Often times, during a criminal investigation, police and crime scene investigators must use all available tools and pieces of evidence to work backwards and create the most likely scenario as to what might have occurred. By examining a crime scene and collecting any traces of evidence, such as hair, fibers, blood, fingerprints, or broken glass, investigators attempt to not only determine what may have happened, but also look for evidence to tie the crime back to possible suspects.

The reason this evidence is so valuable is because of Locard's Principle. Edmond Locard was director of police investigative laboratory in France during the early 1900s. According to Locard, "There is no such thing as a clean contact between two objects. When two bodies or objects come into contact, they mutually contaminate each other with minute fragments of material."

Based on Locard's reasoning, during the commission of a crime, the perpetrator is likely to leave some material at the scene, such as hair, fibers, DNA, or fingerprints. The perpetrator is also likely to leave the scene of the crime with materials that may have been present, such as fibers, broken glass fragments, animal or human hair, or specific soils, if the crime was committed outdoors. Using all available evidence, the investigator then attempts to establish a link between suspected perpetrators and materials at the scene.

One type of trace evidence, glass, is often used to establish a connection between suspect and scene. Glass may be very prevalent in burglaries, which may involve the breaking of windows to gain entry, or in car accidents, such as hit-and-runs, which may result in broken headlights or car windows. The ability to show that the glass fragments taken from a suspect match the glass at a crime scene or that glass at an accident scene matches that of the glass found on a suspect's car can help support the link between suspect and scene.

What Is Glass?

On a basic level, glass is formed when silica (sand) is fused with some sort of oxide, such as boric oxide or lead oxide. Other materials may be added to give the glass different properties. The glass may also be manufactured under different conditions, such as thermal or chemical treatments being applied during manufacture. All of these factors create a large variability in the properties of different types of glass.
Three properties used when investigating glass are the refractive nature of the glass (the way light passes through it), the density of the glass, and the way the glass breaks. Other properties are also examined, such as the microscopic nature of the surface of the glass, which may yield evidence as to the nature of the manufacture of the glass or the source of glass. For example, a curved surface may lead investigators to conclude that glass a scene is from a source such as bottle or jar as opposed to a broken window, which would likely be flat. Patterns on the surfaces of the glass may be indicative of a certain type of architectural glass or unique type of headlight or taillight from a specific car manufacturer.

**Refractive Index**

As previously mentioned, refractivity refers to the way light passes through the glass. More specifically, refractivity refers to the way the glass bends the light as it passes through. Variations in composition cause glass to bend light differently as it passes through. The extent to which glass bends light is referred to as its refractive index and is a quantifiable measurement, called the refractive index.

In order to measure the refractivity of a glass sample, scientists will often employ a special set of solutions, called refractive index standards. Like glass, liquids also have specific refractive properties. Using a set of standard liquids, with known refractive properties, scientists will add the glass evidence and observe.

If glass refracts light differently than the known solution, light will pass into the solution being refracted and then be further refracted by the glass in the solution. This further refraction makes the glass visible in the solution. However, if the glass refracts light to the same extent as the solution, the light will enter the solution, being refracted, and then pass through the glass, not being refracted any further as the glass and solution refract light to the same degree, making the sample invisible or almost invisible in the solution.

Since the set of standard solutions have known refractive indices, the refractive index value of the solution in which the sample is therefore the refractive index value of the glass sample.

**Density**

Like the refractive index, which is affected by both the type and amount of material of which the glass is composed, the density of the glass is also affected by composition. Not only do different types of glass have different densities but even the same types of glass can display different densities depending on the percentages of materials used. Like refractive index in another way, density measurements can also provide quantifiable results through measurement. Another advantage of density measurements is that they are not affected by the size or shape of the material on which the measurements are being performed. This is very important in that possible glass evidence recovered at a crime scene can vary greatly in both amount and shape of the recovered materials.

The easiest method of measuring the density of a sample is to first determine the mass of the sample and then determine the volume of the sample. Mass is simply determine
by weighing the sample on an analytical balance. The volume can then be determined by placing the sample in graduated measuring cylinder with water. After first recording the volume of water in the cylinder, the sample is added to the cylinder and the amount of water the sample displaces is determined, representing the volume of the sample. The mass of the sample is divided by the volume of the sample yielding the density of the glass in question.

Shattered Glass

Broken glass is not uncommon at certain types of crime scenes, such as car accidents or burglaries. Like the refractive index or density of the glass, the way glass breaks can yield valuable information. Unlike the two former measurements, however, the analysis of broken glass tends to be less quantifiable and a little more subjective. Ideally, a criminal investigator would like to recover glass fragments from a crime scene and suspect, fit them together, much like a jigsaw puzzle, and show the link between suspect and scene. Unfortunately, the amount of evidence may be small and this is not always possible. However, analysis can still yield usable results.

Like the other properties of glass, the way the glass breaks is also affected by composition. The materials used in the manufacture of the glass affects how easily it will break, the degree to which it may break (e.g. shatter into many small fragments or several large fragments), or even the shape of the broken glass pieces. Again, since there may be unknown factors affecting the broken glass, such as the force with which the glass was broken or the item that may have broken the glass, this analysis may or may not be helpful in supporting a case against a suspect.

Fortunately, when glass is struck, it tends to break in a specific manner. This is especially true in regards to flat glass, such as window panes. Glass tends to be weaker under tension than under compression. When force is applied to glass, the side of the glass to which the force is applied is compressed, meaning a struck piece of glass will initially begin to break on the opposite side of applied force. The glass tends to fracture in a radial fashion outward from the point of impact, forming what are referred to as radial fractures. Between the radial fractures, secondary fracture often occur, called concentric fractures, on the side of the glass to which force was applied. This is roughly analogous to a spider web, with the radial fractures representing the long strands of web radiating from the center and the concentric fractures representing the connecting circular pieces of web.
While most of the broken glass is projected outward, the concentric fractures can cause some of the glass to be projected inward, possibly leaving evidence trapped in the hair or clothing of a perpetrator.

Other types of glass can also show a discreet pattern of fracture. Heat-tempered glass (sometimes called safety glass) tends to break into small cube-like pieces when struck. Designed and manufactured to break in this fashion, heat-tempered glass is used in car windows and windshields as a safety measure. In the case of car accidents that may involve broken windows and flying glass, these cube-like pieces are likely to be less dangerous than small, sharp triangular pieces of projected glass.

While broken windshield glass at a crime scene (e.g. hit-and-run accident) and pieces which may be found in suspects' car are probably not enough to prove link, investigators may also examine the surface of the broken glass pieces. Imperfections in the manufacture, or distinct marks and scratches, which may have been caused by debris on a windshield wiper, might be used to suggest a possible link. When combined with refraction and density measurements, suggesting the glass was from the same source, or at least same manufacturer, this evidence may be strong enough to support a link between suspect and crime scene.

**Summary**

When examining a crime scene, it is the role of the investigators to collect and analyze all possible evidence present. While some types of evidence may be very strong, such as fingerprints and DNA, other evidence may be less compelling. Yet when all available evidence is combined, such as broken glass, hair and fibers, traces of chemicals, such as cleaning chemicals that may be present at the crime scene and on the suspect, it may be possible to suggest a strong enough link to pursue the case in a court of law.
Procedure

Part I: Physical Observations

Materials Needed per Group

Borosilicate Glass Beads
Flint Glass Beads
Soda-lime Glass Beads
Magnifying Lens

1. Obtain 3-4 of each of borosilicate, flint, and soda-lime glass beads.

2. Observe each type of glass using a hand magnifying lens. Be sure to note any physical characteristics, such as color, clarity, surface texture, etc.

3. Record your observations in the Data Analysis sheet.

4. Optional: If a UV light source is available, expose each type of glass to UV light and record your observations in Data Analysis sheet. DO NOT look directly into the UV light source.

Part II: Density of Glass

Materials Needed per Group

Borosilicate Glass Beads
Flint Glass Beads
Soda-lime Glass Beads
10 ml graduated cylinder
Balance
Water

1. Add approximately 3 ml of water to the graduated cylinder. Record the volume to the nearest 0.01 ml in the Data Analysis sheet.

2. Using a balance, determine the mass of the cylinder and water. Record the mass in the Data Analysis sheet.
3. Add enough borosilicate glass beads to increase the volume of water in the cylinder to about 5 ml. Record the new volume, to the nearest 0.01 ml, in the Data Analysis sheet.

4. Using a balance, determine the mass of the cylinder, water, and glass beads. Record the mass in the Data Analysis sheet.

5. Determine the mass of the glass beads by subtracting the initial mass of the water and cylinder from the mass of the water, cylinder, and glass beads. Record the mass of the glass beads in the Data Analysis sheet.

6. Determine the volume of the glass beads by subtracting the initial volume of water in the cylinder from the volume after the glass beads were added. Record the volume of glass beads in the Data Analysis sheet.

7. Calculate the density of the glass by dividing the mass of the glass beads by the volume of the glass beads. Record the density in the Data Analysis sheet.

8. Add more borosilicate glass beads until the volume of water is increased by about another 2 ml. Record the new volume, to the nearest 0.01 ml, in the Data Analysis sheet.

9. Using a balance, determine the mass of the cylinder, water, and glass beads. Record the mass in the Data Analysis sheet.

10. Repeat the procedure for determining density. Record your results in the Data Analysis sheet.

11. Determine the average for both trials by adding both density readings and dividing by two. Record this result in the Data Analysis sheet.

12. Repeat steps 1-11 for both the flint glass beads and the soda-lime glass beads.

Part III: Refractive Index

Materials Needed per Group

Borosilicate Glass Beads
Flint Glass Beads
Soda-lime Glass Beads
3 test tubes
2-3 ml each Refractive Index Solutions

1. Obtain 3 test tubes. Using a small piece of tape, label each tube with “RI1”, “RI2”, and “RI3.”
2. Add several milliliters of each Refractive Index Standard Solution to their respective test tubes.

3. Place a few borosilicate glass beads in each of the labeled test tubes. Examine each of the tubes, with the added glass beads, and record your observations in the Data Analysis sheet.

4. Repeat step 3 for both the flint glass beads and the soda-lime glass beads. Be sure to record your observations.