Unit 6 Forensics Learning Goals: Glass

6.1 I can identify the features of a glass fracture pattern.
6.2 I can describe how to determine the direction of an impact that produces a fracture pattern.
6.3 I can interpret a glass fracture pattern to determine the order of impact.
6.4 I can determine the physical properties of a shard of glass.
6.5 I can explain the process and cause of refraction.

Fracture Patterns in Glass

When a projectile such as a bullet or stone hits a glass surface the impact causes changes, in the form of fractures, to occur within the glass. When a projectile smashes into the surface of a glass pane, the glass bends slightly before it breaks. When the glass reaches a certain point of distortion it breaks and the projectile passes through the glass. In accordance with the laws of physics the energy from the projectile that was absorbed by the glass will dissipate along the path of least resistance, creating cracks. Shock waves of energy emanate from the point of impact causing specific types of damage to the glass. This is what makes it possible to determine the order of fractures.

Determining the Order of Shots

When glass is broken with a projectile, such as a bullet or rock, it will form two distinct types of fractures, radial and concentric. The figure to the right shows how the difference between radial and concentric fractures. But how do these fracture lines occur, and can they be useful in determining the order of shots when multiple projectiles have hit a single pane of glass?

When a projectile first hits the glass, the glass will be stretched, causing tension on the back side directly behind the projectile. This causes compression around the point of tension. The radial cracks begin on the opposite side of the force at the point where the projectile hits the glass (A) and radiate out from the origin of the impact. They will always end if they encounter an existing fracture line. The concentric cracks begin on the same side as the force, where the tension occurs (B).
Radial fractures will always travel along the path of least resistance, and they will always end if they encounter an existing fracture line. This fact allows an investigator to determine the order of multiple impacts to a single pane of glass. For example, examine the figure below:

Both impacts created radial and concentric fractures. However, if you look carefully, you should be able to see how the radial fractures from the right impact were stopped by the pre-existing fractures caused by the left impact. Therefore, the left impact occurred first, followed by the right impact.

It is important to note that when there are more than 2 impacts, it is sometimes not possible to get an entire order. For instance, try to determine the order of impact of the three shots below:

You should notice that the radial fractures indicate that the middle shot was fired first. However, the fracture patterns caused by the left and right shots do not intersect; therefore, it is impossible to tell which of those shots came first.
Determining the direction of Impact

Visible along the edge of broken glass are stress lines. Stress lines appear from both radial and concentric fractures. The appearance of stress lines coming from concentric fractures varies, but the stress lines coming from radial fractures are quite predictable and can be used to determine the direction of impact. They are shaped like arches with the perpendicular at the surface opposite to the side where the crack originated. Also, a high-velocity projectile always leaves a hole wider at the exit side of the glass. The size of the hole itself is not necessarily indicative of the size of the projectile.

When glass breaks, most of the glass falls inward. However, the tiny shards produced in the formation the concentric fractures spray backwards towards the person wielding the weapon or tool. These tiny bits of glass can get caught in the hair and clothing of a person near the point of impact. Even after washing, tiny fragments of glass can remain caught in the fibers of clothing and footwear.

Tempered glass and laminated glass do not behave in the ways described above. Tempered glass breaks into small squares when it is broken. Laminated glass, used in windshields and side windows in vehicles, has a layer of plastic imbedded between two sheets of glass (Innes, 2002).

Determining the side from which glass was broken is important in burglaries and other crimes involving home invasion. Arson investigators have particular interest in knowing whether a pane of glass was broken from the inside or the outside. Windows broken from the inside at the top of a structure can indicate an attempt to ventilate the building. Ventilation causes the fire to spread upward following the source of oxygen. A fire started at the bottom of a structure can be made to race through a structure more rapidly than normal by ventilating the upper levels.

Holes in a window can also be used to pinpoint the location of a shooter if the projectile leaves a mark somewhere behind the first one. For example, fixing a laser pointer so that it passes from the hole to the mark will show a probable point of origin. Factors affecting trajectory, such as wind, distances, and type of projectile, must be taken into account.
There are five panes of glass set out around the room; each pane is matched to a description of a crime below. Your task is to examine each pane of glass, and, based on the fracture patterns and the known facts, to decide how the crime was committed. In some cases, the fracture pattern may not conclusively tell you; you should provide as thorough a description as the evidence allows. Additionally, sketch the region(s) of the pane that convinced you of your answer, and explain how you interpreted them.

You may complete the panes in any order!

Pane 1:
A man is found dead in an abandoned house. Upon examination the medical examiner finds that the man was killed by a single gunshot to the head. Three local teens where observed near the house two days earlier. They are picked up and questioned by police. When pressured, the teens admit to having stolen one of the boys' father's guns. They had taken turns shooting at the windows of an abandoned house. The teens admit that John shot the gun first, then Jay and last was Fred. At the scene the investigators find three bullet holes in a window. They analyze the angle of each bullet hole in relation to the victim and find that the bullet that passed through the far right side of the windowpane is the one which fatally wounded the man. Who is responsible for the death?

Pane 2:
A shootout between a suspect and a policeman resulted in three shots being fired through a window. The suspect, who was inside his house, claims he shot in self defense – only after the policeman, who was outside, started shooting. Examining the size of the holes, investigators determine that the two holes on the left side were fired from inside the residence, and the one on the right was fired from the outside. What was the order of shots, and was the suspect’s story true?

Pane 3:
A young boy was caught as he was shooting a pellet gun at a window in a neighbor’s garage. He claims that he shot only once, and that he thought it would be OK since the window pane already had multiple holes in it. When investigators examined the scene, they could locate only one pellet in the interior of the garage, which was lodged into the handle of a tool that had been hanging in front of the window. Based on where the tool had been hanging, the police determined that the pellet traveled through the left-most hole in the window. Was the boy telling the truth when he claimed that he fired only that shot?

Pane 4:
Jeff and Sam were playing with a pellet gun outside their neighbor’s house. They admit to each firing 2 shots at the window of what they believed was an empty shed. Each boy used a different brand of pellets, and the pellets recovered showed that Jeff fired the pellets that caused the damage to the left of the windowpane, and that Sam fired the pellets that caused the damage on the right. Which of the boys started firing first, and what was the order of the shots?

Pane 5:
A homeowner fired a gun through his window in an attempt to scare away an intruder. Identify the order of shots based on the fracture pattern.

(Additional Questions on the next page)
**Additional Questions:** The two pictures below represent glass fracture patterns caused by a BB gun. Cut and paste the two photos below into your journal.

**Photo 1:** Is this fracture series possible? If not, why not? What is wrong?

**Photo 2:**
(a) Identify three radial fractures;
(b) Identify three concentric fractures;
(c) Determine to the best of your ability the order of the impacts. Explain your reasoning.
(d) Explain what an investigator should look for to determine which side of the window the BB pellets were shot from.

*Photo 1*

*Photo 2*

*LGs: 6.1, 6.2, 6.3*
How Can Glass Shards Be Used as Evidence?

Glass shards (fragments) found at a crime scene can be used to place a suspect at the scene. The fragments may be found in a suspect's clothing or embedded in shoes as a result of breaking a window to gain entry to a house, or they may be found on a victim of a hit-and-run accident. If the fragments can be pieced together, like the pieces of a jigsaw puzzle, the evidence can be individualized (see Figure 1). Most often, however, glass shatters into so many fragments that piecing them together is impossible; thus it must be considered as class evidence.

It is the task of the forensic scientist to use as many physical properties of glass as possible to characterize the fragments and associate the fragments from the crime scene to a suspect.

What Is Glass?

Glass is a very common material found in our environment. It is a hard, amorphous material, usually transparent, composed primarily of silica (SiO2) and various amounts of element oxides. It is brittle and exhibits a predictable fracture pattern when hit. Glass can be classified into families (taxonomy) like many other materials you have studied. The families differ widely in chemical composition and physical properties.

The physical properties of glass are often used in forensic science to determine if two pieces of glass (one from the crime scene, the other found on the suspects clothing or shoes) have a common origin. If only one piece glass is obtained from either the crime scene or suspect, then the physical properties of the glass provide some direction as to what type of glass to look for in order to make a comparison. Glass from various sources, such as bottles, windowpanes, automobile headlights, and plate glass doors, all have slightly different physical properties. This can, in some cases, make it possible to place a suspect at the scene of a crime.

Color, thickness, ability to magnify (typical of optical glass), and any extraordinary markings, such as striations, dimples, and so on, are helpful in identifying the origin of a glass shard. Fluorescence is also routinely observed; while most glass does not fluoresce, some, such as uranium glass, lead glass, and quartz glass do. In addition, the density and refractive index of a glass shard can be measured and compared with known samples to narrow down the possible source.

From these values the analyst can usually determine the type of glass the sample came from. Determining the type of glass gives investigators evidence which is considered to have 'class' characteristics. Only in cases where the suspect fragments exactly match fragments from the crime scene is it possible to consider this type of evidence as showing 'individual' characteristics that point to a specific source.
Physical Properties of Glass Pieces

Please remember that glass edges are *sharp*; please handle all glass with care. Thick gloves are available if you’d like to protect your hands.

**Preliminary Question**
Identify which types of glass would have the following properties, choosing from the list of glass types on the following page.
- a. Fluoresces
- b. Magnifies print
- c. Curved surface
- d. Textured surface

**Procedure**

**Part 1: Density of Glass**
The density of an object is determined by measuring its mass and then its volume. Since we think of volume with liquids and not solids, the method for determining the volume of glass is based on a physical relationship known as *Archimede’s principle*. This principle states that an object immersed in a fluid displaces a volume of fluid equal to its own volume. If an object displaces 1 milliliter (mL) of water then its volume is also 1mL. In this activity, you will suspend a piece of glass in a beaker of water that has been placed on a balance and you will convert the mass of the glass fragment suspended in the water to mL by using the density of water (1g/mL).

1. Obtain a single glass shard – the bigger it is, the easier the process will be.
2. Use an electronic balance to determine the mass of the shard. **Be sure you get the mass of the DRY shard – if it’s wet, you’ll be massing the water as well!**
3. Take your glass sample and attach it securely with your slip knot string.
4. Measure approximately 75 mL of tap water and place it in a 150 mL beaker.
5. Using the same electronic balance as in step 2, place your beaker with the water on the balance. (If you spill any water, please clean it immediately as it could damage the balance.)
6. With your beaker still on the balance, press the zero or tare button so that your balance now reads 0.00 g with your beaker on the balance.
7. Very carefully, suspend your glass fragment in the beaker of water, taking special care not to touch the sides or bottom of the beaker. Record this mass when everything has stabilized.
8. The density of the glass fragment is determined by the following relationship:

   \[
   \text{Density of Object} = \frac{\text{mass of the glass shard}}{\text{mass of the glass shard suspend in water}}
   \]

9. Repeat steps 1-8 for each glass sample.
Part 2: Other Physical Properties

Create a table to record the physical properties of each glass sample provided to you. List each sample along the top of the chart, and identify each property you observe in a row of the table.

10. **Color** is an identifying property that may be difficult to identify in small, thin fragments of glass. Use a good magnifying lens to examine samples of small fragments.

11. Use both long- and short-wave UV light to determine which glass samples **fluoresce**. Be sure to note subtle differences.

12. **Thickness** may vary greatly in a bottle, yet be quite uniform in plate glass. Measure the thickness of the original glass from fragments large enough to show smooth, parallel sides.

13. Certain **surface features** are imparted during glass manufacturing and fabricating processes, or during use. These features can include mold and polish marks, mirrored backings, scratches, and decorative finishes such as texturing, etching or frosting, and coatings. Note any surface features of the shards provided to you.

14. Record whether or not each glass sample is **flat or curved**; if the shards are too small to tell, write “undetermined”.

15. Record whether each glass sample has the **ability to magnify**. To do this, hold a large shard up to some printed letters. Then, move the glass away from the letters and observe whether the letters appear to grow larger.

**Conclusions**

The density of various types of glass can be found in the table below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Approximate Density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windowpane glass</td>
<td>2.46 – 2.49</td>
</tr>
<tr>
<td>Headlight HDPE</td>
<td>1.2 – 1.8</td>
</tr>
<tr>
<td>Optical glass</td>
<td>2.64 – 2.81</td>
</tr>
<tr>
<td>Uranium glass</td>
<td>2.48</td>
</tr>
<tr>
<td>Quartz</td>
<td>2.65</td>
</tr>
<tr>
<td>Pyrex</td>
<td>2.23 – 2.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Approximate Density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottle glass</td>
<td>2.40 – 2.50</td>
</tr>
<tr>
<td>Lightbulb glass</td>
<td>2.45 – 2.55</td>
</tr>
<tr>
<td>Lead Glass</td>
<td>2.9 – 5.9</td>
</tr>
<tr>
<td>Plastics</td>
<td>.9 – 1.2</td>
</tr>
<tr>
<td>Silica Glass</td>
<td>2.2</td>
</tr>
<tr>
<td>Tempered Glass</td>
<td>2.48 – 2.52</td>
</tr>
</tbody>
</table>

1. Use the table above, as well as the information in the Background section, to try to determine the identity of each glass sample provided to you. Use as many of the properties you observed as possible – **not JUST the density**! Try to be as specific as possible, justifying each identification with the properties you recorded.

2. Explain why glass is usually considered class evidence.

*LG 6.4*
Light travels in straight lines at approximately 300,000,000 meters per second in air. When it strikes the surface of a transparent material such as glass, it can be reflected or it can travel through the material. Such a material is called a medium. When light passes from one medium into another, there is a change in its direction and velocity. This phenomenon is called refraction. Light traveling from a less dense medium to a more dense medium (as from air to glass) will slow down, and it will bend away from the normal (a line perpendicular to the boundary between the two media). How much it slows down and bends is quantified by the substance’s refractive index (symbol: n). Because the speed of light is so fast, it is nearly impossible to measure the change in speed as light travels from one medium to another. However, measuring how much a ray of light bends is quite simple. It is that measurement that allows a scientist to measure any medium’s refractive index.

To understand the process better, consider the diagram below, which shows a ray of light moving from one medium (in this case, the air) into a second medium.

Each medium has a different refractive index. The angle between the light ray and the normal as it leaves a medium is called the angle of incidence. The angle between the light ray and the normal as it enters a medium is called the angle of refraction.

The refractive index of the second medium is then calculated by knowing the refractive index of the air (n_{air} = 1.0003), and by measuring the angle of incidence and angle of reflection. The equation used is called Snell’s Law; it utilizes the trigonometric function sin, which can be found on all scientific calculators:

\[
\begin{align*}
\sin \phi_1 &= \frac{n_2}{n_1} \\
\sin \phi_2 &= \frac{n_1}{n_2}
\end{align*}
\]
Procedure

1. Obtain a piece of paper that has been marked with lines at 5, 10, 15, 20, 25, 30, 35, and 40 degrees. Place it on top of a corrugated piece of cardboard.

2. Place the flat side of a semi-circular plastic dish on the horizontal line so that the bottom center of the dish is located at the intersection of the two bold lines (as shown to the right).

3. Push the cardboard, paper, and dish so that the flat edge of the semicircular dish is parallel to the edge of the table, as shown to the right.

4. Fill the dish 3/4 full with water.

5. Place a pin next to the straight side of the dish and on the origin of the 2 axes.

6. Place a second pin near the curved side of the dish and on the 10 degree line.

7. Position your head so that your eyes are parallel to the table, just above the table. Looking through the water (not over the top of the surface), place another pin on the straight side of the dish so that it is in line with the other two pins. You should place this pin around four inches from the dish.

8. Remove the second and third pins.

9. Repeat steps 6 – 8 for three other angles that are marked on the paper.

10. Remove all three pins and the dish from the paper.

11. Write the location of each medium on the paper:

- **Medium #1** was “water” (above the thick horizontal line);
- **Medium #2** was “air” (below the thick horizontal line).

12. Using a different colored pencil for each angle you measured, draw a line from the hole on the semi-circular side to the hole on the flat side to the hole made by the third pin. For example, one such line might look like the diagram to the left.

Conclusions

1. Begin with first trial you completed (where the angle of incidence was 10 degrees). Use the diagram and equation outlined in the background to calculate the refractive index of water ($n_{water}$).

2. Repeat the calculations for the other two trials you completed.

3. Average your three calculated values for $n_{water}$.

*LG 6.5*
Refractive index is a physical property of any substance that will transmit light. Since glass transmits light, it has a measurable refractive index that can be used to identify its origin. However, because the glass shards are so small, measuring their refractive index in a way similar to what you did in the previous experiment would be highly inaccurate at best.

To get an accurate measure of the refractive index of a very small sample, we are luckily able to utilize an interesting consequence of refractive indexes. If a clear material such as glass is immersed in a liquid that has the same refractive index, both the glass and the liquid will bend light at the same angle, and the glass will appear to disappear! So, to determine the refractive index of a small glass shard, you will immerse it in liquids until you find one that causes the shard to seem to disappear.

Helpful values:

<table>
<thead>
<tr>
<th>Medium</th>
<th>Refractive Index</th>
<th>Medium</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitreous Silica</td>
<td>1.458</td>
<td>Bottle Glass</td>
<td>1.51 – 1.52</td>
</tr>
<tr>
<td>Pyrex</td>
<td>1.470</td>
<td>Optical Glass</td>
<td>1.52 – 1.53</td>
</tr>
<tr>
<td>Lead Glass</td>
<td>1.47 – 1.49</td>
<td>(Optical glasses)</td>
<td></td>
</tr>
<tr>
<td>Headlight Glass</td>
<td>1.47</td>
<td>Quartz</td>
<td>1.54 – 1.55</td>
</tr>
<tr>
<td>Television Glass</td>
<td>1.49</td>
<td>Bead Glass</td>
<td>1.56 – 1.61</td>
</tr>
<tr>
<td>Window Glass</td>
<td>1.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To get an accurate measure of the refractive index of a very small sample, we are luckily able to utilize an interesting consequence of refractive indexes. If a clear material such as glass is immersed in a liquid that has the same refractive index, both the glass and the liquid will bend light at the same angle, and the glass will appear to disappear! So, to determine the refractive index of a small glass shard, you will immerse it in liquids until you find one that causes the shard to seem to disappear.

Helpful values:

Procedure
1. Create at least 6 small glass shards (about 1-2 mm) by placing a large shard into a druggist’s fold and striking the fold with a hammer. Repeat as necessary until you have the required number of small shards.
2. Fill the wells of a well plate about ¾ full with the refractive index oils available. Order the liquids from lowest refractive index to the highest refractive index. Be sure to keep track of which liquid is in which well!
3. Immerse a small shard entirely in each of the selected refractive index oils,
4. Observe each shard within the liquids with a good magnifying lens. You are looking for the liquid in which the glass seems to disappear; if the glass can be seen in all of the liquids, identify the liquid in which the glass seems to disappear the most.

Conclusions
1. Briefly explain the process and cause of refraction (in general, not for glass only).
2. Explain why a shard of glass “disappears” when it is placed in a liquid that has the same index of refraction as the glass.
3. The table below shows refractive indexes of several common types of glass. Compare your results to the values in the table to identify the source of your sample. Then, use any other physical properties (see page 65) to further justify your conclusion.

LG 6.4, 6.5

Unit 7 Forensics Learning Goals: Blood

7.1 I can describe the components of human blood and what distinguishes the various blood types.
What Is Blood?

Approximately one-twelfth of the human body is blood, which is basically cells suspended in a liquid. The fluid portion is called **plasma** (55% of the blood). It is composed of 90% water and waste, salts, ions (mostly Na⁺, Cl⁻, HC0³⁻), and 10% metabolites - waste, salts, ions (mostly Na⁺, Cl⁻, HC0³⁻), and proteins. The solid portion of blood is composed of three principal types: (1) **Red (erythrocytes)**, which contain hemoglobin, transport oxygen from the lungs to the cells and in return carry carbon dioxide back to the lungs, where it is exhaled. (2) **White cells (leukocytes)** are the primary cells of the immune system. They produce antibodies. (3) **Platelets** start the clotting process by initiating the formation of fibrin to form a clot. Removing the solid clotting material leaves a pale yellow, watery fluid called **serum**.

In 1901, Austrian biologist Karl Landsteiner recognized that all human blood was not the same and worked out the **ABO classification system** to describe the differences. This was important because so many blood transfusions had resulted in immediate death of the patient for no apparent reason. In 1940, Landsteiner discovered the **rhesus factor (Rh)** in blood. Now over 100 different factors are known to exist. Theoretically, no one, except identical twins, has the same combination of **blood factors**; practically, however, the complete identification is difficult, time-consuming, and expensive. Also, many factors break down as blood dries and ages. In the forensic-science world, blood-factor identification is not yet practical as a means of individualization. DNA analysis, on the other hand, offers individualization, but also is time-consuming and expensive. Nevertheless, ABO and Rh blood characterization is an important component of forensic serology because it can be done on whole blood as well as dried bloodstains, quickly and without expensive apparatus. Additionally, about 80% of the population are **secretors**, meaning their blood-type antigens are found in body fluids other than just blood.

Present on the surface of each red blood cell (RBC) are millions of characteristic chemical structures called **antigens**. These proteins are responsible for the different blood types. For the ABO system, there are two types of antigens, A and B. Type A...
blood cells have A antigens, type B blood cells have B antigens, and type 0 blood cells have neither antigen.

Some white blood cells manufacture proteins called antibodies that are found in the serum, the yellowish liquid that separates from blood clots. These antibodies, known as antiserum, are produced to attack invaders that do not belong in your system, such as snake venom and bacteria. When viruses responsible for the mumps enter the bloodstream, the body recognizes them as foreign invaders and begins synthesizing antibodies that can combine only with the specific antigens of the virus. Antibody-coated viruses are destroyed by white blood cells. If the person is again exposed to mumps, the existing antibodies are able to prevent a repetition of the illness. This is the basis of vaccines.

A person with type A blood (A antigens on their red blood cells) will produce specific antibodies in their serum to attack and destroy type B blood cells as they are introduced into the body. Type A’s serum containing the B antibodies is called anti-B antibodies or anti-B serum, because it destroys type B blood cells. Likewise, a person with type B blood will have A antibodies in their serum. Type AB blood has both A and B antigens on the red blood cells and no antibodies in the serum. Type 0 blood, which has neither A nor B antigens, has anti-A and anti-B antibodies in its serum. This is confusing—you may have to think about it for a while to fully understand. Table 1 provides a summary of blood types.

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Antigens on Red Blood Cells</th>
<th>Antibodies in Serum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>anti-B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>none</td>
</tr>
<tr>
<td>O</td>
<td>none</td>
<td>Anti-A and anti-B</td>
</tr>
</tbody>
</table>

Antibodies are bivalent, which means that they can attach to two antigen sites, thus causing agglutination, or clumping, similar to cross-linking in polymers. If a person with type B blood receives a transfusion of type A blood, the anti-A antibodies in the recipient's B blood will attach to the donor's A red blood cells and cause agglutination, as depicted in Figure 3.

The result can be fatal. This is why ABO typing is
necessary before undergoing blood transfusions. The anti-B antibodies received from the donor are diluted by the larger volume of the recipient's blood, so the transfused antibodies do not cause a problem. Table 2 shows safe blood-donor and recipient combinations.

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Antibody Donor For</th>
<th>Recipient For</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, AB</td>
<td>A, O</td>
</tr>
<tr>
<td>B</td>
<td>B, AB</td>
<td>B, O</td>
</tr>
<tr>
<td>AB</td>
<td>AB</td>
<td>All</td>
</tr>
<tr>
<td>O</td>
<td>Anti-A and anti-B</td>
<td>O</td>
</tr>
</tbody>
</table>

The Rh factor is another important means of classifying blood type for forensic serology. It is sometimes referred to as the D antigen. Those who have it are called Rh positive (Rh+); those without it, Rh negative (Rh-). Approximately 85% of the population is Rh+.

The distribution of blood type varies both with location and race throughout the world. In the United States, a typical ABO distribution is illustrated in Table 3.

Thus, blood typing can be important in forensic science because it can show that two samples did not have the same origin; that is, typing evidence can exclude suspects. Also, the distribution of blood types within a specific population can be used to statistically determine the probability of someone having a particular combination of blood types. For example, what is the probability of a person having type B+ blood?

\[
\frac{10 \times 85}{100 \times 100} = \frac{850}{10,000} \text{ or about 1 out of every 12 people}
\]
In your bound journal, answer the following questions, based on the reading.

1. Define all terms in bold print.

2. What is the probability of a person having type AB- blood? Show your calculations.

3. Blood typing can be applied to a host of enzymes and proteins that perform specific functions in the body. More than 150 serum proteins and 250 cellular enzymes have been isolated. Therefore, it is possible to use blood typing as individual evidence; however, it is not practical to achieve the statistics required because of the time and techniques involved. Rather, ABO/Rh typing, and often another kind of typing called MNS, are used as exclusionary tests in forensic science and paternity testing. The typical population in the United States shows an MNS distribution of M = 30%, N = 27%, S = 48%. If a blood stain found at the scene of a crime is found to be B, N, Rh-, what are the chances that a suspect would have this combination of antigens? Is this good enough to convince a jury?

4. Why can a person with type O blood safely donate blood to any person, regardless of their blood type?

3. Why can a person with type AB blood receive blood from any person, regardless of their blood type?

_LGs: 1.4 & 7.1_
A red-brown stain is found on a piece of fabric. Maybe it is blood, but maybe it is paint, ketchup, food coloring, rust, or and number of other substances that can look like blood.

**Group Procedure**

3. Observe the different samples of what may be blood stains on pieces of fabric and/or Q-tips. Record their appearance and what you think each stain is and why (color, shape, smell, texture, etc.).

There are several presumptive tests of chemical color that can be used to detect the presence of blood.

- The Blue-Star test is a very sensitive indicator similar to uminal for dried and even washed blood. Spraying a suspected area with Blue-Star reagent can be achieved quickly and cause even old blood stains to glow (called *chemiluminescence*). The area must be very dark and your eyes conditioned to the darkness in order to see the luminescence. False positives can be caused by certain metals (Cu, Fe, Co), bleach, and sometimes even plaster walls.

  Substances other than blood, such as dry bleach residues and some plastics, can cause false positive results. A false positive is a test result that comes out positive when it is not. It is therefore sometimes necessary to run a different type of test.

- Commercial blood testing reagent – The hemoglobin found in red blood cells breaks down peroxides and gives off oxygen. Oxygen reacts with a chemical in a Hemastix™ test strip to turn it blue/green. So, if a sample is blood, the test strip turns blue/green; if the stain is not blood, no blue color will appear.
  - A Hemastix™ strip can be rubbed on the wet stain with a green to blue color denoting the presence of blood.

2. For each sample, use a Hemastix to determine whether the stain is blood or some other substance. Record your results, noting whether the Hemastix indicated the presence of blood.

3. Take your sample to the back room with Mrs. Damian to perform the BlueStar test. Record your results, noting whether the BlueStar indicated the presence of blood.

*LG: 7.2*
After a stain has been determined to be blood, the next step is to determine what blood type it is. A precipitin test is the standard method: it uses anti-serums that contains antibodies specific to human antigens; therefore, different types of blood will agglutinate (clump) in the various types of anti-serum. If the blood sample agglutinates, that means that the blood sample HAS that antigen on its blood cells. Remember that a single blood sample may agglutinate with one, two or all three of the anti-serums, or none of them.

Procedure

Liquid Blood
1. Obtain a well plate for each blood sample you will test. Place the plates on a piece of paper and label the plates by writing on the white paper.
2. Add 2-3 drops of each sample blood to each well of a well plate.
3. Add 3 drops of each of the anti-serums into the appropriate well of each plate. That is, the anti-A serum should be placed into the A well, the anti-B serum should be placed into the B well, and the anti-Rh serum should be placed into the Rh well.
4. Stir each well with a CLEAN, DRY toothpick for about 30 seconds. Observe the solution after being stirred and record whether it has agglutinated. Be sure that you use a new toothpick for each well! You should therefore be using 3 toothpicks for each well plate!
5. Once all three wells have been observed, combine the results to determine the overall blood type of each sample. Be sure to record the sample numbers!

Blood Stained Objects
You will be given the same three samples, but instead of using liquid blood, you will be provided either a Q-tip or a blood stained piece of fabric. As you know, CSI most often receive blood samples in one of these two ways; you are doing this part of the experiment so that you will know what results to expect, and so you can get a feel of how much water and serum you need to see those results.
6. Place the blood soaked object over one well at a time and place 2-3 drops of water from a dropper bottle on top of the blood-soaked object. Make sure at least a drop or two falls into each well.
7. Complete the procedure as above. Remember, you should see the SAME results as you did in steps 4 and 5; if you don’t, add more serum and/or place another drop of water onto the sample (while it is over the well plate).
Blood Spatter Analysis is a field of forensic science that deals with the physical properties of blood and the patterns produced under different conditions as a result of various forces applied to the source of blood. The patterns left by falling, projected, or smeared blood can help the forensic investigator interpret and reconstruct what has happened at a crime scene. Blood spatter patterns are often used to corroborate or refute the suspect's account of what happened. Careful observation of the position and shape of stain patterns can give information such as the direction of travel, the angle of impact, the position of origin, and the blood droplet's speed at the time of impact.

Early on the morning of July 4, 1954, police received a call from Dr. Sam Sheppard. He reported that his wife, Marilyn, was dead in the bedroom of their two-story lakefront home. He explained to police that the night before, Marilyn had left him on the couch and went to sleep in the twin bed next to Sam's. He fell asleep and awoke some time later, believing he heard his wife calling his name. He went upstairs and saw Marilyn covered with blood. He checked for her pulse and found none. Sheppard heard a noise below, ran downstairs and saw a form moving toward the lake. He chased the person across the lawn and down the steps leading to the beach. He struggled with a man, 6'3", middle aged, with dark bushy hair and a white shirt. Sheppard was choked to unconsciousness. Marilyn had 35 wounds to the head; blood drenched the walls, door, and bed where she lay. Her face was almost unrecognizable.

Sheppard served 10 years in prison before the U.S. Supreme Court ruled that his trial was tainted. The evidence was re-examined; blood spatters in the bedroom and blood drops throughout the house gave some of the most telling evidence. The expert, Dr. Paul Kirks, concluded that the killer could not have been Sheppard based on the fact that the blood spatter analysis conclusively demonstrated that the killer was left handed. Dr. Sheppard was right handed.
You will be conducting tests to determine the answer to the following questions:

- What is the effect of release height on the pattern left by drops of blood?
- How does the angle of impact affect the appearance of drops of blood?
- What is the effect of changing texture on the pattern left by drops of blood?
- How can the original position of blood be determined from blood spatter?

For each of the above questions, you will need to conduct a test and photograph the results using a Dinoscope or a camera. Each member of your group should answer the questions as you complete the procedure, and should glue a copy of the photos in their journal.

**Procedure 1: What is the effect of release height on the pattern left by drops of blood?**

Get a bottle of artificial blood and small white board. Tape a sheet of construction paper on the white board; write one or more group member’s names in a corner of the paper. Then, release a single drop of blood vertically onto the white board, from heights of 2.5 m, 2 m, 1.5 m, 1 m, and 0.5 m (label each spatter as you make it!). Take a single picture that includes all five spatter spots.

**Question:**
1. Describe the shape of each spatter stain and any patterns that you notice.

**Procedure 2: How does the angle of impact affect the appearance of drops of blood?**

Obtain another sheet of construction paper and again write your name(s) in one corner. Prop the board up so that it is resting at the angle you want to test (use a protractor to measure the angle). Then, release a single drop of blood onto the paper from a height of .5 m. Test angles 15°, 30°, 45°, 60°, and 75° (*all angles should be measured from the horizontal!*) label each spatter as you make it). Take a single picture that includes all five spatter spots.

**Question:**
2. Describe how the shape of each spatter stain changes as the angle with the horizontal increases.

**Procedure 3: What is the effect of changing texture on the pattern left by drops of blood?**

Release a single drop of blood vertically from a height of 1 m, having the drops land on two other surface textures. Take pictures of the spatter on each surface.

**Question:**
3. Compare these results to the results you got in the previous experiment. Comment on how texture might affect the shape and size of spatter stains.

(continued on next page)
Procedure 4: How can the original position of blood be determined from blood spatter?

Unscrew the lid of your bottle of blood. You will use a pipe cleaner to flick drops of blood onto the floor, being sure to keep your arm stationary as you fling the blood (just flick your wrist). Before you fling the blood, mark on the floor (using wet-erase marker) the location of your hand as you fling the blood. Your blood spatter should include at least 10 spatter stains; ask Mrs. Damian if your spatter is sufficient before attempting to photograph or answer the questions! When you are done, WIPE UP YOUR BLOOD SPATTER!

**Question:**
4. Begin by looking at just a single drop of blood. Summarize how the shape of the blood is related to the direction the blood is traveling in.

Use a wet erase maker and a meter stick to draw a straight line from the spatter backwards to the point of release (by using the logic you summarized in question 4). Repeat this process for at least three other spatter stains.

**Questions:**
5. Summarize how a serologist could use the shape of spatter stains to pinpoint an approximate location of the origin of the blood.

**Day 2: Quantitative Questions**
The questions you have answered so far were all qualitative – observations that are made without taking measurements. Use your blood spatter drops on the construction paper (from Procedures 1 and 2) to answer then

Using the construction paper from the first procedure,
6. Prepare a line graph that shows the relationship between the height from which the drop fell and the measured diameter of the spatter.
7. Use the graph to predict the diameter of the spatter if it fell from 1.7 m.

Using the construction paper from the second procedure,
8. Calculate the length to width ratio (divide the length of the spatter, in cm, by the width of the spatter, in cm) for each angle.
9. Does the length to width ratio increase or decrease as the angle from the horizontal gets larger?

\[LG: 0.4, 0.5, 7.2\]
Two men get into an altercation over a woman. The men, named Ted and Jim, have been dating the same woman, named Sally. Neither man knew about the other until Ted saw Jim and Sally together on a date.

Ted followed Jim to his apartment and confronted Jim about his interest in Sally. After several minutes of arguing, a fight broke out. The men were equally matched in that both men are in their late 20’s, athletic, and about 6 feet tall.

One of Jim’s neighbors called the police after he heard yelling combined with the sounds of a fight.

The police arrived and found Jim leaning up against the wall, near the north door of the dining area. His face was puffy and the knuckles on his right hand were scraped raw. He was breathing heavily. They also observed Ted unconscious on the floor; blood was apparent both on his chest and his nose.

Paramedics were called to the scene and rendered assistance to both men. Ted was transported to a local hospital where he regained consciousness several hours later, but he did not remember what happened.

Jim tells the officers the following story:

“Ted showed up at my apartment and wanted to talk about my relationship with Sally. Ted attacked me and in the ensuing fight I injured Ted. I first grabbed a vase from the table and swung it low – just to try and get him to back away. The vase crashed against his legs, though, and cut him. After a short scuffle, I hit Ted very hard in the face, causing his nose to started bleeding. That’s when he fell and went unconscious. I was about to call for help when the officers arrived.”

Due to Ted’s condition at the time the police arrived, the scene was secured as a crime scene and investigated accordingly. However, nobody was arrested at that time.

Crime scene technicians documented the bloodstain patterns and created a sketch that, other than the size of the bloodstains, is to scale. The well-formed bloodstains are shown at the bottom of the sketch and provided in magnified form so that you can make the measurements needed for estimating impact angles. The satellite spatter you see is provided to help you determine the direction of travel.

Examine the sketch and the bloodstain spatter on page 78, then answer the questions found on page 79.
Enlarged Blood Spatter
Conclusions

1. Cut out the sketch and bloodstains and glue them in your journal.

2. On the sketch, use a straight edge to trace the direction of each drop of blood before it hit the floor.

3. How many events probably occurred? Explain your reasoning.

4. Based on the police interview with Jim and your answers to the above questions, determine the order of events. Label the first event “A” and the second event “B”, and briefly describe what happened at each location.

5. Make length and width measurements for each bloodstain. Then, calculate the length to width ratio for each bloodstain.

6. Which event began higher, Event A or Event B? Explain your reasoning.

7. Compare Jim’s statement with the information you generated from the analysis you’ve done so far. Does the evidence support Jim’s statement? Explain why.

LG: 7.3