood fell straight down (90-degree angle of impact). This is typical if the blood was passively produced (without any force). This would be typical of blood dripping from a wound.

When a blood drop is elongated (longer than it is wide), it is possible to determine the direction the blood was traveling when it struck a surface.

As moving blood strikes a surface, several forces affect the droplet of blood. These forces are cohesion, adhesion, and surface tension. *Cohesion* is a force between two similar substances. *Adhesion* is a force between two unlike surfaces, such as blood and the surface of a wall. *Surface tension* is an elastic characteristic along the outer edge of a liquid caused by the attraction of like molecules.

When blood comes into contact with another surface, the blood tends to adhere or stick to it. As a result, the point of impact may appear to be darker and wider than the rest of the drop of blood spatter (Figure 8-18).

Figure 8-18. Pattern of cast-off blood.

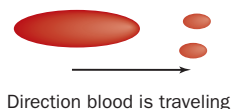


Momentum tends to keep the blood moving in the direction it was traveling. As it travels, some of the blood adheres to the new surface. However, because of cohesion, most of the blood tends to remain as one drop. As blood droplets move away from their source, the blood droplet elongates and may produce a thinner tail-like appearance. The tail points in the direction of blood's movement. Smaller satellite or secondary droplets may break away from the main drop of blood. These satellites will appear in front of the moving droplet of blood (Figure 8-19). Note that satellites are not connected to the main drop of blood.



Perpetrators often try to remove blood evidence from a crime scene. If blood has fallen on a floor, even if the floor is washed hundreds of times, blood can still be detected with Luminol.

Figure 8-19. Satellite drops.



Science



Physics

A number of forces act on the blood droplet as it moves through space. Gravity pulls it downward. The mechanism of injury (gunshot, etc.), the victim's fall, and other forces such as momentum, cohesion, and adhesion also impact the droplet's direction. The shape of the final spatter provides clues for all of these forces.

Science



Physics

To discover the direction of the path of the blood droplet at the instant of impact, investigators recreate the elliptical pattern by dropping "blood" drops from various angles. The direction can be detected by noting which side of the blood droplet seems to taper, creating a "tail." Blood is moving in the direction of the elongated "tail." When the blood first impacts a surface, the spatter tends to be wider and darker than the thinner, elongated "tail."

Differentiated Learning

Teaching At-Risk Students

At-risk students might better comprehend blood-spatter patterns if you practice with simple patterns first. Use the images in the text as guides to draw larger pictures. Have students determine the direction that blood was moving when it created the blood spatter pattern.



Evaluate

Ask students the following questions:

- What four properties of a crime scene can be identified from blood spatter?
- Can blood spatter be used to identify a victim or suspect? Explain your answer.

Science



Physics

Convergence is the point at which all lines come together. Imagine drawing lines from each blood droplet and viewing your work from above. As you look down on your work, you will see the area where all of the lines come together—the convergence point.

Science



Physics

Using the property of convergence, investigators can determine the location of the blood source. Investigators once laid out lengths of string from each stain found at the crime scene. The point where the string intersected—the convergence point—was the location of the blood source. Now investigators use lasers and computers to find the convergence point.

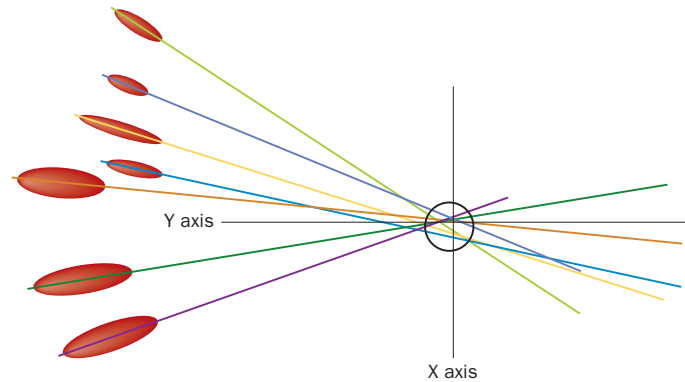
Teaching Tip

Images pictured in Figure 8-21 are not in proportion to actual size.

LINES OF CONVERGENCE

The location of the source of blood can be determined if there are at least two drops of blood spatter. By drawing straight lines down the long axis of the blood spatter and noting where the lines intersect, this will indicate the **lines of convergence** (Figure 8-20). When there are numerous blood spatters, the area where the lines of convergence meet is where the source of blood originated. One can draw a small circle around this intersecting area to note the area of convergence. The circle locates the area of convergence and identifies in a two-dimensional view the location of the source of the blood.

Figure 8-20. Lines of convergence.



BLOOD SPATTER TYPES

Blood spatter may also be classified by its speed or velocity on impacting a surface (Figure 8-21).

Figure 8-21. Table of blood-spatter parameters.

Velocity	Size of Droplets (mm)	Visual Image	Velocity of Blood	Examples of Injuries
High	Less than 1		100 ft/sec.	Gunshot wounds
Medium	1–4		25 ft/sec.	Beating, stabbing
Low	4–6		5 ft/sec.	Blunt object impact

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Science



Physics

The term *velocity*, when used in analyzing blood spatter, does not refer to how fast the blood droplets are traveling. It is a reference to the energy of the object (weapon) transferred to the source of the blood. Using the property of convergence, investigators can determine the location of the blood source based upon the blood spatter evidence. Investigators can lay out lengths of string from each stain found at the crime scene. The point where the strings intersect—the convergence point—is the location of the blood source. This analysis can now be performed by computers.

CRIME-SCENE INVESTIGATION OF BLOOD

Obj. 8.5

In an attempt to hide evidence, a perpetrator may try to remove blood evidence by cleaning the area. Although a room may look perfectly clean and totally free of blood after a thorough washing of the walls and floor, blood evidence still remains. Red blood cells contain hemoglobin, the iron-bearing protein that carries oxygen. To detect hemoglobin, an investigator mixes Luminol powder with hydrogen peroxide in a spray bottle. The mixture is then sprayed on the area to be examined for blood. The iron from the hemoglobin, acting as a catalyst, speeds up the reaction between the peroxide and the Luminol. As the reaction progresses, light is generated for about 30 seconds on the surface of the blood sample.

Luminol can also be used to detect blood in darkened rooms or at night. Even with the most thorough of cleaning, blood residue is difficult to remove. Traces of blood may adhere to surfaces for years, even after cleaning. Luminol works best in an area where an attempt has been made to clean up the blood.

Once found, there are several steps used in processing a bloodstain, and each can provide a different kind of critical information:

1. Confirm the stain is blood.

At a crime scene, clothing is found with a red stain. It appears to be blood, but is it? Could ketchup, ink, or any other red substance cause the red stain? Before trying to collect the blood, it is first necessary to confirm that the evidence is blood. There are two tests:

- Kastle-Meyer test. If blood is present, a dark pink color is produced.
- Leukomalachite green. This chemical undergoes a color change, producing a green color in the presence of blood.

2. Confirm the blood is human.

Someone is accused of leaving the scene of a crime. The police later question the owner of a car that fits the description provided by witnesses. Blood is located under the bumper of the car. When asked about this blood, the owner of the car said he hit a dog a few days ago. To confirm his story, the crime-scene investigators are able to perform tests to determine if the blood came from a human.

One test known as an ELISA test (Enzyme Linked Immunosorbent Assay) involves an antibody-protein reaction. This test is similar to one used in blood typing but uses different antibodies. Human blood is injected into a rabbit or some other animal to produce antibodies against human blood. These antibodies are isolated and stored. When a sample of human blood is mixed with some of these anti-human antibodies produced by the rabbit or other animal, a positive reaction will occur, and the presence of human blood is confirmed.

Digging Deeper

with Forensic Science e-Collection

In what kinds of cases are blood-spatter patterns used? Search the Gale Forensic Science eCollection on school.cengage.com/forensicscience using the terms "spatter" and "case" or "evidence." Find articles about specific cases in which blood spatter played a role in the evidence used to solve the case. Write a brief summary of two of the cases you find, pointing out how the blood-spatter evidence was used and what it showed.



Blood and Blood Spatter 207

Evaluate

Have students answer these questions:

- What steps should be taken when blood is found at a crime scene?
- If the crime scene appears clean, can evidence still be found? Explain.

Science



Chemistry

Luminol is a synthetic compound that has important uses in forensic field investigations. It is extremely sensitive and can detect bloodstains diluted up to 300,000 times. Synthetic chemicals are those that are made in a laboratory. Some synthetic chemicals have the same composition and structure of chemicals found in nature.

Science



Chemistry

Investigators mix Luminol ($C_8H_7O_3N_3$) with hydrogen peroxide (H_2O_2) to detect blood. If blood is present, the hemoglobin and Luminol mixture come into contact. The iron in the hemoglobin accelerates a chemical (oxidation) reaction between the Luminol and the hydrogen peroxide. The Luminol loses nitrogen and hydrogen atoms, and is left in an energized state. As the electrons fall back to a lower energy state, they emit light energy, which is visible or detectable with a fluorescent lamp. This is an example where more energy is found in the reactants than the products. Therefore, energy is released in the form of light.

Evaluate

Ask students to answer this question: Because blood type is class evidence, which type point is the “strongest” evidence? AB because only 3% of the population has that type.

3. Determine blood type.

Blood collected from a crime scene is tested using specific antibodies. The person’s blood type is determined by examining antigen–antibody reactions. Remember, the resulting match is considered class evidence. However, if the blood does not match, then a particular person may be excluded as a suspect. Depending on the circumstances, blood typing may not be done at all, just DNA analysis.

SUMMARY

- Blood consists of cellular components and plasma containing dissolved ions, proteins, and other molecules.
- Blood types result from the presence of proteins on the surface of red blood cells and vary among individual humans. This variation can be used to exclude blood samples from belonging to a group of individuals.
- Other proteins in the blood, such as enzymes, also show variation and can be used as class evidence.
- Combinations of specific blood and enzyme types can narrow the possible source of a blood sample to a fairly small group of individuals.
- Blood-spatter analysis can be used to recreate a crime scene.
- The angle of impact is calculated as the arc sine = width/length.
- The characteristics of blood drops on surfaces can show how the blood was deposited, at what rate the blood was moving, the location of the origin or source of blood, and the direction in which the blood was moving when it struck the surface.
- Crime-scene investigators use several tests to locate and identify blood at a crime scene, including visualization with Luminol and identification with the Kastle-Meyer test.

CASE STUDIES

Ludwig Tessnow (1901)

The dismembered bodies of eight-year-old Hermann and his six-year-old brother, Peter, were found in the woods near their home. Ludwig Tessnow, a local carpenter, was a suspect. Both his clothing and boots had dark stains on them. Tessnow told officials the stains were from wood dye, which he used in his carpentry work.

Three years earlier in Griefswald, similar murders had taken place. Two young girls, ages seven and eight, had been murdered in a similar manner. Their bodily remains had been found in a nearby wooded area. Ludwig Tessnow had been detained for questioning in that murder as well.

A German biologist, Paul Uhlenhuth, developed a test that could be used to differentiate between blood and other types of stains. His test could also discriminate between human and animal blood. The test he developed used an antigen–antibody reaction to test for the presence of human blood.

Uhlenhuth examined the boots and clothing belonging to Tessnow and concluded that the clothing did contain wood dye as Tessnow has claimed. Seventeen spots of human blood were identified, as well as several stains of sheep's blood. Based on this evidence, Tessnow was found guilty and executed at Griefswald Prison.

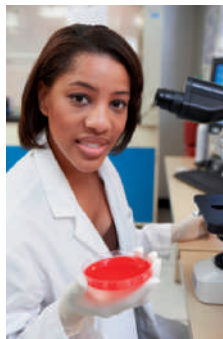
Thomas Zeigler (1975)

On Christmas Eve in 1975, Tommy Zeigler was found shot in his store. His wife, her parents, and a citrus worker were also found dead. Tommy claimed they were all victims of a gang that had attempted to rob the store. Blood evidence was found throughout the store. Herbert MacDonnell, a blood-spatter expert, was called to examine the crime scene. He spent many hours reconstructing the events of the crime scene. Blood-spatter patterns and trajectory velocities helped explain the chain of events leading to each murder. Zeigler was given a life sentence. Zeigler has since filed a request for DNA testing. Judge Whitehead rejected his plea, stating that DNA evidence would not exonerate him from any of the shootings.

Graham Backhouse (1985)

Graham Backhouse was accused of killing his neighbor and attempting to kill his wife to collect his wife's life insurance. Backhouse's wife had been injured in an explosion of a homemade car bomb. Backhouse claimed his neighbor had a grudge against him, and the bomb was really intended for him.

When police arrived at the Backhouse home, the neighbor, Colyn Bedale-Taylor, was found dead from shotgun wounds. Backhouse had sustained wounds to his chest and face. He claimed self-defense. The blood-spatter evidence contradicted Backhouse's statement. The blood spots on the kitchen floor were those made by dripping blood, circular in appearance and not what would have been produced by a violent encounter as Backhouse related. His wounds appeared to be self-inflicted. Chairs and furniture had been overturned on top of the blood spots, indicating a staged crime scene. Backhouse was convicted of the murder of his neighbor and the attempted murder of his wife.



©ERProductions Ltd/Getty Images



©AP Photo/Kristin Murphy

Close

Write the following topics on the board or overhead projector: composition of blood, blood types, blood spatter, point of origin, and directionality. Organize students into five groups and assign each group a topic. Have the groups develop a 3- to 5-minute presentation that reviews the topic for the class.



Think Critically Select one of the Case Studies and imagine you can interview the forensic scientist who studied the blood evidence. Write the questions and answers from the interview. Be sure your questions demonstrate what you have learned about blood and blood-spatter evidence.

CAREERS

Forensic pathologists investigate sudden or unexpected deaths. Pathologists are interested in physical, medical, and chemical causes of death, and may perform many different tests on the tissues and body fluids of those who have died.

CAREERS IN FORENSICS



Michael Baden

Dr. Michael M. Baden is a Board-certified forensic pathologist and medical doctor. After earning a Bachelor of Science degree from the City College of New York, he attended New York University School of Medicine, where he was awarded a medical degree in 1959. He trained in internal medicine and pathology at Bellevue Hospital, and then worked in the Office of the Chief Medical Examiner in New York City from 1961 to 1986, serving as the Chief Medical Examiner from 1978 to 1979. He was also the Deputy Chief Medical Examiner for Suffolk County in New York from 1981 to 1983. Dr. Baden has held professorial appointments at Albert Einstein Medical School, Albany Medical College, New York Law School, and John Jay College of Criminal Justice.

Dr. Michael Baden, forensic pathologist and medical doctor.



©AP Photo/Robyn Beck

Dr. Baden has been a practicing medical examiner for 45 years and has performed more than 20,000 autopsies. He was the chairperson of the Forensic Pathology Panel of the U.S. Congress Select Committee on Assassinations that investigated the deaths of President John F. Kennedy and Dr. Martin Luther King, Jr.

During his career, Dr. Baden has published articles on aspects of forensic medicine in several national and international medical journals. He has also written two nonfiction books, *Unnatural Death*, *Confessions of a Medical Examiner* and *Dead Reckoning, the New Science of Catching Killers*.

Dr. Baden has appeared as an expert in forensic pathology in high-profile cases of national and international interest. He served as an expert witness in the O.J. Simpson trial. Dr. Baden was the forensic pathologist member of a team of U.S. forensic scientists asked by the Russian government to examine the remains of Tsar Nicholas II of Russia and other members of the Romanov family found in Siberia in the 1990s.

In addition to practicing forensic pathology, Dr. Baden has served on the boards of directors of several drug abuse and alcohol abuse treatment programs. Dr. Baden calls himself “a witness for the dead.” Finding spirituality on the autopsy table, he says, “It’s a sacred place, and I always treat a body with the utmost care. I’m not religious, but when I’m looking inside a person’s body, which is the first time a human being has done that, it’s a wondrous thing. And it never fails to convince me that each one of us is a miracle.”



Learn More About It

To learn more about the work of blood-spatter experts, go to school.cengage.com/forensicscience.

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CHAPTER 8 REVIEW

Chapter 8 Review

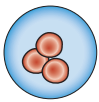
Multiple Choice

- Blood types are determined by the presence of protein located on *Obj. 8.4*
 - all of the blood cells
 - only the white blood cells
 - only on the T-helper cells
 - only on the red blood cells
- Blood proteins that determine blood types are *Obj. 8.4*
 - on the surface of the cell membrane
 - inside of the cytoplasm
 - both on the cell membrane and inside of the cytoplasm
 - found in the bone marrow
- If a person has type A- blood, then they have *Obj. 8.4*
 - only the A protein
 - both the A and the Rh proteins
 - all three blood proteins
 - It is impossible to tell what proteins they have
- If a person has type O+ blood, then they have *Obj. 8.4*
 - the A and the B protein, but lack the Rh protein
 - an O protein but not the Rh protein
 - none of the ABO nor the Rh proteins
 - the Rh protein but not the A or the B proteins
- To determine one's blood type, what is added to the slide? *Obj. 8.4*
 - blood and antibodies
 - only the antibodies
 - luminol
 - none of the above

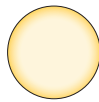
Short Answer

For the following questions, determine the blood type being tested. State if the person is type A, B, AB, or O. Be sure to indicate if the person is Rh+ or Rh- for each blood test shown below.

- Type _____ *Obj. 8.4*



Antibodies A



Antibodies B



Anti-Rh antibodies

Multiple Choice

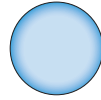
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Short Answer

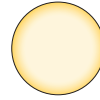
- A+

- 2. 0+
- 3. Sample answer: Sample B most likely came from a gunshot wound because it is diffused and spread out. Sample A most likely came from a blow to the head because it is thick and centered around a single point.
- 4. Sample answer: The velocity with which the blood was dropped may account for the difference of the pattern that resulted.

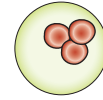
2. Type _____ Obj. 8.4



Antibodies A



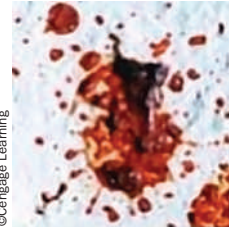
Antibodies B



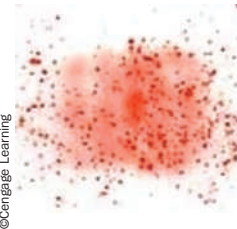
Anti-Rh antibodies

Blood spatter

Refer to the pictures of blood spatter below:

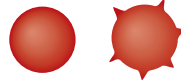


Sample A



Sample B

- 3. Which pattern most likely came from a gunshot and which one was produced from a blow on the head? Explain your answer. Obj. 8.7 and 8.8



- 4. Blood was dropped from a distance of 30 cm. Although the height was the same, two different patterns emerged. How do you account for the difference? Obj. 8.7 and 8.9

5. The following bloodstains were produced by dropping the blood from heights of 6 inches and 12 inches. *Obj. 8.7*



Drop 1



Drop 2

- Which one was dropped from 12 inches: drop 1 or drop 2? _____
- How do you account for the different patterns?

6. Explain how it is possible to tell that this blood was emitted from an artery and not just a cut. *Obj. 8.7*

7. How is it possible to determine the direction of blood flow from blood spatter? *Obj. 8.7*

8. Determine the point of origin for the blood-spatter stains. *Obj. 8.7*

- Use a pencil and a straight edge.
- Draw a circle around the point of origin.



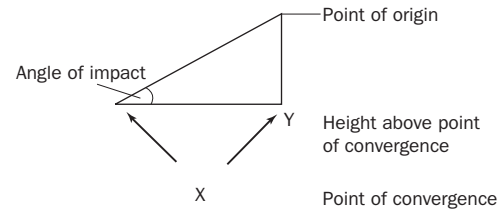
5. a. Drop 2.
 - b. Drop 2 reached a higher velocity before impact, therefore leaving a spatter with more spikes and satellites.
6. Sample answer: Blood emitted from an artery will pulse as the heart pulses, leaving a different pattern than blood from a cut elsewhere on the body. Also, when the ventricles of the heart contract, blood is expelled from the heart under the highest pressure. When the ventricles are filling with blood, no blood is discharged. Blood from an arterial gush will appear to rise and fall. The height of each peak will decrease as the person loses more blood.
7. Sample answer: Blood spatter identifies direction of blood flow because of the shape and location of the marks.
8. Check students' diagrams.

9. Answers will vary.

10. Answers will vary.

9. A crime has been committed. From the blood spatter, it is possible to determine: *Obj. 8.7 and 8.9*

- Angle of impact for a drop of blood.
- Point of convergence for several drops of blood.
- Distance from the point of convergence and a blood drop (X).
- Point of origin, the source of the blood.



10. A prosecuting attorney was given the forensic lab results from the blood-typing activity. She found that the crime-scene blood matched the blood type of one of the suspects' blood. The prosecutor told the jurors that the crime-scene evidence blood matched the defendant's blood type. She further stated that this evidence proved that the suspect was indeed the perpetrator of the crime. *Obj. 8.4, 8.6, and 8.9*

You are the defendant's attorney. How would you respond to the prosecutor's argument that because the blood types matched, then the defendant is proven to be guilty of the crime?

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- <http://www.practicalhomicide.com/bio/bioBADEN.htm>
- http://www.shsu.edu/~chm_tgc/JPPdir/JPP1999
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ACTIVITY 8-1

Background

This activity gives students an opportunity to determine the presence of blood in a stain. Students use reagents to test a bloodstain, a nonblood stain, and an unknown stain.

Safety Precautions

1. Emphasize to students that all procedures should be done while wearing protective gloves.
2. Dispose of all samples in the biohazard container provided.



ACTIVITY 8-1 Ch. Obj. 8.4 and 8.5

A PRESUMPTIVE TEST FOR BLOOD

Objective:

By the end of this activity, you will be able to:

Use the Kastle-Meyer Presumptive Blood Test to determine if a given stain contains blood.

Scenario:

At dusk, a young man was seen riding his bicycle along the narrow, winding road that encircled a lake. On that same quiet road, an animated young couple was seen speeding around the many turns in the road. They were in a hurry to arrive at a friend's party at the lake. In his haste, the driver of the car lost control of the car while trying to swerve to avoid the young man on the bike. Unfortunately, the biker was hit from behind, causing him to be knocked off his bike and to fall down the hill toward the lake. The young driver of the car panicked and, without looking back, fled the scene of the crime. Although somewhat injured, the biker was able to provide a description of the car to the police.

Later that evening, the police arrived at the party on the lake to question the owner of the car. Although there was no visible blood on the car, the police did find a red stain on the car's bumper. At first the young driver said it was red paint or perhaps the blood from a squirrel he had struck the day before. Is the stain blood or paint? If it is blood, is it possible to distinguish human blood from animal blood? In this activity you will perform tests that confirm the presence of blood.

Time Required to Complete Activity: 45 minutes

Materials:

Activity Sheets for Activity 8-1
ketchup (1 oz or 10 ml)
blood from animal source (1 oz or 10 ml)
cloth or shirt with dime-sized blood stain
cloth or shirt with dime-sized ketchup stain
20 mL 3% hydrogen peroxide solution in dropper bottle
20 mL 95% ethyl alcohol in dropper bottle
20 mL distilled water in dropper bottle
20 mL 2% phenolphthalein solution in dropper bottle
biohazard container
latex or nitrile gloves

Safety Precautions:

Wear protective gloves.

Dispose of all samples in a biohazard container provided.

Assume that all red solutions are blood and handle according to safety regulations.

All procedures should be done while wearing protective gloves.
Do not contaminate any of the reagents.
Be sure to drop the solutions onto the cotton swab without touching the cotton swab.
Return the caps of all reagent bottles to the correct reagent bottle. Do not switch the caps from one bottle to the other.



Background:

Dried drops of red fluid found on a murder weapon, clothing, or automobile are noted, photographed, and analyzed. Did blood cause the red stain? If the red stain is not blood, then valuable time and money can be saved by not sending the red stain in to the laboratory for further testing. If it is determined that the red stain is blood, then further testing needs to be ordered to identify the source of the blood as human or animal.

A sample of the stain is tested using a presumptive chemical reagent. The Kastle-Meyer test is a catalytic color test that will produce a color change in the presence of blood. When phenolphthalein and hydrogen peroxide react with heme (iron) molecules in hemoglobin, the presence of blood is indicated by a pink color. A negative Kastle-Meyer test indicates the absence of blood. Because animal blood also contains heme molecules, it will also give a positive result. If animal blood is present and pertinent to the case, then additional tests can be performed to determine what type of animal blood is present.

Procedure:

1. Obtain a section of cloth that contains a known bloodstain (positive control). Before testing any unknown stains, it is important to check all reagents on a known sample of blood. If you do not get the expected results on blood, then you know that your reagents were malfunctioning and you need to replace them.
2. Wet a cotton swab with four drops of distilled water and gently rub the wet swab on the known bloodstain.
3. Drop two drops of ethyl alcohol onto the swab (don't allow the dropper to touch the swab).
4. Drop two drops of the phenolphthalein solution onto the swab (don't allow the dropper to touch the swab).
5. Drop two drops of the hydrogen peroxide onto the swab (don't allow the dropper to touch the swab).
6. A positive pink color will appear within seconds if blood is present. Record your results in Data Table 1. (This is your positive control demonstrating what happens when blood is present.)
7. Using a permanent marker, record your initials next to the stain that was just tested.
8. Dispose of all used cotton swabs and bloodstain samples into the Biohazard Waste container.
9. Using clean cotton swabs, repeat steps 1 to 8 using the shirt containing the ketchup stain. (This is your negative control since ketchup is not blood.)
10. Record the appearance of the ketchup test in Data Table 1.

Procedures

1. Print, copy, and distribute Activity Sheet 8-1 from the IRCD.
2. Make sure there are no state or county regulations prohibiting the use of animal blood in high school laboratories.
3. Make sure blood is obtained from a reputable supply company and the blood is sterile.
4. Before beginning the activity, demonstrate the correct procedure for testing a reagent without contaminating the solution.
5. Use universal precautions—treat all blood as if it is a source of blood-borne pathogens.
6. Use cotton swabs to test stains with reagents.
7. Have the students put their initials on stains so they can identify theirs.
8. Record observations in the table.

Answers

Check students' Data Table 1.

1. Sample answers (Data Table 2):

- Distilled water—Used to help dissolve blood from the stained fabric.
- Ethyl alcohol—"Cleans" the area so that hemoglobin is more exposed.
- Phenolphthalein—Serves as the reducing agent, oxidized phenolphthalein turns pink.
- Hydrogen peroxide—Substrate for the peroxidase-like chemicals found in hemoglobin.

2. Sample answers:

- A positive control is used to verify that all chemical reagents are functioning in the expected manner. If the expected color change does not occur using the positive control, then new reagents are needed before testing any unknowns.
- A negative control is used to verify that a pink color will not result when using these reagents. If a pink color is produced with the negative control, you need to get new reagents or reexamine your technique. There could be some contamination of your reagents.

3. Sample answer: Pink color should only become visible after adding the hydrogen peroxide. If the pink color appears after adding the phenolphthalein, something is wrong. A new test should be performed. Recall that the pink color occurs after the oxygen is released from the hydrogen peroxide. It is the heme molecule that acts as the peroxidase, causing the hydrogen peroxide to break down.

- With fresh cotton swabs, repeat steps 1 to 8 on the section of the shirt containing the unknown stain 1.
- Using fresh cotton swabs, repeat steps 1 to 8 on the section of the shirt containing the unknown stain 2.

Data Table 1: Table of Test Results

Stains	Color Pink or not pink?	Describe Your Observations Is it blood or not blood?
Blood stain (positive control)		
Ketchup (negative control)		
Unknown 1		
Unknown 2		

Questions:

- Complete the following Data Table indicating the role or function of each of the chemical reagents used in this experiment.

Data Table 2: The Role of Chemical Reagents in Blood Sample Analysis

Chemical	Function
1. Distilled water	
2. Ethyl alcohol	
3. Phenolphthalein	
4. Hydrogen peroxide	

- Explain why you need to use both a positive and negative control before testing the unknown stains:
 - Positive control
 - Negative control
- Should the pink color first be evident:
 - when applying the phenolphthalein to the cotton swab?
 - when applying the hydrogen peroxide to the cotton swab?Explain your answers.

4. If animal blood is different from human blood, how is it possible to get a positive reaction with the Kastle-Meyer test using dog blood?
5. List two types of substances that might produce a false-positive test when performing the Kastle-Meyer test for the presence of blood.
 - a. Substance 1 _____
 - b. Substance 2 _____
6. Why is it important to use a cotton swab when doing this test?
7. Why aren't the reagents applied directly to the original bloodstain?
8. Suppose that a red stain was found in a bathtub along with some bathwater. Would it be possible to detect the blood since it might have been diluted? Explain your answer.



Further Research:

1. Research the history of using this method as a presumptive blood test. Investigate the role of each of these scientists:
 - a. Louis-Jacques Thenard
 - b. Christian Freidrich Schonbein
 - c. Dr. Kastle
 - d. Dr. Meyer
2. Research how to distinguish dog blood from human blood.
3. Investigate the presumptive test for the presence of semen. Describe how this test is performed.
4. If a man has had a vasectomy, how will this affect the results of tests to detect semen? Explain.
5. Research each of the following cases. Explain the role of blood analysis in helping to solve the crime.
 - a. Peter Porco case (2006)
 - b. O.J. Simpson case (1994)

4. Sample answer: The Kastle-Meyer test detects the presence of heme (or iron) found in hemoglobin of the blood. Both dogs and humans have hemoglobin in their blood. Therefore, both dog and human blood will produce a positive reaction using the Kastle-Meyer test.
5. Sample answers: Raw vegetables, such as potatoes, beets, and horseradish, contain peroxidases. Animal blood will also produce a positive reaction using the Kastle-Meyer test.
6. Sample answer: It is important to use a cotton swab to preserve the evidence and avoid any contamination of the original piece of evidence. The bloody fabric may need to be reexamined at a later date. Therefore, avoid adding anything to the original stained fabric.
7. Sample answer: Adding reagents directly to the original bloodstain will cause a chemical reaction that would permanently change the composition of the stain, making further testing impossible.
8. Sample answer: The Kastle-Meyer blood test is sensitive to dilutions of one part blood to 10,000 parts water. If the dilution of the blood does not exceed this level, then the blood could indicate a positive reaction. The more diluted the blood, the lighter the reaction color.

Further Research and Extensions

1. Louis-Jacques Thenard discovered hydrogen peroxide in 1818. Christian Freidrich Schonbein developed one of the first presumptive tests in 1863. Dr. Kastle developed a presumptive test for hemoglobin using phenolphthalein in the early 1900s. Dr. Meyer later refined and improved on Dr. Kastle's test.
2. To determine if blood is human or from some other animal, a precipitin test is performed. Essentially, this test uses an antigen-antibody response. This test was developed in Germany in 1901 by Paul Uhlenhuth. To determine if the blood is human, it is necessary to produce antihuman antibodies. Injecting some human blood into an animal (e.g., a rabbit) does this. When human blood is injected into the rabbit, the rabbit produces antihuman antibodies or antiserum. Have students study these scientists and their contributions.

ACTIVITY 8-2

Background

In this activity, students have an opportunity to perform a simulated blood test using artificial blood. Students use blood serums and microscopes to determine blood types.

Safety Precautions

1. Handle the artificial blood as if it were actual human blood.
2. If any blood spills, it must be cleaned using a 10 percent Clorox solution.
3. The wastes must be placed in a container labeled “Biological Wastes” for disposal.
4. Gloves should be worn to reinforce the need for proper technique.
5. If a student is allergic to latex, substitute a different type of glove, such as nitrile.
6. Caution students that bleach can cause skin and eye irritation and can remove color from fabric immediately. Teachers should check with custodial staff to make sure a bleach solution will not react with any other cleaning products that may have been used on surfaces in the classroom.



ACTIVITY 8-2 Ch. Obj. 8.3 and 8.4 BLOOD TYPING

Objectives:

By the end of this activity, you will be able to:

1. Perform a simulated blood test.
2. Describe the procedure for testing blood.
3. Analyze different blood tests to determine the blood type of a suspect.
4. Describe how blood test results are used to determine if an individual is linked to crime-scene blood evidence.
5. Describe agglutination of red blood cells.
6. Describe the protein–antibody reaction that occurs when typing blood.
7. Describe the role of blood typing in forensics.

Time Required to Complete Activity: 45 minutes

Materials:

(per group of three students)

Activity Sheets for Activity 8-2

Ward’s Natural Science Kit 360021 or similar artificial blood-typing kit that includes:

- simulated human blood types
- antibodies for testing type A, B and Rh blood
- plastic blood testing slides each containing three wells
- plastic or paper cup labeled “Biological Waste”
- 10% bleach solution in spray bottle
- paper towels
- latex or nitrile gloves
- marking pen
- red pencil or marker
- toothpicks

Safety Precautions:

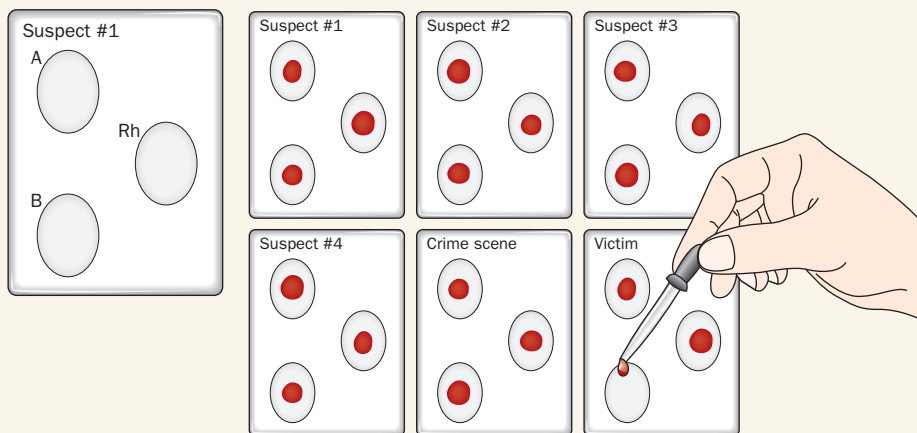
Handle artificial blood as if it were actual human blood to practice lab safety techniques. Any blood spills must be cleaned using a 10-percent bleach solution. Dispose of all waste in a container labeled “Biological Waste.” Wear disposable gloves. If a student is allergic to latex, substitute a different type of glove, such as nitrile. Students should be careful to avoid spilling any bleach on themselves or on their clothing. Bleach can cause skin and eye irritation and can remove color from fabric immediately.

Background:

Blood typing is a common tool used to solve crimes. It may allow the examiner to match or exclude a suspect from a crime scene. To detect the presence of blood proteins, you will add specific antibodies to individual drops of blood and determine whether clumping (agglutination) occurs.

Procedure:

1. Obtain six clean plastic three-well slides.
2. Place the slides on a clean, white sheet of paper.
3. Write the name of the blood donor in the top left-hand corner of the plastic slide. On the clean white paper, write the name of the blood donor above the slide.
4. Put on your gloves for the rest of the procedure.
5. Add two drops of blood to each of the three wells of the slide labeled Suspect 1.
6. Repeat the process for each of the Suspects 2, 3, 4, Crime Scene, and the Victim slide.
7. Add two drops of Anti-A serum (blue bottle) to each of the six wells labeled A.
8. Add two drops of Anti-B serum (yellow bottle) to each of the six wells labeled B.
9. Add two drops of Anti-Rh serum to each of the six wells labeled Rh.
10. Gently rock each slide back and forth and up and down. (Do not let the blood from one well contaminate the blood from another well!) You can also use a toothpick to help mix the contents. A new toothpick must be used in each of the wells. You will need 18 toothpicks. Stir gently to avoid scratching the plastic wells.
11. Wait five minutes to allow reactions to occur.
12. Observe the blood samples. When using this artificial blood:
 - a. A cloudy, opaque, or goopy mixture is a positive reaction indicating the presence of a blood-type protein.
 - b. A clear mixture is a negative reaction indicating the absence of a blood-type protein.Note: Placing each slide on an overhead projector may help in examining the reactions.

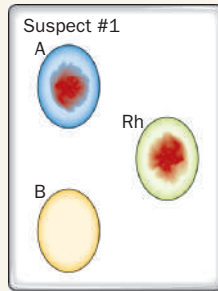
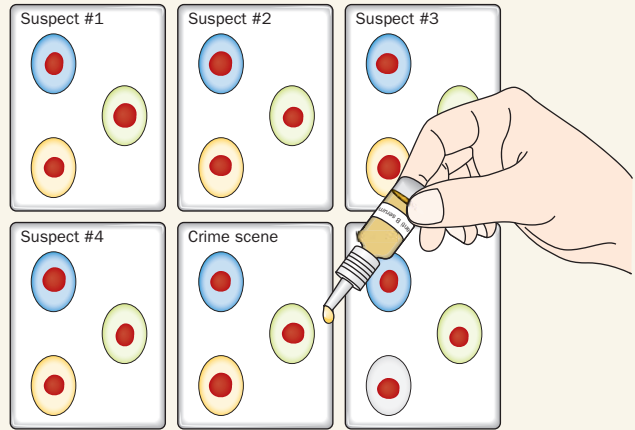
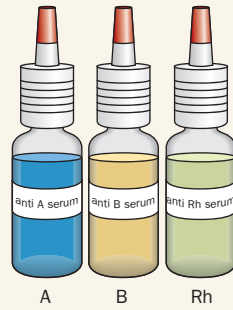


Procedures

1. Print, copy, and distribute Activity Sheet 8-2 from the IRCD.
2. Rocking the plastic slides will facilitate the reactions and is preferable over using toothpicks to mix the slide contents. If students press the toothpicks too hard, they can scratch the plastic slides.
3. To observe the reactions better, have students observe plastic well slides against a white sheet of paper or on the overhead projector. Allow several minutes for the reaction to occur before recording your results.
4. Plastic well slides can be soaked immediately after use, and then washed and reused.
5. The refill kit can be purchased for minimal cost.
6. This activity does not produce real biologically hazardous waste, but to stress good techniques, encourage students to use gloves and a waste container.



13. Record your data on Figure 1. Include the suspect's name and blood type.



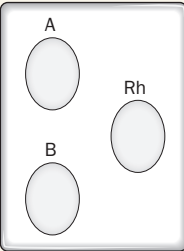
Type A+

14. For a positive reaction (indicating the presence of the blood-type protein), shade in the circle using a red-colored pencil or marker. If the blood test is negative, indicating the absence of blood-type protein, leave the circle empty.
15. Dispose of all typing materials in the "Biological Waste" container provided by your instructor.

Blood Results:

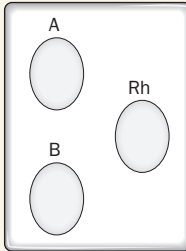
1. To indicate a positive reaction (protein present), use a red pencil or marker to shade in the well.
2. To indicate a negative reaction (no protein), leave the well blank.
3. Label each reaction slide with the blood type.

Suspect #1



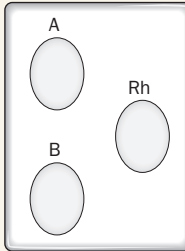
Blood type of:
Suspect #1 _____

Suspect #2



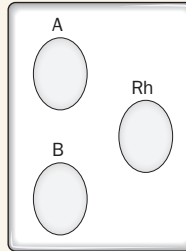
Suspect #2 _____

Suspect #3



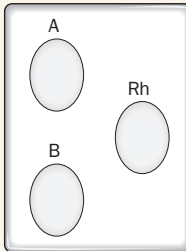
Suspect #3 _____

Suspect #4



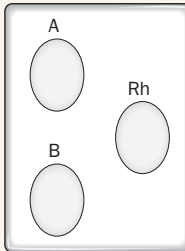
Suspect #4 _____

Crime scene



Crime scene _____

Victim



Victim _____

Questions:

1. Why is simulated (man-made) blood instead of real human blood used in this activity?
2. Explain why it is necessary to type the victim's blood when trying to determine if any of the blood found at the crime scene belongs to a particular suspect.
3. In this lab activity, how many different blood-type proteins were examined?
4. List all of the blood-type proteins examined in this activity.
5. Is it possible to exclude any of the suspects based on blood types? Explain your answer.
6. Based on your results, does the crime-scene blood match the blood type of any of the four suspects? Explain your answer.
7. If blood from one of the suspects matches the crime-scene blood, does that prove that the suspect is guilty? Explain your answer.
8. Poor laboratory techniques may lead to erroneous results that could impact the outcome of a trial. Describe some examples of poor laboratory techniques involved in a blood-typing analysis that might produce erroneous results.
9. Explain why identifying the blood type found in both the suspect and at a crime scene as AB⁻ provides a higher degree of probability of a match than if the blood type found in the suspect and at the crime scene is O⁺.
10. Explain why white blood cells are not used in blood typing.

Answers

Check the results of students' blood-typing tests.

1. Sample answer: For health reasons (e.g., AIDS, hepatitis), body fluids are not used in student activities. Many states mandate that body fluids cannot be used in high school laboratories.
2. Sample answer: The victim's blood needs to be excluded from the crime-scene evidence. If the victim's blood and the crime-scene blood are the same type, further testing would be needed.
3. 3
4. A, B, and Rh
5. If the blood type of a suspect differs from the crime-scene evidence, then that suspect may be excluded.
6. Results will vary.
7. Sample answer: This is not conclusive evidence because other people could have a similar blood type. If eyewitness accounts place the suspect at the crime scene, it does reinforce the case against him. If sufficient blood were available for a DNA analysis, this would further reinforce his presence at the crime scene.
8. Sample answer: Samples could become contaminated. Testing materials could become contaminated. Not enough time was allowed for a reaction to occur before recording the results.
9. Students should note that type AB is much rarer than type O. Type AB⁻ blood is the rarest blood type, while O⁺ is the most common. Therefore, finding AB⁻ blood at the scene of a crime provides a higher degree of probability that a suspect with that blood type was, in fact, at the scene.

10. Students should state that the blood proteins are associated with the red blood cells and plasma but not the white cells. White blood cells are not used to type blood because the antigens for blood type are embedded in the cell membrane of red blood cells.



Further Research:

1. Research cases of innocent people who were convicted as a result of laboratory errors. (Refer to The Innocence Project, www.innocenceproject.org)
2. Research what other blood-type proteins are used in blood typing in addition to the A, B, and Rh proteins.
3. Research information on protein and antibodies. Explain why the red blood cells clump, or agglutinate, when mixed with certain antibodies.
4. Investigate the predominant blood type found in each ethnic group:
 - a. European
 - b. Asian
 - c. African

Math Connection:

1. Explain how the laws of probability are used in determining the probability that a particular person's blood will match the blood found at a crime scene.
2. If blood is found at a crime scene, describe what testing is done to determine if the blood is human blood or not human blood.
3. Research how it is possible to determine blood types from other body cells such as cheek cells or skin cells. (Hint: research secretors and non-secretors)
4. Paternity cases: If a man is the biological father of a child, he has a moral and a legal obligation to provide child support for at least the first 18 years of the child's life.

Explain how blood typing can exonerate a man from paternity, but explain why it alone cannot determine paternity.
5. Investigate the role Rhesus monkeys played in the research involving the Rh protein.

Further Research and Extensions

Have interested students research answers to the following questions:

- How many known blood proteins are present in the general population?
- Is it necessary to have a complete match between all blood proteins for a successful blood transfusion?

ACTIVITY 8-3 Ch. Obj. 8.7 and 8.9

BLOOD-SPATTER ANALYSIS: EFFECT OF HEIGHT ON BLOOD DROPS



Scenario:

The police examined the blood spatter at a crime scene. From the size of the droplets, it appeared that the blood had passively dripped as the injured person walked across the floor. The person may have experienced a second injury, because two different patterns of blood spatter appeared halfway across the room. The second injury seemed to be from a source higher up on the person's body.

By examining the size and shape of blood spatter, forensic scientists are able to reconstruct a crime. A partial story of the crime emerges as the blood-spatter analysis starts to "tell the story."

In this activity, you will experiment with dropping artificial blood from different heights, and you will make observations about the effect of height on blood spatter.

Objectives:

By the end of this activity, you will be able to:

1. Prepare reference cards of blood spatter produced from varying heights.
2. Compare and contrast the blood spatter produced from different heights.
3. Distinguish between the blood spatter formed at the point of contact with satellite blood droplets.
4. Distinguish between satellite droplets and spike-like formations of blood droplets.
5. Form a hypothesis about the effect of height on the size and shape of blood-spatter droplets.

Time Required to Complete Activity:

Two 45-minute class periods (one period to do the blood drop, the second period to measure the blood drops)

Materials:

(per group of four students)
2 dropper bottles of simulated blood
12 five-by-eight-inch index cards
4 meter sticks
4 six-inch rulers showing cm or four calipers
newspapers

Safety Precautions:

Cover the floor in the work area with newspaper.
Simulated blood may stain clothing.

ACTIVITY 8-3

Background

In this activity, students will study the effect of height on blood spatter patterns.

Safety Precautions

1. Cover the floor in the work area with newspaper.
Simulated blood may stain clothing.
2. Treat all waste as biological and dispose of it accordingly.

Procedures

1. Print, copy, and distribute Activity Sheet 8-3 from the IRCD.
2. Recipe for simulated blood: red food coloring, glycerin (or Karo syrup), and water. Also, adding a little melted chocolate and white glue makes it appear more realistic.
3. You may wish to have student teams of four divide into pairs to measure the heights for the blood drops. One group of two students could drop blood from heights of 25, 50, and 100 cm, and the other pair within the group could drop blood from heights of 150, 200, and 250 cm.
4. Using a disposable pipette, dispense one to three drops of blood from various heights: 25, 50, 100, 150, 200, and 250 cm. Make sure students avoid dropping one drop of blood on top of another drop of blood.
5. Use separate cards for each height.
6. Have students label cards with their initials and height before dropping blood on them. Let them dry for at least 30 minutes (if possible). The cards must be dry before moving them, otherwise the blood will run.
7. Use lots of newspaper. The floor may become stained if not enough paper is used to cover it. If weather permits, this is a good activity to do outside. Avoid wind!
8. Have each team designate at least one team member to oversee that drops are dispensed from the correct height.
9. Do not rush students—provide extra 5×8 cards as necessary.



Background:

A blood-spatter pattern is created when a wound is inflicted and blood leaves the body. This pattern can help reconstruct the series of crime-scene events surrounding a shooting, stabbing, or beating. Recall that blood forms droplets as it falls from a wound. A drop of blood that falls on a flat surface will not totally flatten out—the blood drop will have a curved surface. The reason for this shape is the cohesive nature of blood. Blood tends to pull together because of cohesion and resist flattening out on a surface. The result is that the surface of the blood is elastic, giving the top of the blood spatter a spherical appearance.

If any of the blood does overcome cohesion and separates from the main droplet of blood, it will form small secondary droplets known as **satellites**.

If blood is dropped onto a smooth surface, such as glass or marble, the edge of the drop of blood appears smooth and circular. However, if the blood lands on a porous surface, such as wood or ceiling tile, then the edge of the drop of blood may form small **spikes** or extensions. Notice that spikes are still connected to the main droplet of blood, whereas satellites are totally separated.

As you compare the blood dropped from various heights, note which height causes blood to form more satellites.

Procedure:

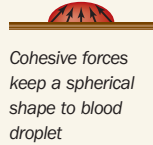
Part A: Preparation of blood-spatter reference cards for blood dropped from different heights

1. Spread newspaper on the floor of the work area.
2. You will prepare two 5×8 cards for each height used in the blood drop.
3. Label the top-right corner of each card with the height of the blood drop and your initials.
4. Place 12 labeled 5×8 index cards on the newspaper.
5. Use a meter stick to help you measure the distance above the card.
6. With the help of your partners holding a meter stick vertically for measurement, squeeze out one drop of simulated blood from a height of 25 cm onto one of the index cards. Hold your hand steady and slowly release the one drop of blood. Aim toward the top of the card.
7. Repeat this process preparing a second card held at 25 cm.
8. Repeat this process for dropping blood for heights of 50,

Your initials and height of blood drop

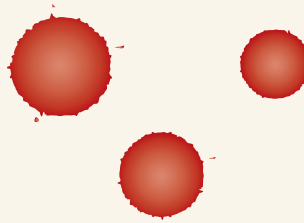
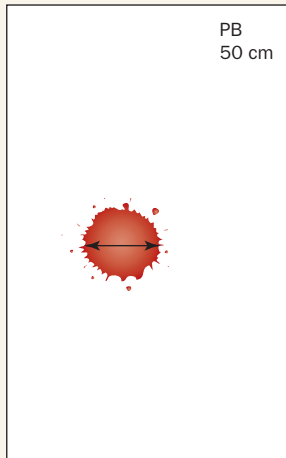
PB
25 cm

10. Droplets of simulated blood will probably not dry for several days. Do not stack the spatter cards.



100, 150, 200, and 250 cm. Remember to prepare two cards for each height.

9. Allow index cards to dry. Do not move the cards until they are dry (at least 20 minutes). When you do move the cards, do not turn them on their sides, because the blood will be affected by gravity.
10. Measure the diameter of each of the spatter patterns and record the data in Table 1. Take your measurements at the widest part of the main drop. Do not include the satellites or spikes within your measurement.



Blood dropped from various heights

11. Determine the average diameter for the blood spatter for each height, and record it in the Data Table.
12. Prepare a bar graph or histogram comparing the effect of height on the average diameter of the blood drop. Your graph should contain title, labeled x-axis and y-axis and an appropriate scale.

Data Table: Effect of Height on Diameter of Blood Drop

Height of drop (cm)	Diameter of drop (cm)	Diameter of drop (cm)	Average diameter (cm)
25			
50			
100			
150			
200			
250			

Answers

Check students' data tables.

1. Yes. See data table.
2. False. See data table.
3. The outer edges of the blood dropped from 250 cm have more spikes and more satellites.
4. Yes, the greater the height from which the blood was dropped, the larger the number of satellites. However, the size of the blood drop will not enlarge after a distance of 7 feet or 200 cm. See data table.
5. Answers will vary depending on the results of the class.



Questions:

1. Is there a relationship between the height from which the blood is dropped and the size of the blood-spatter droplets? Support your answer with data.
2. True or False: As the height from which the blood is dropped increases, the size of the blood spatter continues to increase. Support your answer with data.
3. Blood is dropped from heights of 25 cm and 250 cm. Compare and contrast the outer edges of blood droplets produced from these two heights.
4. Examine the blood spatter produced by dropping blood from the six different heights. Is there a relationship between the height from which the blood is dropped and the number of satellites produced? Support your answer with data.
5. Compare your results with your classmates.
 - a. Were your results similar to those of your classmates? If not, how did they differ?
 - b. If someone accidentally dropped two or more drops of blood in the same location, what effect would it have on the blood-spatter pattern?

Further Study:

A drop of blood will continue to pick up speed until it reaches its terminal velocity.

1. What is terminal velocity?
2. What factors affect the terminal velocity of a substance?
3. What is the terminal velocity of blood?
4. How far does blood need to fall until it reaches its terminal velocity?

You may also research blood-spatter patterns at these Web sites:

www.bloodspatter.com/bloodspatter.pdf

www.crimelibrary.com/criminal_mind/forensics/serology/8.html

Further Research and Extensions

Students may want to find out if terminal velocity varies from substance to substance. Encourage interested students to design and perform an experiment to verify the information.

ACTIVITY 8-4 Ch. Obj. 8.4, 8.5, 8.6, 8.7, 8.8, and 8.9

BLOOD-SPATTER IMPACT ANGLE



Scenario:

Two police officers walk into a neighborhood convenience store. They soon realize that no one is inside the store. They discover a series of blood-spatter patterns on the walls and ceiling. “What happened here?” says one officer as she walks around the store. The officers call in the situation, and a forensics team is dispatched to the scene. Forensic scientists will investigate the crime scene and seek answers for the questions listed below:

- Whose blood is this?
- Does it belong to just one or several people?
- How many people were injured?
- If more than one person was injured, is it possible to tell who was injured first?
- What type of injury caused the blood loss?
- What type of weapon caused the injury?
- If the weapon was a gun, from which direction was the bullet fired? Did the shooter point the gun upward, downward, or straight ahead?
- In what direction(s) did the injured person move?

Objectives:

By the end of this activity, you will be able to:

1. Create blood-spatter patterns from different angles of impact.
2. Examine the relationship between angle of impact and blood-spatter patterns.
3. Calculate the angle of impact from blood-spatter patterns.

Time Required to Complete Activity:

Two 45-minute class periods

First period: create blood-spatter patterns from different angles

Second period: measure blood spatter and calculate angle of impact

Materials:

(per group of four students)
Activity Sheets for Activity 8-4
1 dropper bottle of simulated blood
4 five-by-eight-inch index cards
2 meter sticks
newspapers
2 clipboards
1 protractor
1 roll masking or drafting tape

Safety Precautions:

Cover the floor in the work area with newspaper.

Simulated blood may stain clothing and furniture, so care should be taken to avoid spilling blood.

ACTIVITY 8-4

Background

In this activity, students will create and examine blood spatter from different angles of impact. Students use simulated blood to make spatters from different angles for observation and conclusions.

Safety Precautions

Cover the floor in the work area with newspaper. Simulated blood may stain clothing.

Procedures

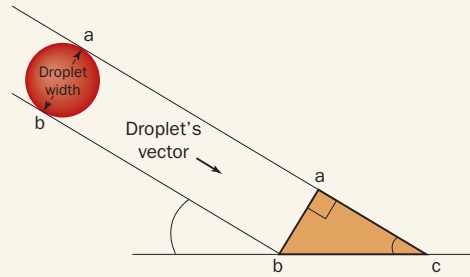
1. Print, copy, and distribute Activity Sheet 8-4 from the IRCD.
2. 30 cm is the distance to the impact point on the card, not the floor.
3. Try not to hit the same place twice.
4. Use a new card for each new angle.
5. Use two clipboards (if available) so one card can be drying while placing drops on the next.
6. Obtain a paper towel and wipe the bottle mouth before dropping liquid.
7. Be sure to allow each card to dry at least 30 minutes before removing it from the clipboard.
8. Label each card with an arrow pointing in the direction the drop is falling. If unsure, turn the card over and notice where bleeding through has occurred. This is the bottom of the drop.



Background:

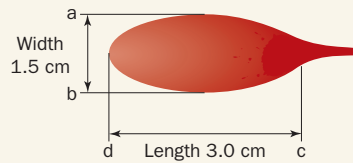
Blood-spatter analysis is a powerful forensic tool. Spatter patterns allow investigators to reconstruct what happened at a crime scene. The blood-spatter patterns "tell a story" of the crime and help the investigators determine if eyewitness accounts are consistent with the evidence. To study impact angle, you will need to use trigonometry math skills.

Use trigonometric functions to determine the impact angle for any given blood droplet.



By accurately measuring the length and width of a bloodstain, you can calculate the impact angle using the following sine (abbreviation *sin*) formula:

By accurately measuring the length and width of a bloodstain, the impact angle can be calculated using the *sin* formula below.



$$\begin{aligned} (c) &= \frac{\text{opposite}}{\text{hypotenuse}} = \frac{\text{width } (a-b)}{\text{length } (b-c)} \\ (c) &= \frac{1.5 \text{ cm}}{3.0 \text{ cm}} \\ (c) &= 0.5 \\ (c) &= 30^\circ \end{aligned}$$

To determine the angle of impact, take the inverse *sin* of 0.5, which is 30 degrees.

Procedure:

Part B: Creating blood spatter from different angles of impact

In this activity, you will drop blood onto 5 × 8 index cards set at various angles. You will drop the blood from 30 cm from the point of impact on the 5 × 8 card. You will observe how the angle of impact affects the size and shape of the blood spatter.

You will drop simulated blood onto 5 × 8 cards that are set to represent impact angles of:

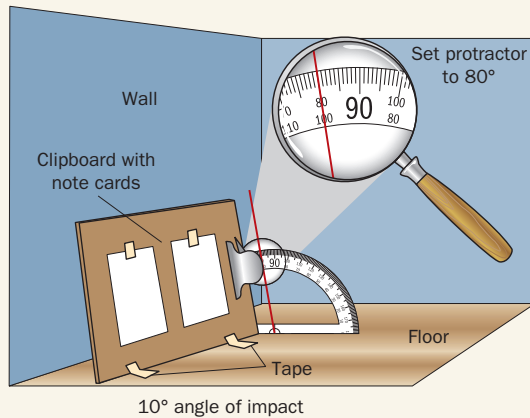
10 degrees	20 degrees	30 degrees
40 degrees	50 degrees	60 degrees
70 degrees	80 degrees	

You will be working in groups. Each group will prepare blood spatter from two different angles of impact. Divide the work as follows:

- Group 1: 10 degrees and 50 degrees
- Group 2: 20 degrees and 60 degrees
- Group 3: 30 degrees and 70 degrees
- Group 4: 40 degrees and 80 degrees

To simulate blood being cast off during bleeding, the following process is used.

1. Turn a 5 × 8 index card over so that no lines are visible.
2. Tape two 5 × 8 index cards on the clipboard as shown.
3. Label the cards with your initials on the top-right corner, along with the angle of impact that you will be using.
4. Working with your partners and a roll of masking tape, locate an area along a wall and set up the clipboard as pictured.



- a. Place the clipboard on the floor. Turn the clipboard so that the metal clasp of the clipboard is on its side. You will move the clipboard up against the wall as indicated in the following diagrams.
 - b. Set your protractor at the zero mark at the end of the clipboard in contact with the floor. (See other examples on the next page.)
 - c. Note: To calculate the desired impact angle, set the protractor reading for 90 degrees minus the desired angle ($90 - 10 = 80$). Tape the end of the clipboard to the floor to keep it at this position.
5. Start with the first angle assigned. Calculate the protractor setting.
 6. From a height of 30 cm drop two drops of blood onto each index card. (See examples of cards on page 233.)
 7. While the first card is drying, prepare the second clipboard and card and repeat steps 1 to 6 for the second angle you were assigned.
 8. Allow cards to dry completely. Do not move or pick up the cards for at least 30 minutes!
 9. Measure the length and width of each droplet in millimeters as indicated in the diagram on page 230. Disregard elongated tails of blood. Measure the main football-shaped or Q-tip rounded area only. If more than one group is assigned the same angle of impact, average your readings for length and width of the drops for the same angle of impact. Record this information in the Data Table on page 233.

Teaching Tip

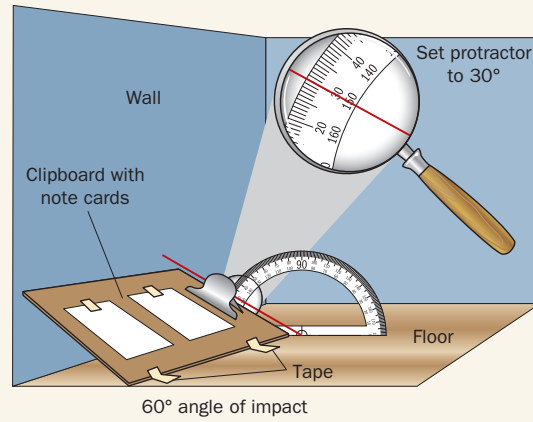
Use protractors that have the 0-180-degree line along the bottom edge of the protractor. Most protractors have this line raised, and this will lead to errors in measurement.

Teaching Tip

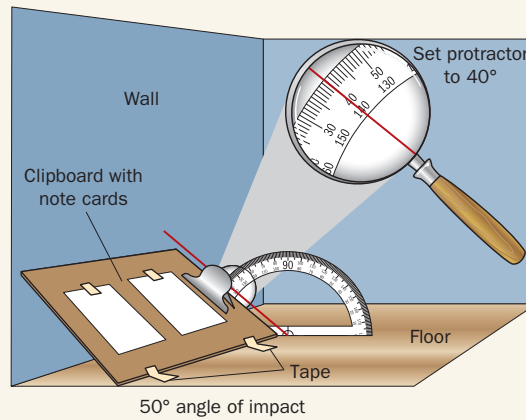
The activities in this chapter may be a good opportunity to review metric measurements and abbreviations.



60 degree angle of impact and set protractor for 30 degrees

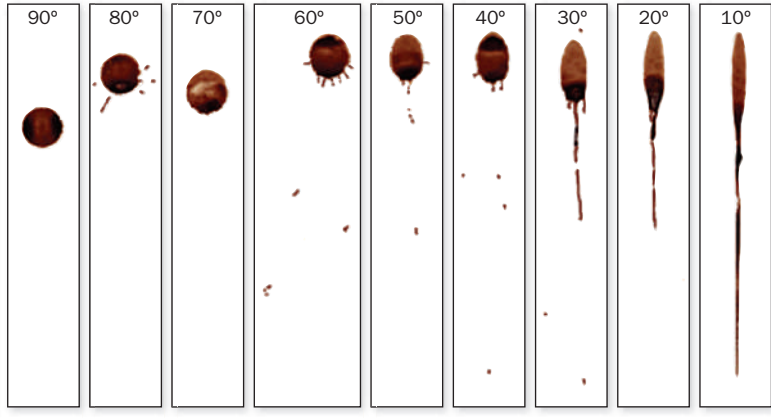


50 degree angle of impact and set protractor for 40 degrees



10. Determine the R value by dividing the length and width of your blood droplets.
11. Using a calculator and the Law of Sines, determine the actual angle of impact based on your blood-spatter marks.
12. Record all information in the Data Table on page 233.

Examples of blood-spatter patterns 90- to 10-degree angles of impact.



Data Table

Expected Impact Angle	Length (mm)			Width (mm)			R=W/L	Actual Impact Angle
	1st Trial	2nd Trial	Average Length	1st Trial	2nd Trial	Average Width	Average W/L	
10°								
20°								
30°								
40°								
50°								
60°								
70°								
80°								
90°								

Answers

Check students' data tables.

1. Answers will vary.
2. Sample answer: Incorrect placement of protractor in determining angle.
3. Sample answer: The determination of the actual position of individuals involved in a conflict can be used to corroborate stories or point out discrepancies.

Teaching Tip

The activities in this chapter may be a good opportunity to review metric measurements and abbreviations.



Questions:

1. How accurate were you in obtaining the desired angles of impact?
2. How would you account for any differences between your actual angle of impact as determined by measuring the length and width of the blood-spatter droplets and your expected angle of impact as determined by your clipboard setup?
3. Provide an example of how knowing the actual angle of impact could help investigators solve crimes.

Further Research and Extensions

Assign students to research the following topic: Can blood spatter alone be used to crack a difficult criminal case? Look for instances where evidence about the sequence of events in a crime led to someone's conviction. How might blood-spatter analysis help establish the sequence of events?

ACTIVITY 8-5 Ch. Obj. 8.7 and 8.9

AREA OF CONVERGENCE



Scenario:

When the police arrived at a crime scene, both the victim and the attackers had already fled. Two areas of blood spatter were the only evidence that an assault had occurred. After drawing lines from the blood spatter, the crime-scene investigator determined not only the direction the blood was traveling and the approximate speed the blood was traveling but also the approximate location where the person was standing when the injury occurred.

Blood-spatter analysis can help investigators reconstruct what happened at a crime scene. When you enter a crime scene, there is always a story waiting to be discovered. An observant crime-scene investigator doesn't always need eyewitnesses to describe what happened, because the scene always tells the story. You can use blood-spatter analysis to reconstruct what happened at a crime scene.

In this activity, you will analyze blood spatter. By noting the direction of the droplet of blood, you will be able to note the direction in which the blood was moving. The size of the blood spatter will provide some indication of the velocity of the blood when it hit a surface. By examining at least two drops of blood spatter, you will be able to determine where the injured person was located when the injury occurred. When blood-spatter analysis is completed and these factors are determined, it may be possible to reconstruct what happened at the crime scene.

Objectives:

By the end of this activity, you will be able to:

1. Distinguish between blood-spatter droplets and blood-spatter satellites.
2. Distinguish between passive blood spatter and blood spatter that was emitted due to some type of force.
3. Use the shape of the blood droplet to determine the direction in which a drop of blood was moving.
4. Use the position of satellites to determine the direction in which a drop of blood was moving.
5. Use blood spatter to draw the lines of convergence to indicate the position where a person was located when bleeding occurred.

Time Required to Complete Activity: 45 minutes

Materials:

- 1 ruler
- 1 colored pencil or marker
- 1 pencil

Safety Precautions:

None

ACTIVITY 8-5

Background

This activity provides students with the opportunity to draw lines of convergence from blood spatter to determine the location of a person when they lost blood.

Safety Precautions

There are no safety precautions for this activity.

Procedures

1. Print, copy, and distribute Activity Sheet 8-5 from the IRCD.
2. Have students use very sharp pencils to draw the lines of convergence.
3. Encourage students to erase and redraw lines if necessary.
4. Remind students to draw through the middle of the droplet.
5. Do not draw the line too far in front of the main droplets, as it creates a mess.



Background:

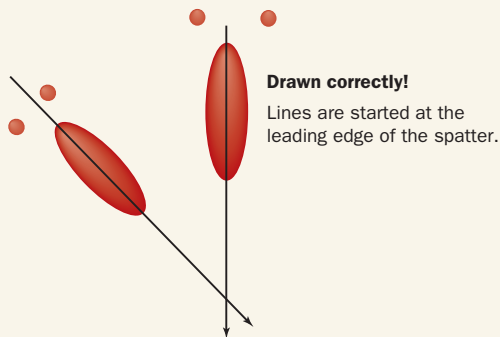
The shape of an individual drop of blood provides clues to the direction from which the blood originated. A drop of blood that has a circular shape (equal width and length) indicates that the blood fell straight down. When blood falls straight down, such as when it drips from a wound, the angle of impact is 90 degrees. This type of blood spatter is known as passively produced, because no applied force caused the spatter. When a drop of blood is elongated (longer than it is wide), it is possible to determine the direction the blood was traveling when it struck a surface.

The location of the source of blood can be determined if there are at least two drops of blood spatter. By drawing straight lines down the long axis of the blood spatter and noting where the lines intersect, this will indicate the lines of convergence. To determine where the source of the blood originated, draw a small circle around all of the intersecting lines. The intersection of the lines of convergence will indicate in a two-dimensional view the location of the source of the blood.

Procedure:

1. For each of the four different blood-spatter patterns pictured (Samples A–D on the next page), you will draw lines of convergence to determine the source of the blood.
2. Determine the direction in which each blood spatter is moving by locating the tail of the blood spatter and any satellites. The satellites will be found ahead of the blood spatter.
3. Draw a line through the middle of the long axis of each of the major drops of blood. Do not draw lines through the satellites.
4. Note: Begin your lines at the leading edge of the drop of blood, and draw the line in the opposite direction from the direction in which the blood was traveling. This will make your diagram easier to read.
5. Draw a small circle around the point where all of the lines intersect using a colored pencil or marker. This is the source of the blood or area of convergence.
6. For each of the four samples, determine how many incidences occurred. See the following example.

Example



Areas of Convergence

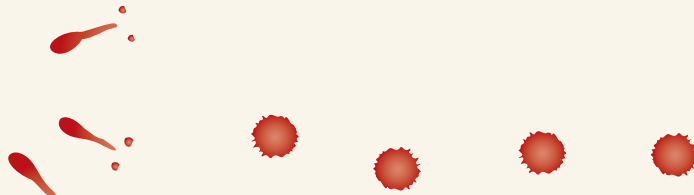
Sample A



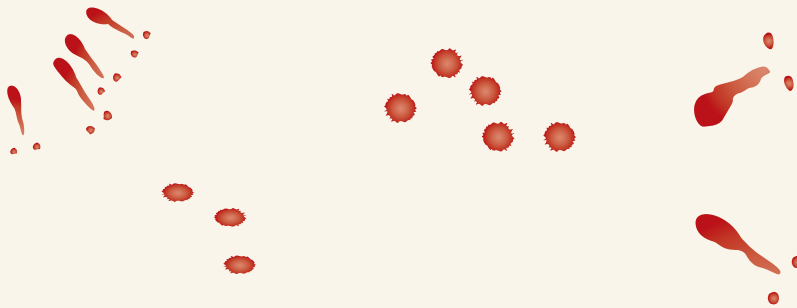
Sample B



Sample C



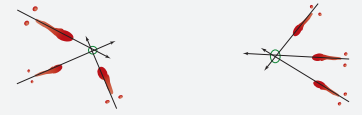
Sample D



Answers

Use the following diagrams as guides to check students' diagrams.

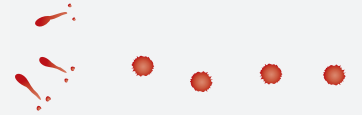
Sample A



Sample B



Sample C



Sample D



Answers

- Sample B shows the entry wound on the left, and the exit wound on the right.
 - Samples A & D
 - Sample C
 - Sample C and D both indicate movement.
- Sample the number of individuals and their direction of movement.
 - 2, none
 - 1, none
 - 1, right
 - 2, toward each other



Note: Circular droplets are formed as blood drops down at a 90-degree angle from a wound and are not considered part of the spatter pattern, but simply a drop.

Questions:

- Indicate which of these blood-spatter patterns (Sample A, B, C, or D) represents bleeding from:
 - a bullet wound that caused bleeding as the bullet entered the body and as the bullet passed through the body of one individual
 - two separate instances of bleeding, possibly from two different individuals
 - a single wound from one individual
 - a change in position of a victim after a wound has been inflicted
- Describe what could have happened in each sample A–D?
 - How many individuals are involved?
 - In what direction is movement?

Further Research and Extensions

Area of convergence can help an investigator find the source of any liquid left at the scene of a crime, not just blood. Have interested students research how area of convergence has helped investigators solve other crimes, such as burglary.

ACTIVITY 8-6 POINT OF ORIGIN

Ch. Obj. 8.7 and 8.9



Objectives:

By the end of this activity, you will be able to:

1. Determine the direction of blood flow based on the shape of the droplet.
2. Use lines of convergence to help determine the position of the victim when the wound was inflicted.
3. Calculate the angle of impact for individual drops of blood spatter.
4. Use the Law of Tangents to calculate the height above floor level where the wound was inflicted.

Time Required to Complete Activity: 45 minutes

Materials:

Activity Sheet for Activity 8-6
1 metric ruler
1 colored pencil or marker
1 pencil
calculator with tangent function
tangent tables (optional)

Safety Precautions:

None

Introduction:

In previous activities, you determined the angle of impact and area of convergence for blood spatter. Now you can use that information and the Law of Tangents to calculate the height (position) of the wound, the point of origin, on the individual.

Background:

Blood-spatter analysis helps crime-scene investigators reconstruct what happened at the crime scene. Using only blood-spatter analysis, you may be able to recognize the events leading up to the crime. Although crime-scene investigators may arrive at the crime scene after the victim and witnesses are no longer present, they still need to determine what happened. Often several witnesses give different accounts of the crime. Which witness is providing an accurate description of what really happened?

During the investigation, the crime-scene investigators need to determine if the evidence, in this case the blood spatter, matches the description given by the witnesses, the suspect(s), and the victim(s). In domestic abuse cases, the victim of domestic abuse may tell a false story to try to protect the abusing partner. A victim may state that a head injury occurred as a result of falling down stairs. However, if the blood-spatter patterns are inconsistent with this type of injury, then what type of injury did cause the blood spatter? What actually happened? Is a witness lying? Further investigation is required

ACTIVITY 8-6

Background

In this activity, students will have the opportunity to determine point of origin for blood spatter. Students use pencils, markers, calculators, and tangent tables for their calculations.

Safety Precautions

There are no safety precautions for this activity.

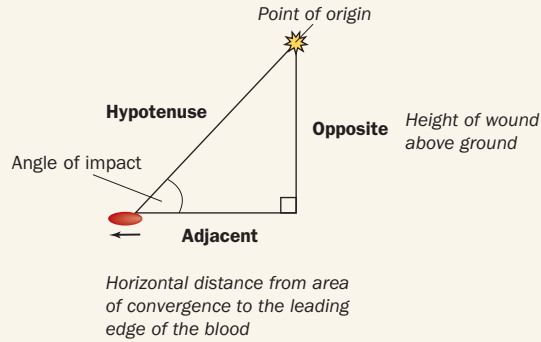
Procedures

1. Print, copy, and distribute Activity Sheet 8-6 from the IRCD.
2. Students might need some help with the tangent function on the calculator and the tables.



when the blood-spatter evidence tells a different story than the witness's account of the incident.

In this activity, you will analyze blood spatter in three dimensions. By noting the shape of the droplet of blood, you will be able to note the direction in which the blood was moving. The size of the blood spatter will provide some indication of the velocity of the blood when it hit a surface. By examining at least two drops of blood spatter, you will be able to determine where the injured person was located when the injury occurred in two dimensions (lines of convergence). You can easily measure the distance from the area of convergence to the drop of blood. If you want to determine the point of origin, or height from the impact surface, you will need to make some calculations. By measuring the width and length of a single drop of blood, you can determine the angle of impact. By using the Law of Tangents, you can calculate the height from which the blood fell, or the point of origin for the blood.



Math Review:

Right triangle

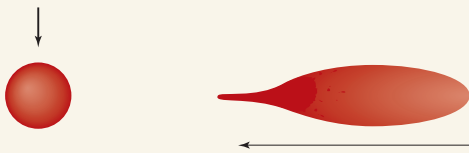
- Contains one 90-degree angle.
- The hypotenuse is the longest side of a triangle, opposite the 90-degree angle (right angle).
- The opposite side to an angle is the side directly opposite the angle of interest.
- The adjacent side to an angle is the side closest to the angle that is not the hypotenuse.

How to use a right triangle and the Law of Tangents in recreating a crime scene:

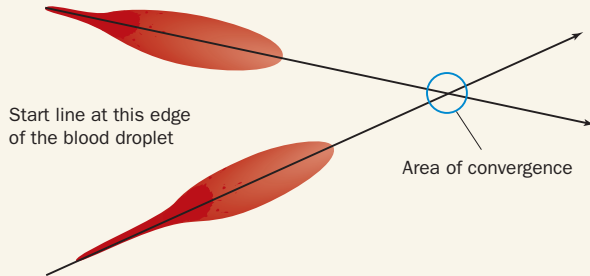
Procedure:

To recreate a crime scene from several drops of blood, you will need to perform several steps.

1. Determine the direction of blood flow in the drops that follow with an arrow next to the droplet. If the blood drop is circular, then the blood fell at a 90-degree angle. If it is not circular, then the angle of impact was less than 90 degrees. The elongated end of a drop of blood points to the direction in which the blood was moving.

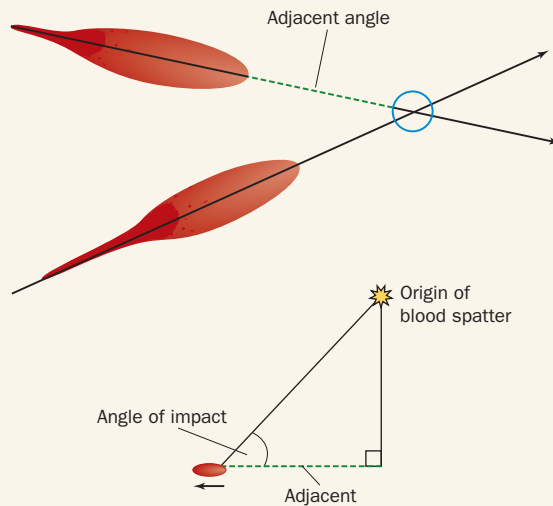


2. From several drops of blood, determine the area of convergence by drawing lines through each of the blood droplets and noting where the lines intersect.
 - a. Determine the direction of the blood when it struck an object.
 - b. Draw your line in the direction opposite to the direction in which the blood was moving.
 - c. The area where the lines intersect represents the area of convergence or the approximate location where the person was located when the blood droplets formed.



3. Once you have determined the area of convergence, you will measure the distance from the area of convergence to the edge of the drop of blood when it first impacted a surface. This distance is indicated in green.

Recall the diagram of a right triangle. This green line next to the angle of impact is known as the adjacent side.



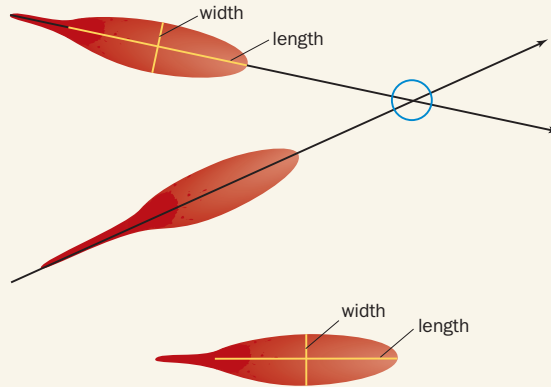
Teaching Tip

Sine and Tangent Tables are in the Appendices.



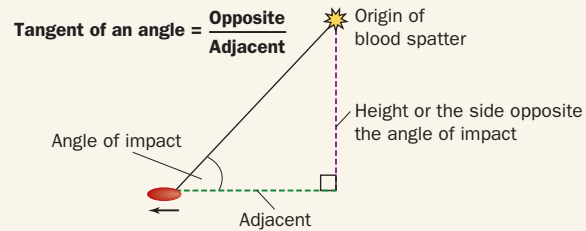
- Next determine the angle of impact for each droplet of blood. Select one of the blood droplets and determine the angle of impact for that drop of blood. To calculate the angle of impact, you will need to use the Law of Sines. Remember, when you measure the length of the blood droplet, do not include the thin extension of the leading edge.

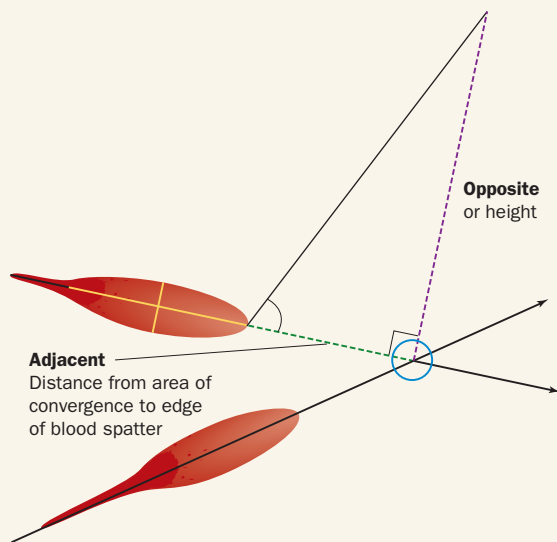
Sin of the impact angle = width of the blood drop/length of the blood drop



Sin of the angle = width/length = $14/45 = 0.3111$
Sin of angle = 0.3111
Determining the inverse sine identifies the impact angle
Angle is 18 degrees

- Using the Law of Tangents to solve for height. Going back to the right triangle and adding the angle of impact, we can determine the height from where the blood originated. The height of the source of blood is the side opposite the angle of impact. To solve for the height (or the side opposite the angle of impact), we apply the Law of Tangents.

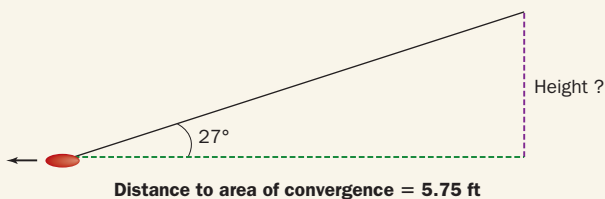




Tangent of angle of impact = Opposite/Adjacent = Height/Distance
 Solving for Height: Tangent of Angle \times Distance = Height

Example:

Crime-scene investigators noted blood spatter on the floor of the kitchen. The investigators drew lines of convergence and measured the distance from the area of convergence to the front edge of a drop of blood. That distance was recorded as 5.75 feet. After measuring the length and width of the blood droplet and using the Law of Sines, it was determined that the angle of impact was 27 degrees. The police wanted to determine the point of origin, or the height from the floor where the person was bleeding.



Solution:

Tan = Opposite/Adjacent = Height/Distance
 Tangent of the blood-spatter angle = Height of the wound/Distance from blood to area of convergence

Substituting values in the equation
 $\tan 27^\circ = \text{Height of wound}/\text{distance}$
 $\tan 27^\circ = \text{height}/5.75 \text{ ft}$
 Consult your calculator or tan chart

Answers

Problem 1

1. Measure the droplet labeled 1.

Length = 8 mm, width = 4.5 mm

2. Determine the W/L and use that value for calculating the angle of impact.

$$W/L = 4.5/8 = .5625$$

Angle from sine table = $\sim 34^\circ$

3. Draw the lines of convergence and use a scale of 1 mm = .2 feet of distance. Calculate the distance to the point of convergence (a) for droplet 1.

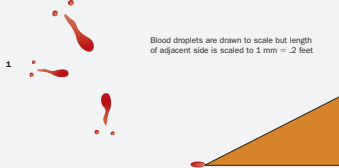
$$D(a) = 17 \text{ mm} \times .2 \text{ ft/mm} = 3.4 \text{ feet}$$

4. Determine the height from which the wound was inflicted by solving for (x).

$$\tan 34^\circ = .6744 = x/3.4 \text{ feet}$$

Tangent of the blood spatter angle = Height of the wound (x) / Distance from blood to point of convergence (a)

$$x = 2.3 \text{ feet}$$



$$\tan 27^\circ = h/5.75 \text{ feet}$$

$$.5095 = h/5.75 \text{ feet}$$

Solving for h:

$$h = \sim 2.9 \text{ feet is the distance above the ground where the wound began bleeding}$$

Problems to Solve:

Make the calculations for each of the following problems and label the right triangle for each blood-spatter drop. Include angle of impact, distance to area of convergence (d), and height (h) above the ground.

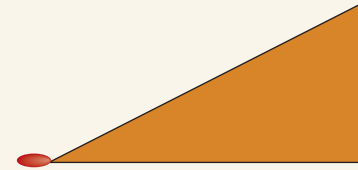
Problem 1:

Refer to Blood-spatter Sketch 1. From these drops of blood, determine the point of origin of the blood. To determine the point of origin, you will need to:

1. Determine the direction in which the blood was traveling.
2. Draw lines of convergence.
3. Draw a small circle around the intersection of the lines of convergence to indicate the area of convergence.
4. Measure the distance in millimeters from the area of convergence to the front edge of the blood spatter using a metric ruler.
5. Using the scale of 1 mm = 0.2 feet, determine the actual distance.
6. Using blood droplet 1, determine the angle of impact:
 - a. Measure the width and the length of the blood droplet.
 - b. Divide the width/length ratio for the blood droplet.
 - c. Using a calculator and the inverse sine function, determine the angle of impact for that blood droplet.



Blood droplets are drawn to scale but length of adjacent side is scaled to 1 mm = .2 feet

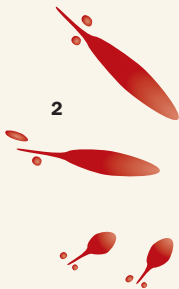


7. Using the Law of Tangents, determine the point of origin or the height of the source of blood for droplet 1.

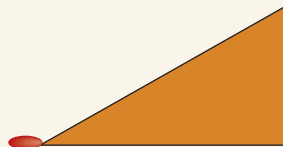
Problem 2:

A 30-year-old man was found shot in the head in his garage. The suspect claims he was being attacked and shot the victim in self-defense. Refer to Blood-spatter Sketch 2 on the next page. From these drops of blood, determine the point of origin of the blood. To determine the point of origin, you will need to:

1. Determine the direction in which the blood was traveling.
2. Draw lines of convergence.
3. Draw a small circle around the intersection of the lines of convergence to indicate the area of convergence.
4. Measure the distance in millimeters from the area of convergence to the front edge of the blood spatter.
5. Use the scale of 1 mm = 0.3 feet to determine the actual distance.
6. Use blood droplet 1 to determine the angle of impact:
 - a. Measure the width and the length of the blood droplet.
 - b. Divide the width/length ratio for the blood droplet.
 - c. Using a calculator and the inverse sine function, determine the angle of impact for that blood droplet.
7. Use the Law of Tangents to determine the point of origin or the height of the source for blood droplet 1.



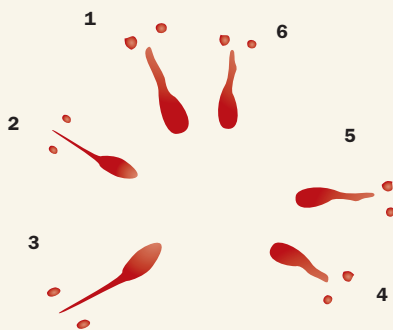
Blood droplets are drawn to scale but length of adjacent side is scaled to 1 mm = .3 feet



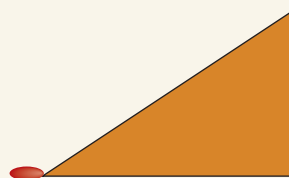
Problem 3:

A victim was found at the foot of a ladder with a chest wound. What is the approximate height of his wound when he was shot? Refer to the blood-spatter sketch below. From these drops of blood, determine the point of origin of the blood. To determine the point of origin, you will need to:

1. Determine the direction in which the blood was traveling.
2. Draw lines of convergence.
3. Draw a small circle around the intersection of the lines of convergence to indicate the area of convergence.
4. Measure the distance from the area of convergence to the front edge of the blood spatter (droplet #3) using a millimeter ruler.
5. Use the scale of 1 mm = 1.5 feet to determine the actual distance.



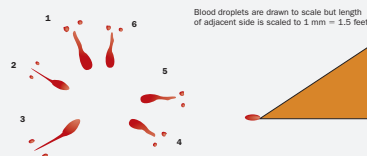
Blood droplets are drawn to scale but length of adjacent side is scaled to 1 mm = 1.5 feet



4. Determine the height from which the wound was inflicted by solving for (x).

$$\begin{aligned} \tan 20^\circ &= 0.3639 \\ .3639 &= x/21 \text{ ft} \end{aligned}$$

5. Approximate height of wound = 7.6 feet



Problem 2

1. Measure the droplets. Notice one blood droplet is different. Should it be used in the calculations?
2. Determine the W/L for droplet 1 and use that value for calculating the angle of impact.

$$\begin{aligned} W/L &= 4/18 = 0.2222 \\ \text{Angle from sine table} &= 13^\circ \end{aligned}$$

3. Draw the lines of convergence and use a scale of 1 mm = .3 feet. Calculate the distance to the point of convergence (a).

$$\begin{aligned} \text{Distance (a)} &= 10 \text{ mm} \times .3 \text{ feet/mm} \\ &= 3 \text{ feet} \end{aligned}$$

4. Solve for the height from which the wound was inflicted by solving for (x).

$$\begin{aligned} \tan 13^\circ &= .2309 = x/3 \\ x &= 0.7 \text{ feet} \end{aligned}$$

5. Was the victim standing when shot? He was lying on the floor. The wound produced a spatter of less than a foot in height. The shooter is lying.



Problem 3

1. Use droplet 3 for measurement.
2. Determine the W/L and use that value for calculating the angle of impact.

$$\begin{aligned} 4.5 \text{ mm} &= W \\ 13 \text{ mm} &= L \\ W/L &= 0.3462 \\ \text{Angle from sine table} &= 20^\circ \end{aligned}$$

3. Draw the lines of convergence and use a scale of 1 mm = .5 feet of distance. Calculate the average distance to the point of convergence (a).

$$\begin{aligned} \text{Distance (a)} &= 14 \text{ mm} \\ 14 \text{ mm} \times 1.5 \text{ ft/mm} &= 21 \text{ feet} \end{aligned}$$



6. Use blood droplet 3 to determine the angle of impact.
 - a. Measure the width and the length of the blood droplet.
 - b. Divide the width/length ratio for the blood droplet.
 - c. Using a calculator and the inverse sine function, determine the angle of impact for that blood droplet.
7. Use the Law of Tangents to determine the point of origin or the height of the source of blood for droplet 3.

Further Research and Extensions

Encourage students to investigate other uses for the geometry and trigonometry used in this activity.

ACTIVITY 8-7 Ch. Obj. 8.7 and 8.9

CRIME-SCENE INVESTIGATION



Objective:

By the end of this activity, you will be able to:

1. Use information collected from a crime scene and your knowledge of spatter analysis to develop a hypothesis to describe the events that occurred at a crime scene.

Time Required to Complete Activity: 40 minutes

Materials:

ruler
pencil
calculator

Safety Precautions:

None

Procedure:

1. Examine Crime Scene Diagram on page 249 and complete the lines of convergence.
 - a. Determine the position of each man at the time of the shootings. Label the position for Man 1 in the diagram. What evidence supports your answer?
 - b. Label the position for Man 2 in the diagram. What evidence supports your answer?
2. Both men died. Man 1 was shot through the forehead and died instantly. Man 2 was shot in the stomach and was found dead at the scene as well. Who was shot first? Support your answer with evidence from the crime scene.
3. Data Table 1 contains some of the measurements for the bloodstains found at each position. Complete the table by filling in the blanks.
4. Did your results agree with statements made in question 2? Explain your conclusions.

Questions:

1. Based on your calculations, which man was most likely standing when he was shot? Support your answer with evidence from the crime scene.
2. In position one, there are four bloodstains in front and one bloodstain behind the victim. How do you account for this?
3. Based on the blood-spatter evidence, describe the series of events resulting in the death of these two men. Support your theory with evidence obtained from the blood-spatter analysis.

ACTIVITY 8-7

Background

This activity gives students the opportunity to use various skills to gather information from blood spatter. Students use crime-scene diagrams to determine direction, height, angle of impact, and so on.

Safety Precautions

There are no safety precautions for this activity.

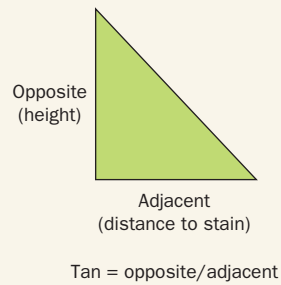
Answers

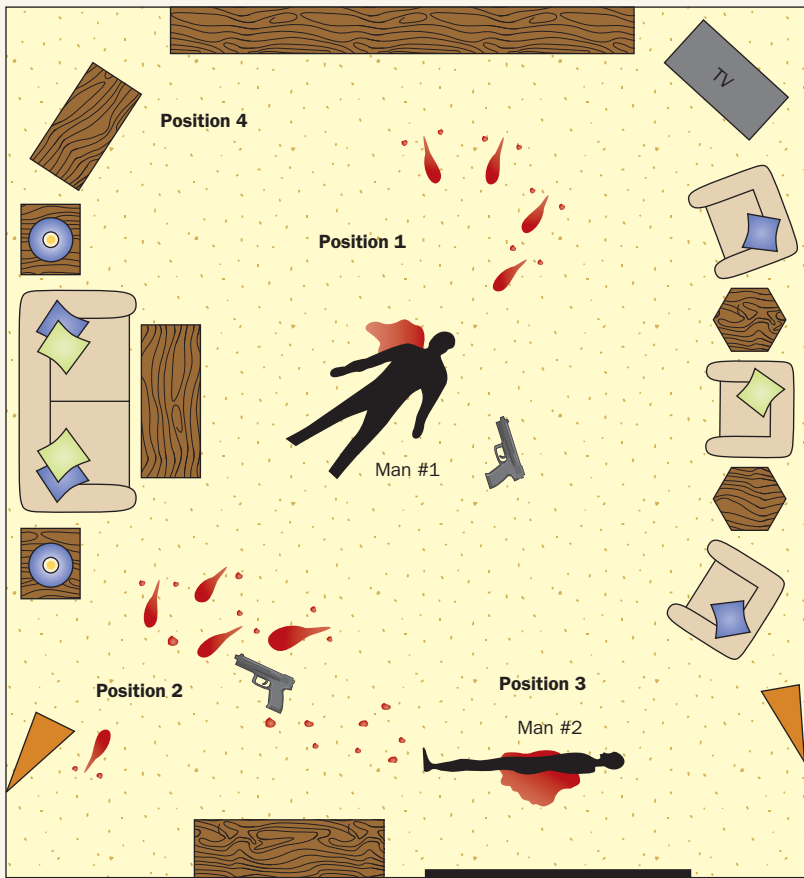
1. Print, copy, and distribute Activity Sheet 8-7 from the IRCD.
2. Man 1. Check students' crime-scene diagrams.
3. Man 2 had an entry and exit wound, and he bled from both.
4. Check students' crime-scene diagrams. Man 1 was shot through the forehead and died instantly. Man 2 was shot in the stomach and was found dead at the scene. The positions of the bodies tell us that Man 2 moved away from where he was shot.



Data Table 1

Stain #	Length of Stain (L) (mm)	Width of Stain (W)(mm)	W/L Ratio (Sine Value)	Angle of Impact (nearest degree)	Distance from Near Edge of Stain (feet)	Tan Value of Angle of Impact (to four decimal places)	Height (h) of Wound above Floor (feet) $h = \text{Tan} \times \text{distance}$
1	18.1	9.6			4.0		
2	18.6	9.0			4.4		
3	17.8	13.2			2.2		
4	18.9	12.8			2.8		
5	19.2	13.2			2.5		
6	9.0	4.5			10.1		
7	10.6	5.1			10.3		
8	8.4	3.9			10.4		
9	8.1	3.6			10.3		





Further Research and Extensions

Ask students to research whether guns of different calibers leave different blood-spatter patterns.