"Criminalists".

- In Section 1 of this course you will cover these topics:
- Introduction
- The Crime Scene
- Physical Evidence
- Physical Properties: Glass And Soil

Topic : Introduction

Topic Objective:

After studying this topic the student should be able to:

- Define and distinguish forensic science and criminalistics
- Recognize the major contributors to the development of forensic science
- Account for the rapid growth of forensic laboratories in the past forty years
- Compare and contrast the Frye and Daubert decisions relating to the admissibility of scientific evidence in the courtroom
- Explain the role and responsibilities of the expert witness

Definition/Overview:

Algor mortis: Postmortem changes that cause a body to lose heat.

Autopsy: The medical dissection and examination of a body in order to determine the cause of death.

Expert Witness: An individual whom the court determines to possess knowledge relevant to the trial that is not expected of the average layperson.

Livor Mortis: The medical condition that occurs after death and results in the settling of blood in areas of the body closest to the ground.

Locards Exchange Principle: Whenever two objects come into contact with one another, there is exchange of materials between them.

Rigor Mortis: The medical condition that occurs after death and results in the stiffening of muscle mass. The rigidity of the body gradually disappears 24 hours after death.

Key Points:

1. Criminalistics

Criminalistics is the forensic science of analyzing and interpreting evidence using the natural sciences. Forensic science pertains to all sciences applied to legal problems. CRIMINALISTS use the science of criminalistics to solve crimes. They examine and identify physical evidence to reconstruct a crime scene. Physical evidence can be a weapon, a piece of clothing, a bloodstain, drugs, or even a vapor in the air. Criminalists use this physical evidence to provide a link between a suspect and the victim. The transfer of clothing fibers or hair fibers between a suspect

and the victim can provide just such a link. Fingerprints, bullets, and shoe impressions are other important links.

Physical evidence is collected from a crime scene that includes the victim's body and the surrounding area of the crime. Criminalists collect physical evidence at crime scenes and receive evidence at the laboratory, which has been collected at the crime scene by crime scene investigators. The proper collection of evidence is essential to prevent contamination and destruction of the evidence. Once the evidence is brought to the crime lab, Criminalists conduct tests depending on the type of evidence. Criminalists are often called to court to provide expert testimony regarding their methods and findings.

Serology is the analysis of body fluid evidence that includes bloodstains, semen stains, and saliva. To determine the identity and origin of the substance, Criminalists analyze blood dried into fabrics or other objects, as well as cigarette butts that may contain saliva residues. Sometimes the stain is not visible to the naked eye. Blood is usually visible due to its color, but often an artificial forensic light source is necessary to see other body fluid evidence. The stained evidence must remain dry and be stored at a cold temperature to maintain its integrity.

DNA typing is possible with a sample of body fluid such as blood, saliva, or semen. DNA typing provides a Criminalist with a genetic blueprint that is unique to each person. Criminalists then try to match the DNA typing results with a suspect. Proper handling and storage is essential to preserve DNA test samples.

Trace evidence is the analysis of hairs, fibers, paint, glass, wood, and soil that are present at a crime scene. Examination of trace evidence helps to establish a relationship between a suspect and the victim. A fiber may be taken from the victim's body revealing the type of fiber from carpet unique to the make and model of the suspect's car. Once trace evidence is discovered, a

Criminalist or other investigator collects the evidence from the crime scene by using a pair of jeweler's tweezers and immediately places the evidence in a folded paper cone and then into a sealed evidence envelope. Trace evidence is later analyzed at the crime lab to determine its composition and origin.

Firearms and toolmarks analysis involves the examination of any firearm that is suspected of being used in a criminal act. Criminalists can determine the kind of bullet used and whether it was fired from the gun used to commit the crime. Toolmark analysis includes any object suspected of containing the impression of another object that served as a tool in the commission of a crime. For instance, a screwdriver makes a distinctive impression when scraped along the surface of a wall. A Criminalist will analyze the marks the screwdriver left behind.

Impression evidence is the evaluation of impressions made by shoes, tires, depressions in soft soils, and all other forms of tracks and impressions. Glove and other fabric impressions, as well as bite marks in skin or food, are included. Criminalists also obtain impressions of dust from surfaces to reveal fingerprints.

Drug identification is used by Criminalists to analyze and identify illegal substances such as cocaine, heroin, and marijuana, that are found in plastic bags or vials at crime scenes. Criminalists must interpret the results of drug analyses in order to determine their significance to the case.

2. History of Forensic Science

The "Eureka" legend of Archimedes (287-212 BC) can be considered an early use of forensic anthropology. He determined that a crown was not completely made up of gold (as it was fraudulently claimed). This conclusion was reached by evaluating the density of the object using measurements of its displacement and its weight, as he was not allowed to damage the

crown.The earliest account of fingerprint use to establish identity was during the 7th century. According to an Arabic merchant, Soleiman, a debtor's fingerprints were affixed to a bill, which would then be given to the lender. This bill was legally recognized as proof of the validity of the debt.

The first written account of using medicine and entomology to solve (separate) criminal cases is attributed to the book Xi Yuan Ji Lu (translated as "Collected Cases of Injustice Rectified"), written in Song Dynasty China by Song Ci (1186-1249) in 1248. In one of the accounts, the case of a person murdered with a sickle was solved by a death investigator who instructed everyone to bring his sickle to one location. Flies, attracted by the smell of blood, eventually gathered on a single sickle. In light of this, the murderer confessed. The book also offered advice on how to distinguish between a drowning (water in the lungs) and strangulation (broken neck cartilage), along with other evidence from examining corpses on determining if a death was caused by murder, suicide, or an accident.

In sixteenth century Europe, medical practitioners in army and university settings began to gather information on cause and manner of death. Ambroise Par, a French army surgeon, systematically studied the effects of violent death on internal organs. Two Italian surgeons, Fortunato Fidelis and Paolo Zacchia, laid the foundation of modern pathology by studying changes which occurred in the structure of the body as the result of disease. In the late 1700s, writings on these topics began to appear. These included: "A Treatise on Forensic Medicine and Public Health" by the French physician Fodr, and "The Complete System of Police Medicine" by the German medical expert Johann Peter Franck.

In 1776, Swedish chemist Carl Wilhelm Scheele devised a way of detecting arsenous oxide, simple arsenic, in corpses, although only in large quantities. This investigation was expanded, in 1806, by German chemist Valentin Ross, who learned to detect the poison in the walls of a victim's stomach, and by English chemist James Marsh, who used chemical processes to confirm arsenic as the cause of death in an 1836 murder trial.

Two early examples of English forensic science in individual legal proceedings demonstrate the increasing use of logic and procedure in criminal investigations. In 1784, in Lancaster, England, John Toms was tried and convicted for murdering Edward Culshaw with a pistol. When the dead body of Culshaw was examined, a pistol wad (crushed paper used to secure powder and balls in

the muzzle) found in his head wound matched perfectly with a torn newspaper found in Toms' pocket. In Warwick, England, in 1816, a farm labourer was tried and convicted of the murder of a young maidservant. She had been drowned in a shallow pool and bore the marks of violent assault. The police found footprints and an impression from corduroy cloth with a sewn patch in the damp earth near the pool. There were also scattered grains of wheat and chaff. The breeches of a farm labourer who had been threshing wheat nearby were examined and corresponded exactly to the impression in the earth near the pool. Later in the 20th century, several British pathologists, Bernard Spilsbury, Francis Camps, Sydney Smith and Keith Simpson would pioneer new forensic methods in Britain.

3. Frye and Daubert

Prior to Daubert, relevancy in combination with the Frye test were the dominant standards for determining the admissibility of scientific evidence in Federal courts. Frye is based on a 1923 Federal Court of appeals ruling involving the admissibility of polygraph evidence. Under Frye, the Court based the admissibility of testimony regarding novel scientific evidence on whether it has "gained general acceptance in the particular field in which it belongs." The trial court's gatekeeper role in this respect is typically described as conservative, thus helping to keep pseudoscience out of the courtroom by deferring to those in the field.

In Daubert, the Supreme Court ruled that the 1923 Frye test was superseded by the 1975 Federal Rules of Evidence, specifically Rule 702 governing expert testimony. Rule 702 originally stated (in its entirety),

> "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise."

In Daubert, the Court ruled that nothing in the Federal Rules of Evidence governing expert evidence "gives any indication that 'general acceptance' is a necessary precondition to the admissibility of scientific evidence. Moreover, such a rigid standard would be at odds with the Rules' liberal thrust and their general approach of relaxing the traditional barriers to 'opinion'

testimony." However, some legal commentators argue that Daubert has resulted in a more conservative rather than liberal standard regarding the admissibility of expert evidence.

The Daubert standard was refined by two additional Supreme Court rulings; together known as the "Daubert trilogy." In General Electric Co. v. Joiner, the Supreme Court held that an abuse-of-discretion standard of review was the proper standard for appellate courts to use in reviewing a trial court's decision of whether expert testimony should be admitted. Thus, appellate courts must defer to the lower trial court's decision regarding the admissibility of expert testimony unless they are strikingly wrong. In Kumho Tire Co. v. Carmichael the Supreme Court held that the judges gatekeeping function identified in Daubert applies to all expert testimony, including that which is non-scientific.

In 2000, the Supreme Court approved amendments to the Federal Rules of Evidence relating to opinion evidence and expert testimony to conform to the "Daubert trilogy." In addition to amending Rules 701 and 703, Rule 702 now includes the additional provisions which state that a witness may only testify if, "1) the testimony is based upon sufficient facts or data 2) the testimony is the product of reliable principles and methods, and 3) the witness has applied the principles and methods reliably to the facts of the case."

The Daubert decision was heralded by many observers as one of the most important Supreme Court decisions of the last century imparting crucial legal reforms to reduce the volume of what has disparagingly been labeled junk science in the court room. Many of these individuals were convinced by Peter Hubers 1991 book Galileos Revenge: Junk Science in the Courtroom which argued that numerous product liability and toxic tort verdicts were unjustly made on the basis of junk science. According to Huber, junk science in the courts threatened not only justice but the workings of the American economy. This threat rested on two premises:

- Juries are not competent to recognize flaws in scientific testimony, especially toxic tort or product liability suits where decisions on causation rested on complex scientific issues.
- The result of junk science is the issuance of jury awards that deter manufacturers from introducing worthwhile products into the marketplace out of fear of unwarranted tort liability for injuries their products have not caused.

By requiring experts to provide relevant opinions grounded in reliable methodology, proponents of Daubert were satisfied that these standards would result in a fair and rational resolution of the scientific and technological issues which lie at the heart of product liability adjudication. According to a 2002 RAND study, post Daubert, the percentage of expert testimony by scientists that was excluded from the courtroom significantly rose. This rise likely contributed to a doubling in successful motions for summary judgment in which 90% were against plaintiffs. Beyond this study, there is little empirical evidence of the impact of Daubert. However, some critics argue that Daubert has disrupted the balance between plaintiffs and defendants, The exclusion of expert testimony affects plaintiffs far more than defendants because plaintiffs may then not be able to meet their required burden of proof. Furthermore, there is little point in plaintiffs going to the expense of Daubert motions to exclude defendants experts until they know if their case will proceed. So if more experts are now being excluded, then Daubert has undoubtedly shifted the balance between plaintiffs and defendants and made it more difficult for plaintiffs to litigate successfully. Similarly, Daubert hearings can be subject to various abuses by attorneys attempting to bolster a weak case. These tactics can range from simply attempting to delay the case to driving up the costs of the litigation forcing settlement.

A different pattern has emerged in criminal cases. In criminal cases, the prosecution has the burden of proof and uses a host of forensic science methods as evidence to prove their case. But, Daubert motions are rarely made by criminal defendants and when they do, they lose a majority of the challenges. Some critics of the use of unreliable science in court argue that Daubert has had beneficial effects in civil litigation, but fails to address the underlying pathologies of the forensic science system that leads to dubious verdicts in criminal cases.

Some commentators believe that Daubert caused judges to becomein the phrase used in former Chief Justice William Rehnquists dissent in Daubertamateur scientists, many lacking the scientific literacy to effectively fulfill their role as gatekeeper of scientific evidence. Although science for judges forums have emerged in the wake of Daubert in order to educate judges in a variety of scientific fields, many are still skeptical about the usefulness of the Daubert standard in discerning valid science.

To summarize, five cardinal points Daubert asks of every new technique in order to be admissible in court are:

- Has the technique been tested in actual field conditions (and not just in a laboratory)? [e.g. fingerprinting has been extensively tested and verified not only in laboratory conditions, but even in actual criminal cases. So it is admissible. Polygraphy on the other hand has been well tested in laboratories but not so well tested in field conditions]
- Has the technique been subject to peer review and publication?
- What is the known or potential rate of error? Is it zero, or low enough to be close to zero?
- Do standards exist for the control of the technique's operation? [e.g. the use of penile plethysmography for sex offender risk assessment is being used by different workers according to their own standards. Thus penile plethysmography does not meet Daubert criteria]
- Has the technique been generally accepted within the relevant scientific community? [this test was earlier the only relevant criterion under Frye]

  The Supreme Court explicitly cautioned that the Daubert list should not be regarded by judges as a definitive checklist or test Yet in practice, many judges regularly judge the admissibility of scientific evidence using the "Daubert factors" as a checklist.

4. Expert Witness

Typically, experts are relied on for opinions on severity of injury, degree of insanity, cause of failure in a machine or other device, loss of earnings, care costs, and the like. In an intellectual-property case, an expert may be shown two music scores, book texts, or circuit boards and asked to ascertain their degree of similarity.

The tribunal itself, or the judge, can in some systems call upon experts to technically evaluate a certain fact or action, in order to provide the court with a complete knowledge on the fact/action it is judging. The expertise has the legal value of an acquisition of data. The results of these experts are then compared to those by the experts of the parties.

The expert has a heavy responsibility, especially in penal trials, and perjury by an expert is a severely punished crime in most countries. The use of expert witnesses is sometimes criticized in the United States because in civil trials, they are often used by both sides to advocate differing positions, and it is left up to a jury of laymen to decide which expert witness to believe.

Sometimes one side has utilized an expert witness to provide fraudulent or junk science testimony in order to convince a jury. Such experts are commonly disparaged as "hired guns." In England and Wales, under the Civil Procedure Rules 1998 (CPR), an expert witness is required to be independent and address his or her report to the Court. A witness may be jointly instructed by both sides if the parties agree to this, especially in cases where the liability is relatively small.

Under the CPR, expert witnesses are usually instructed to produce a joint statement detailing points of agreement and disagreement to assist the court or tribunal. The meeting is held quite independently of instructing lawyers, and often assists in resolution of a case, especially if the experts review and modify their opinions. When this happens, substantial trial costs can be saved when the parties to a dispute agree to a settlement. In most systems, the trial (or the procedure) can be suspended in order to allow the experts to study the case and produce their results. More frequently, meetings of experts occur before trial.

Topic : The Crime Scene

Topic Objective:

After studying this topic the student should be able to:

- Define physical evidence
- Discuss the responsibilities of the first police officer who arrives at a crime scene
- Explain the steps to be taken to thoroughly record the crime scene
- Describe proper procedures for conducting a systematic search of a crime scene for physical evidence
- Describe proper techniques for packaging common types of physical evidence
- Define and understand the concept of chain of custody

Definition/Overview:

Buccal swab: A swab of the inner portion of the cheek; cheek cells are usually collected to determine the DNA profile of an individual.

Chain of custody: A list of all people who came into possession of an item of evidence.

Finished sketch: A precise rendering of the crime scene, usually drawn to scale.

Physical evidence: Any object that can establish that a crime has been committed or can link a crime and its victim or its perpetrator.

Rough sketch: A draft representation of all essential information and measurements at a crime scene. This sketch is drawn at the crime scene.

Standard/reference sample: Physical evidence whose origin is known, such as blood or hair from a suspect, that can be compared to crime-scene evidence.

Substrate control: Uncontaminated surface material close to an area where physical evidence has been deposited. This sample is to be used to ensure that the surface on which a sample has been deposited does not interfere with laboratory tests.

Key Points:

1. Physical evidence

Physical evidence is any evidence introduced in a trial in the form of a physical object, intended to prove a fact in issue based on its demonstrable physical characteristics. Physical evidence can conceivably include all or part of any object.

In a murder trial for example (or a civil trial for assault), the physical evidence might include DNA left by the attacker on the victim's body, the body itself, the weapon used, pieces of carpet spattered with blood, or casts of footprints or tire prints found at the scene of the crime.

Where physical evidence is of a complexity that makes it difficult for the average person to understand its significance, an expert witness may be called to explain to the jury the proper interpretation of the evidence at hand.

A piece of evidence is not physical evidence if it merely conveys the information that would be conveyed by the physical evidence, but in another medium. For example, a diagram comparing a defective part to one that was properly made is documentary evidenceonly the actual part, or a replica of the actual part, would be physical evidence. Similarly, a film of a murder taking place would not be physical evidence (unless it was introduced to show that the victims blood had splattered on the film), but documentary evidence (as with a written description of the event from an eyewitness).

2. First Police Officer

Most police investigations begin at the scene of a crime. The scene is simply defined as the actual site or location in which the incident took place. It is important that the first officer on the crime scene properly protect the evidence. The entire investigation hinges on that first person being able to properly identify, isolate, and secure the scene. The scene should be secured by establishing a restricted perimeter. This is done by using some type of rope or barrier. The purpose of securing the scene is to restrict access and prevent evidence destruction.

It is the duty of the first police officer on the scene to take any steps necessary to make certain that the scene is kept as undisturbed as possible. If there too much movement at the scene by too many people, vital evidence is likely to be moved or destroyed.**:**Securing a scene can be very

complicated say in the case of a fire or a road accident as the preservation of life will take precedence over anything else.

Once the scene is secured, the restrictions should include all nonessential personnel. An investigation may involve a primary scene as well as several secondary scenes at other locations. On major scenes a safe space or comfort area should be designated at the crime scene to brief investigators, store needed equipment, or as a break area.

In critical incident management the protocol that is being taught today identifies a three layer or tier perimeter. The outer perimeter is established as a border larger than the actual scene, to keep unlookers and nonessential personal safe and away from the scene, an inner perimeter allowing for a command post and comfort area just outside of the scene, and the core or scene itself. An extreme advantage will be seen by taking the time to properly teach the uniform officers and first responders to evaluate and secure the scene.

3. Recording a Crime Scene

Police officers and crime scene examiners will have limited time to investigate a scene, it is important therefore to record the scene, normally through still photography and videotaping by specialist photographers. Sketch diagrams and contemporaneous notes by attending police officers will also be important in recording the scene.

3.1 The Camera

Forensic photographers usually prefer to use 35 mm cameras, or medium format, as it tends to balance the portability and ease of use with quality images. When taking close-up photos of evidence, the camera is often mounted onto a tripod for stability to ensure the necessary quality required of photographs presented as evidence in court. Some forensic labs have their own darkroom facilities, which then enable photographers to develop the pictures themselves.

3.2 Digital Cameras

Digital cameras have a number of advantages when used in forensic photography as they require no chemical processing, can be displayed on the camera straight after being taken to ensure that the image was captured and the photos can be immediately transferred to a computer and stored in the database. However, digital photos are very easy to alter which therefore prevents them from being used as evidence in court.

3.3 Video Cameras

Video cameras also provide an easy and inexpensive way to document crime scenes and can give the jury with a more realistic sense of the crime scene than still pictures of a room. The zoom on video cameras are however,more often digital rather than optical and thus provide pictures of slightly less clarity than actual photographs. Videos are in general a good briefing tool for police officers who have not visited the crime scene.

3.4 Techniques

Close-up shots of evidence have precise requirements, such as exactness, angle taken and balance, in order to achieve the best possible shots. These pictures of evidence form a factual record and must be able to be reproduced in terms of size, shape and colour, thus, balance and accuracy is an absolute must. The use of basic camera flash and flood lights are quite sufficient for general crime scene photography, but close-up shots of evidence require careful lighting. Artificial sources of light have proved very useful in the photography of evidence. An example of this concerns oblique-angled light, whereby the light is angled or slanted towards the subject. This is used for bringing out the detail in textured surfaces, such as foot and shoe prints left in mud.

3.5 Light

With the help of coloured filters and adaptable light-guides, lamps can direct a narrow beam of light at the subject of the photograph to enhance the object details. Different light filters also allow for the exposure of distinct evidence. For example, ultraviolet light can make stains and fingerprints glow, violet makes gunshot residue and blood more visible and blue and green lights are used with enhanced fingerprints to show up

fibres and urine. This is because some materials absorb the ultraviolet light, while others reflect it, causing the material to become present under the ultraviolet light and flash of the camera when the photo is taken.

A crime scene is also documented by writing down what the scene was like upon discovery, sketching, videoing, evidence tables to document artifacts found, voice recording and witness interviews.

4. Systematic screening of the scene for evidence

Searching the crime scene is obviously important, how it is carried out depends on the scene. It may be as small and contained as a single room or it may be as large as a forest. It may include the dead (or living) body of the victim. Whatever the scene the search has to be as systematic and thorough as possible. Training is important, but so also is experience as it is often the experience eye which will pick up something that does not seem "quite right".

The goal of the evidence-collection stage is to find, collect and preserve all physical evidence that might serve to recreate the crime and identify the perpetrator in a manner that will stand up in court. Evidence can come in any form. Some typical kinds of evidence a CSI might find at a crime scene include:

- Trace evidence (gunshot residue, paint residue, broken glass, unknown chemicals, drugs)
- Impressions (fingerprints, footwear, tool marks)
- Body fluids (blood, semen, saliva, vomit)
- Hair and fibers
- Weapons and firearms evidence (knives, guns, bullet holes, cartridge casings)
- Questioned documents (diaries, suicide note, phone books; also includes electronic documents like answering machines and caller ID units)

With theories of the crime in mind, CSIs begin the systematic search for incriminating evidence, taking meticulous notes along the way. If there is a dead body at the scene, the search probably starts there.

4.1 Examining the body

A CSI might collect evidence from the body at the crime scene or he might wait until the body arrives at the morgue. In either case, the CSI does at least a visual examination of the body and surrounding area at the scene, taking pictures and detailed notes.

Before moving the body, the CSI makes note of details including:

- Are there any stains or marks on the clothing?
- Is the clothing bunched up in particular direction? If so, this could indicate dragging.
- Are there any bruises, cuts or marks on body? Any defense wounds? Any injuries indicating, consistent with or inconsistent with the preliminary cause of death?
- Is there anything obviously missing? Is there a tan mark where a watch or ring should be?
- If blood is present in large amounts, does the direction of flow follow the laws of gravity? If not, the body may have been moved.
- If no blood is present in the area surrounding the body, is this consistent with the preliminary cause of death? If not, the body may have been moved.
- Are there any bodily fluids present beside blood?
- Is there any insect activity on the body? If so, the CSI may call in a forensic entomologist to analyze the activity for clues as to how long the person has been dead.

After moving the body, he performs the same examination of the other side of the victim. At this point, he may also take the body temperature and the ambient room temperature to assist in determining an estimated time of death (although most forensic scientists say that time of death determinations are extremely unreliable -- the human body is unpredictable and there are too many variables involved). He will also take fingerprints of the deceased either at the scene or at the ME's office.

Once the CSI is done documenting the conditions of body and the immediately surrounding area, technicians wrap the body in a white cloth and put paper bags over the hands and feet for transportation to the morgue for an autopsy. These precautions are for the purpose of preserving any trace evidence on the victim. A CSI will usually attend the autopsy and take additional pictures or video footage and collect additional evidence, especially tissue samples from major organs, for analysis at the crime lab.

4.2 Examining the scene

There are several search patterns available for a CSI to choose from to assure complete coverage and the most efficient use of resources. These patterns may include:

Topic : Physical Evidence

Topic Objective:

After studying this topic the student should be able to:

- Review the common types of physical evidence encountered at crime scenes
- Explain the difference between the identification and comparison of physical evidence
- Define and contrast individual and class characteristics of physical evidence
- Appreciate the value of class evidence as it relates to a criminal investigation

Definition/Overview:

Class characteristics: Properties of evidence that can be associated only with a group and never with a single source.

Comparison: The process of ascertaining whether two or more objects have a common origin.

Identification: The process of determining a substances physical or chemical identity. Drug analysis, species determination, and explosive residue analysis are typical examples of this undertaking in a forensic setting.

Individual characteristics: Properties of evidence that can be attributed to a common source with an extremely high degree of certainty.

Product rule: Multiplying together the frequencies of independently occurring genetic markers to obtain an overall frequency of occurrence for a genetic profile.

Reconstruction: The method used to support a likely sequence of events by observing and evaluating physical evidence and statements made by those involved with the incident.

Key Points:

1. Physical Evidence

Physical evidence is any object that could link a suspect to a crime scene, a victim to a crime scene, or it can tell us something about whether a crime has taken place or not. Now, what is an object? That in itself is pretty interesting. An object can be anything such as a gun or it can be a bullet, but it also can be something as small as a human cell, because with current technology we can extract information from a single cell that can tell us something about the DNA type of an individual that was present at the crime scene. So I use the term 'object' very loosely. It can be anything from the large to the infinitely small.

2. Types of Physical Evidence

There are certain items that we see on a repeated basis at crime scenes, such as hairs, fibers, paint chips, glass, guns, bullets, cartridges, and different types of ropes. Also, what's interesting and very important are these carriers of physical evidence - things that we see at scenes that somebody may have touched with their lips or their fingers and have deposited a finger print or DNA onto. We're not going to know much about that until we get it back to the crime lab and we have it analyzed.

The types of physical evidence that can be collected from crime scenes vary greatly and depend heavily on location and type of crime. For example, the physical evidence available for collection at the scene of a robbery is quite different from that available at a murder scene. Physical evidence might include marks on a victim's body, such as abrasions or bite marks. Fingerprints on a door or a window frame also constitute physical evidence, as does blood left behind by a likely perpetrator. Trace evidence is a type of physical evidence that can be collected and forensically examined; this kind of evidence is commonly depicted in CSI episodes. Trace evidence is found when a small amount of material has transferred from either one location or person to another location or person. Examples of trace evidence include gunshot residue and fibers from clothing or carpeting.

2. Trace evidence

Trace evidence might include gun-shot residue (GSR), paint residue, chemicals, glass and illicit drugs. To collect trace evidence, a CSI might use tweezers, plastic containers with lids, a filtered vacuum device and a knife. He will also have a biohazard kit on hand containing disposable latex gloves, booties, face mask and gown and a biohazard waste bag.

If the crime involves a gun, the CSI will collect clothing from the victim and anyone who may have been at the scene so the lab can test for GSR. GSR on the victim can indicate a close shot, and GSR on anyone else can indicate a suspect. The CSI places all clothing in sealed paper bags

for transport to the lab. If he finds any illicit drugs or unknown powders at the scene, he can collect them using a knife and then seal each sample in a separate, sterile container. The lab can identify the substance, determine its purity and see what else is in the sample in trace amounts. These tests might determine drug possession, drug tampering or whether the composition could have killed or incapacitated a victim.

Technicians discover a lot of the trace evidence for a crime in the lab when they shake out bedding, clothing, towels, couch cushions and other items found at the scene. At the CBI Denver Crime Lab, technicians shake out the items in a sterile room, onto a large, white slab covered with paper.

The technicians then send any trace evidence they find to the appropriate department. In the Denver Crime Lab, things like soil, glass and paint stay in the trace-evidence lab, illicit drugs and unknown substances go to the chemistry lab, and hair goes to the DNA lab.

2.1. Body fluids

Body fluids found at a crime scene might include blood, semen, saliva, and vomit. To identify and collect these pieces of evidence, a CSI might use smear slides, a scalpel, tweezers, scissors, sterile cloth squares, a UV light, protective eyewear and luminol. He'll also use a blood collection kit to get samples from any suspects or from a living victim to use for comparison.

If the victim is dead and there is blood on the body, the CSI collects a blood sample either by submitting a piece of clothing or by using a sterile cloth square and a small amount of distilled water to remove some blood from the body. Blood or saliva collected from the body may belong to someone else, and the lab will perform DNA analysis so the sample can be used later to compare to blood or saliva taken from a suspect. The CSI will also scrape the victim's nails for skin -- if there was a struggle, the suspect's skin (and therefore DNA) may be under the victim's nails. If there is dried blood on any furniture at the scene, the CSI will try to send the entire piece of furniture to the lab. A couch is not an uncommon piece of evidence to collect. If the blood is on something that

can't reasonably go to the lab, like a wall or a bathtub, the CSI can collect it by scraping it into a sterile container using a scalpel. The CSI may also use luminol and a portable UV light to reveal blood that has been washed off a surface.

If there is blood at the scene, there may also be blood spatter patterns. These patterns can reveal the type of weapon that was used -- for instance, a "cast-off pattern" is left when something like a baseball bat contacts a blood source and then swings back. The droplets are large and often tear-drop shaped. This type of pattern can indicate multiple blows from a blunt object, because the first blow typically does not contact any blood. A "high-energy pattern," on the other hand, is made up of many tiny droplets and may indicate a gun shot. Blood spatter analysis can indicate which direction the blood came from and how many separate incidents created the pattern. Analyzing a blood pattern involves studying the size and shape of the stain, the shape and size of the blood droplets and the concentration of the droplets within the pattern. The CSI takes pictures of the pattern and may call in a blood-spatter specialist to analyze it.

2.2. Hair and Fibers

A CSI may use combs, tweezers, containers and a filtered vacuum device to collect any hair or fibers at the scene. In a rape case with a live victim, the CSI accompanies the victim to the hospital to obtain any hairs or fibers found on the victim's body during the medical examination. The CSI seals any hair or fiber evidence in separate containers for transport to the lab.

A CSI might recover carpet fibers from a suspect's shoes. The lab can compare these fibers to carpet fibers from the victim's home. Analysts can use hair DNA to identify or eliminate suspects by comparison. The presence of hair on a tool or weapon can identify it as the weapon used in the crime. The crime lab can determine what type of animal the hair came from (human? dog? cow?); and, if it's human, analysts can determine the person's race, what part of the body the hair came from, whether it fell out or was pulled and whether it was dyed.

2.3. Fingerprints

Tools for recovering fingerprints include brushes, powders, tape, chemicals, lift cards, a magnifying glass and Super Glue. A crime lab can use fingerprints to identify the victim or identify or rule out a suspect. There are several types of prints a CSI might find at a crime scene:

- Visible: Left by the transfer of blood, paint or another fluid or powder onto a surface that is smooth enough to hold the print; evident to the naked eye
- Molded: Left in a soft medium like soap, putty or candle wax, forming an impression
- Latent: Left by the transfer of sweat and natural oils from the fingers onto a surface that is smooth enough to hold the print; not visible to the naked eye

A perpetrator might leave prints on porous or nonporous surfaces. Paper, unfinished wood and cardboard are porous surfaces that will hold a print, and glass, plastic and metal are non-porous surfaces. A CSI will typically look for latent prints on surfaces the perpetrator is likely to have touched. For instance, if there are signs of forced entry on the front door, the outside door knob and door surface are logical places to look for prints. Breathing on a surface or shining a very strong light on it might make a latent print temporarily visible. When you see a TV detective turn a doorknob using a handkerchief, she's probably destroying a latent print. The only way not to corrupt a latent print on a non-porous surface is to not touch it. Proper methods for recovering latent prints include:

- Powder (for non-porous surfaces): Metallic silver powder or velvet black powder

A CSI uses whichever powder contrasts most with the color of material holding the print. He gently brushes powder onto the surface in a circular motion until a print is visible; then he starts brushing in the direction of the print ridges. He takes a photo of the print before using tape to lift it (this makes it stand up better in court). He adheres clear tape to the powdered print, draws it back in a smooth

motion and then adheres is to a fingerprint card of a contrasting color to the powder.

- Chemicals (for porous surfaces): Iodine, ninhydrin, silver nitrate
  The CSI sprays the chemical onto the surface of the material or dips the material into a chemical solution to reveal the latent print.
- Cyanoacrylate (Super Glue) fuming (for porous or non-porous surfaces)
  The CSI pours Super Glue into a metal plate and heats it to about 120 F. He then places the plate, the heat source and the object containing the latent print in an airtight container. The fumes from the Super Glue make the latent print visible without disturbing the material it's on.

2.4. Footwear Impressions and Tool Marks

A latent fingerprint is an example of a two-dimensional impression. A footwear impression in mud or a tool mark on a window frame is an example of a three-dimensional impression. If it's not possible to submit the entire object containing the impression to the crime lab, a CSI makes a casting at the scene.

A casting kit might include multiple casting compounds (dental gypsum, Silicone rubber), snow wax (for making a cast in snow), a bowl, a spatula and cardboard boxes to hold the casts.

If a CSI finds a footwear impression in mud, she'll photograph it and then make a cast. To prepare the casting material, she combines a casting material and water in a Ziploc-type bag and kneads it for about two minutes, until the consistency is like pancake batter. She then pours the mixture into the edge of the track so that it flows into the impression without causing air bubbles. Once the material overflows the impression, she lets it set for at least 30 minutes and then carefully lifts the cast out of the mud. Without cleaning

the cast or brushing anything off it (this would destroy any trace evidence), she puts the cast into a cardboard box or paper bag for transport to the lab.

For toolmark impressions, a cast is much harder to use for comparison than it is with footwear. If it's not feasible to transport the entire item containing the tool mark, a CSI can make a silicone-rubber cast and hope for the best. There are two types of tool marks a CSI might find at a crime scene:

- Impressed: A hard object contacts a softer object without moving back and forth (for example, a hammer mark on a door frame). The tool mark is an impression of the tool's shape. It's difficult to make a definite match with an impressed tool mark.
- Striated: A hard object contacts a softer object and moves back and forth (for example, pry marks on a window frame). The tool mark is a series of parallel lines. It's easier to make a definite match with a striated tool mark.

In toolmark analysis, the lab might determine what sort of tool made the mark and whether a tool in evidence is the tool that made it. It can also compare the tool mark in evidence to another toolmark to determine if the marks were made by the same tool.

2.5. Firearms

If a CSI finds any firearms, bullets or casings at the scene, she puts gloves on, picks up the gun by the barrel (not the grip) and bags everything separately for the lab. Forensic scientists can recover serial numbers and match both bullets and casings not only to the weapon they were fired from, but also to bullets and casings found at other crime scenes throughout the state (most ballistics databases are statewide). When there are bullet holes in the victim or in other objects at the scene, specialists can determine where and from what height the bullet was fired from, as well as the position of the victim when it was fired, using a laser trajectory kit**.** If there are bullets embedded in a wall or door frame, the CSI cuts out the portion of the wall or frame containing the bullet -- digging the bullet out can damage it and make it unsuitable for comparison.

2.6. Documents

A CSI collects and preserves any diaries, planners, phone books or suicide notes found at a crime scene. He also delivers to the lab any signed contracts, receipts, a torn up letter in the trash or any other written, typed or photocopied evidence that might be

related to the crime. A documents lab can often reconstruct a destroyed document, even one that has been burned, as well as determine if a document has been altered. Technicians analyze documents for forgery, determine handwriting matches to the victim and suspects, and identify what type of machine was used to produce the document. They can rule out a printer or photocopier found at the scene or determine compatibility or incompatibility with a machine found in a suspect's possession. Whenever a CSI discovers a piece of evidence at the scene, she photographs it, logs it, recovers it and tags it. An evidence tag may include identification information such as time, date and exact location of recovery and who recovered the item, or it may simply reflect a serial number that corresponds to an entry in the evidence log that contains this information. The **crime scene report** documents the complete body of evidence recovered from the scene, including the photo log, evidence recovery log and a written report describing the crime scene investigation.

2.7. Bite Marks

Bite marks are found many times in sexual assaults and can be matched back to the individual who did the biting. They should be photographed using an ABFO No. 2 Scale with normal lighting conditions, side lighting, UV light, and alternate light sources. Color slide and print film as well as black and white film should be used. The more photographs under a variety of conditions, the better. Older bitemarks which are no longer visible on the skin may sometimes be visualized and photographed using UV light and alternate light sources. If the bitemark has left an impression then maybe a cast can be made of it. Casts and photographs of the suspect's teeth and maybe the victim's teeth will be needed for comparison. For more information consult a forensic odontologist.

2.8. Fracture Matches

Fracture matches can positively link broken pieces at the scene with pieces found in the possession of a suspect. For example, headlight fragments found at the scene of a hit and run could be positively matched to a broken headlight (just like putting together a jigsaw puzzle) on a suspect's vehicle. Larger fragments should be placed in paper bags or envelopes. Smaller fragments should be placed in a paper packet and then placed in an envelope.

While searching the scene, a CSI is looking for details including:

- Are the doors and windows locked or unlocked? Open or shut? Are there signs of forced entry, such as tool marks or broken locks?
- Is the house in good order? If not, does it look like there was a struggle or was the victim just messy?
- Is there mail lying around? Has it been opened?
- Is the kitchen in good order? Is there any partially eaten food? Is the table set? If so, for how many people?
- Are there signs of a party, such as empty glasses or bottles or full ashtrays?
- If there are full ashtrays, what brands of cigarettes are present? Are there any lipstick or teeth marks on the butts?
- Is there anything that seems out of place? A glass with lipstick marks in a man's apartment, or the toilet seat up in a woman's apartment? Is there a couch blocking a doorway?
- Is there trash in the trash cans? Is there anything out of the ordinary in the trash? Is the trash in the right chronological order according to dates on mail and other papers? If not, someone might have been looking for something in the victim's trash.
- Do the clocks show the right time?
- Are the bathroom towels wet? Are the bathroom towels missing? Are there any signs of a cleanup?
- If the crime is a shooting, how many shots were fired? The CSI will try to locate the gun, each bullet, each shell casing and each bullet hole.
- If the crime is a stabbing, is a knife obviously missing from victim's kitchen? If so, the crime may not have been premeditated.
- Are there any shoe prints on tile, wood or linoleum floors or in the area immediately outside the building?
- Are there any tire marks in the driveway or in the area around the building?
- Is there any blood splatter on floors, walls or ceilings?

The actual collection of physical evidence is a slow process. Each time the CSI collects an item, he must immediately preserve it, tag it and log it for the crime scene record. Different types of evidence may be collected either at the scene or in lab depending on conditions and resources. Mr. Clayton, for instance, never develops latent fingerprints at the scene. He always sends fingerprints to the lab for development in a controlled environment. In the next section, we'll talk about collection methods for specific types of evidence.

5. Chain of custody

Chain of custody refers to the chronological documentation, and/or paper trail, showing the seizure, custody, control, transfer, analysis, and disposition of evidence, physical or electronic. Because evidence can be used in court to convict persons of crimes, it must be handled in a scrupulously careful manner to avoid later allegations of tampering or misconduct which can compromise the case of the prosecution toward acquittal or to overturning a guilty verdict upon appeal. The idea behind recording the chain of custody is to establish that the alleged evidence is in fact related to the alleged crime - rather than, for example, having been planted fraudulently to make someone appear guilty.

Establishing chain of custody is especially important when the evidence consists of fungible goods. In practice, this most often applies to illegal drugs which have been seized by law enforcement personnel. In such cases, the defendant at times disclaims any knowledge of possession of the controlled substance in question. Accordingly, the chain of custody documentation and testimony is presented by the prosecution to establish that the substance in evidence was in fact in the possession of the defendant.

An identifiable person must always have the physical custody of a piece of evidence. In practice, this means that a police officer or detective will take charge of a piece of evidence, document its collection, and hand it over to an evidence clerk for storage in a secure place. These transactions, and every succeeding transaction between the collection of the evidence and its appearance in court, should be completely documented chronologically in order to withstand legal challenges to the authenticity of the evidence. Documentation should include the conditions under which the

evidence is gathered, the identity of all evidence handlers, duration of evidence custody, security conditions while handling or storing the evidence, and the manner in which evidence is transferred to subsequent custodians each time such a transfer occurs (along with the signatures of persons involved at each step).

An example of "chain of custody" would be the recovery of a bloody knife at a murder scene: Officer Andrew collects the knife and places it into a container, then gives it to forensics technician Bill. Forensics technician Bill takes the knife to the lab and collects fingerprints and other evidence from the knife. Bill then gives the knife and all evidence gathered from the knife to evidence clerk Charlene. Charlene then stores the evidence until it is needed, documenting everyone who has accessed the original evidence (the knife, and original copies of the lifted fingerprints).

The chain of custody requires that from the moment the evidence is collected, every transfer of evidence from person to person be documented and that it be provable that nobody else could have accessed that evidence. It is best to keep the number of transfers as low as possible.
In the courtroom, if the defendant questions the chain of custody of the evidence it can be proven that the knife in the evidence room is the same knife found at the crime scene. However, if there are discrepancies and it cannot be proven who had the knife at a particular point in time, then the chain of custody is broken and the defendant can ask to have the resulting evidence declared inadmissible.
Chain of custody is also used in most chemical sampling situations to maintain the integrity of the sample by providing documentation of the control, transfer, and analysis of samples. Chain of custody is especially important in environmental work where sampling can identify the existence of contamination and can be used to identify the responsible party.

Physical Evidence

Topic Objective:

After studying this topic the student should be able to:

- Review the common types of physical evidence encountered at crime scenes
- Explain the difference between the identification and comparison of physical evidence
- Define and contrast individual and class characteristics of physical evidence
- Appreciate the value of class evidence as it relates to a criminal investigation

Definition/Overview:

Class characteristics: Properties of evidence that can be associated only with a group and never with a single source.

Comparison: The process of ascertaining whether two or more objects have a common origin.

Identification: The process of determining a substances physical or chemical identity. Drug analysis, species determination, and explosive residue analysis are typical examples of this undertaking in a forensic setting.

Individual characteristics: Properties of evidence that can be attributed to a common source with an extremely high degree of certainty.

Product rule: Multiplying together the frequencies of independently occurring genetic markers to obtain an overall frequency of occurrence for a genetic profile.

Reconstruction: The method used to support a likely sequence of events by observing and evaluating physical evidence and statements made by those involved with the incident.

Key Points:

1. Physical Evidence

Physical evidence is any object that could link a suspect to a crime scene, a victim to a crime scene, or it can tell us something about whether a crime has taken place or not. Now, what is an object? That in itself is pretty interesting. An object can be anything such as a gun or it can be a bullet, but it also can be something as small as a human cell, because with current technology we can extract information from a single cell that can tell us something about the DNA type of an individual that was present at the crime scene. So I use the term 'object' very loosely. It can be anything from the large to the infinitely small.

2. Types of Physical Evidence

There are certain items that we see on a repeated basis at crime scenes, such as hairs, fibers, paint chips, glass, guns, bullets, cartridges, and different types of ropes. Also, what's interesting and very important are these carriers of physical evidence - things that we see at scenes that somebody may have touched with their lips or their fingers and have deposited a finger print or DNA onto. We're not going to know much about that until we get it back to the crime lab and we have it analyzed.

The types of physical evidence that can be collected from crime scenes vary greatly and depend heavily on location and type of crime. For example, the physical evidence available for collection at the scene of a robbery is quite different from that available at a murder scene. Physical evidence might include marks on a victim's body, such as abrasions or bite marks. Fingerprints on a door or a window frame also constitute physical evidence, as does blood left behind by a likely perpetrator. Trace evidence is a type of physical evidence that can be collected and forensically examined; this kind of evidence is commonly depicted in CSI episodes. Trace evidence is found when a small amount of material has transferred from either one location or

person to another location or person. Examples of trace evidence include gunshot residue and fibers from clothing or carpeting.

2. Trace evidence

Trace evidence might include gun-shot residue (GSR), paint residue, chemicals, glass and illicit drugs. To collect trace evidence, a CSI might use tweezers, plastic containers with lids, a filtered vacuum device and a knife. He will also have a biohazard kit on hand containing disposable latex gloves, booties, face mask and gown and a biohazard waste bag.

If the crime involves a gun, the CSI will collect clothing from the victim and anyone who may have been at the scene so the lab can test for GSR. GSR on the victim can indicate a close shot, and GSR on anyone else can indicate a suspect. The CSI places all clothing in sealed paper bags for transport to the lab. If he finds any illicit drugs or unknown powders at the scene, he can collect them using a knife and then seal each sample in a separate, sterile container. The lab can identify the substance, determine its purity and see what else is in the sample in trace amounts. These tests might determine drug possession, drug tampering or whether the composition could have killed or incapacitated a victim.

Technicians discover a lot of the trace evidence for a crime in the lab when they shake out bedding, clothing, towels, couch cushions and other items found at the scene. At the CBI Denver Crime Lab, technicians shake out the items in a sterile room, onto a large, white slab covered with paper.

The technicians then send any trace evidence they find to the appropriate department. In the Denver Crime Lab, things like soil, glass and paint stay in the trace-evidence lab, illicit drugs and unknown substances go to the chemistry lab, and hair goes to the DNA lab.

2.1. Body fluids

Body fluids found at a crime scene might include blood, semen, saliva, and vomit. To identify and collect these pieces of evidence, a CSI might use smear slides, a scalpel, tweezers, scissors, sterile cloth squares, a UV light, protective eyewear and luminol. He'll also use a blood collection kit to get samples from any suspects or from a living victim to use for comparison.

If the victim is dead and there is blood on the body, the CSI collects a blood sample either by submitting a piece of clothing or by using a sterile cloth square and a small amount of distilled water to remove some blood from the body. Blood or saliva collected from the body may belong to someone else, and the lab will perform DNA analysis so the sample can be used later to compare to blood or saliva taken from a suspect. The CSI will also scrape the victim's nails for skin -- if there was a struggle, the suspect's skin (and therefore DNA) may be under the victim's nails. If there is dried blood on any furniture at the scene, the CSI will try to send the entire piece of furniture to the lab. A couch is not an uncommon piece of evidence to collect. If the blood is on something that can't reasonably go to the lab, like a wall or a bathtub, the CSI can collect it by scraping it into a sterile container using a scalpel. The CSI may also use luminol and a portable UV light to reveal blood that has been washed off a surface.

If there is blood at the scene, there may also be blood spatter patterns. These patterns can reveal the type of weapon that was used -- for instance, a "cast-off pattern" is left when something like a baseball bat contacts a blood source and then swings back. The droplets are large and often tear-drop shaped. This type of pattern can indicate multiple blows from a blunt object, because the first blow typically does not contact any blood. A "high-energy pattern," on the other hand, is made up of many tiny droplets and may indicate a gun shot. Blood spatter analysis can indicate which direction the blood came from and how many separate incidents created the pattern. Analyzing a blood pattern involves studying the size and shape of the stain, the shape and size of the blood droplets and the

concentration of the droplets within the pattern. The CSI takes pictures of the pattern and may call in a blood-spatter specialist to analyze it.

2.2. Hair and Fibers

A CSI may use combs, tweezers, containers and a filtered vacuum device to collect any hair or fibers at the scene. In a rape case with a live victim, the CSI accompanies the victim to the hospital to obtain any hairs or fibers found on the victim's body during the medical examination. The CSI seals any hair or fiber evidence in separate containers for transport to the lab.

A CSI might recover carpet fibers from a suspect's shoes. The lab can compare these fibers to carpet fibers from the victim's home. Analysts can use hair DNA to identify or eliminate suspects by comparison. The presence of hair on a tool or weapon can identify it as the weapon used in the crime. The crime lab can determine what type of animal the hair came from (human? dog? cow?); and, if it's human, analysts can determine the person's race, what part of the body the hair came from, whether it fell out or was pulled and whether it was dyed.

2.3. Fingerprints

Tools for recovering fingerprints include brushes, powders, tape, chemicals, lift cards, a magnifying glass and Super Glue. A crime lab can use fingerprints to identify the victim or identify or rule out a suspect. There are several types of prints a CSI might find at a crime scene:

- Visible: Left by the transfer of blood, paint or another fluid or powder onto a surface that is smooth enough to hold the print; evident to the naked eye
- Molded: Left in a soft medium like soap, putty or candle wax, forming an impression
- Latent: Left by the transfer of sweat and natural oils from the fingers onto a surface that is smooth enough to hold the print; not visible to the naked eye

A perpetrator might leave prints on porous or nonporous surfaces. Paper, unfinished wood and cardboard are porous surfaces that will hold a print, and glass, plastic and metal are non-porous surfaces. A CSI will typically look for latent prints on surfaces the perpetrator is likely to have touched. For instance, if there are signs of forced entry on the front door, the outside door knob and door surface are logical places to look for prints. Breathing on a surface or shining a very strong light on it might make a latent print temporarily visible. When you see a TV detective turn a doorknob using a handkerchief, she's probably destroying a latent print. The only way not to corrupt a latent print on a non-porous surface is to not touch it. Proper methods for recovering latent prints include:

- Powder (for non-porous surfaces): Metallic silver powder or velvet black powder

  A CSI uses whichever powder contrasts most with the color of material holding the print. He gently brushes powder onto the surface in a circular motion until a print is visible; then he starts brushing in the direction of the print ridges. He takes a photo of the print before using tape to lift it (this makes it stand up better in court). He adheres clear tape to the powdered print, draws it back in a smooth motion and then adheres is to a fingerprint card of a contrasting color to the powder.

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  The CSI sprays the chemical onto the surface of the material or dips the material into a chemical solution to reveal the latent print.

- Cyanoacrylate (Super Glue) fuming (for porous or non-porous surfaces)

  The CSI pours Super Glue into a metal plate and heats it to about 120 F. He then places the plate, the heat source and the object containing the latent print in an airtight container. The fumes from the Super Glue make the latent print visible without disturbing the material it's on.

2.4. Footwear Impressions and Tool Marks

A latent fingerprint is an example of a two-dimensional impression. A footwear

impression in mud or a tool mark on a window frame is an example of a three-dimensional impression. If it's not possible to submit the entire object containing the impression to the crime lab, a CSI makes a casting at the scene.

A casting kit might include multiple casting compounds (dental gypsum, Silicone rubber), snow wax (for making a cast in snow), a bowl, a spatula and cardboard boxes to hold the casts.

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For toolmark impressions, a cast is much harder to use for comparison than it is with footwear. If it's not feasible to transport the entire item containing the tool mark, a CSI can make a silicone-rubber cast and hope for the best. There are two types of tool marks a CSI might find at a crime scene:

- Impressed: A hard object contacts a softer object without moving back and forth (for example, a hammer mark on a door frame). The tool mark is an impression of the tool's shape. It's difficult to make a definite match with an impressed tool mark.
- Striated: A hard object contacts a softer object and moves back and forth (for example, pry marks on a window frame). The tool mark is a series of parallel lines. It's easier to make a definite match with a striated tool mark.

In toolmark analysis, the lab might determine what sort of tool made the mark and whether a tool in evidence is the tool that made it. It can also compare the tool mark in evidence to another toolmark to determine if the marks were made by the same tool.

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2.6. Documents

A CSI collects and preserves any diaries, planners, phone books or suicide notes found at a crime scene. He also delivers to the lab any signed contracts, receipts, a torn up letter in the trash or any other written, typed or photocopied evidence that might be related to the crime. A documents lab can often reconstruct a destroyed document, even one that has been burned, as well as determine if a document has been altered. Technicians analyze documents for forgery, determine handwriting matches to the victim and suspects, and identify what type of machine was used to produce the document. They can rule out a printer or photocopier found at the scene or determine compatibility or incompatibility with a machine found in a suspect's possession. Whenever a CSI discovers a piece of evidence at the scene, she photographs it, logs it, recovers it and tags it. An evidence tag may include identification information such as time, date and exact location of recovery and who recovered the item, or it may simply reflect a serial number that corresponds to an entry in the evidence log that contains this information. The **crime scene report** documents the complete body of evidence recovered from the scene, including the photo log, evidence recovery log and a written report describing the crime scene investigation.

2.7. Bite Marks

Bite marks are found many times in sexual assaults and can be matched back to the individual who did the biting. They should be photographed using an ABFO No. 2 Scale

with normal lighting conditions, side lighting, UV light, and alternate light sources. Color slide and print film as well as black and white film should be used. The more photographs under a variety of conditions, the better. Older bitemarks which are no longer visible on the skin may sometimes be visualized and photographed using UV light and alternate light sources. If the bitemark has left an impression then maybe a cast can be made of it. Casts and photographs of the suspect's teeth and maybe the victim's teeth will be needed for comparison. For more information consult a forensic odontologist.

2.8. Fracture Matches

Fracture matches can positively link broken pieces at the scene with pieces found in the possession of a suspect. For example, headlight fragments found at the scene of a hit and run could be positively matched to a broken headlight (just like putting together a jigsaw puzzle) on a suspect's vehicle. Larger fragments should be placed in paper bags or envelopes. Smaller fragments should be placed in a paper packet and then placed in an envelope.

Topic : Physical Properties: Glass And Soil

Topic Objective:

After studying this topic the student should be able to:

- Define and distinguish the physical and chemical properties of matter
- Understand how to use the basic units of the metric system
- Define and understand the properties of density and refractive index
- List and explain forensic methods for comparing glass fragments

Definition/Overview:

Amorphous solid: A solid in which the constituent atoms or molecules are arranged in random or disordered positions. There is no regular order in amorphous solids.

Atom: The smallest unit of an element; not divisible by ordinary chemical means. Atoms are made up of electrons, protons, and neutrons plus other subatomic particles.

Becke line: A bright halo that is observed near the border of a particle immersed in a liquid of a different refractive index.

Birefringence: A difference in the two indices of refraction exhibited by most crystalline materials.

Celsius scale: The temperature scale using the melting point of ice as 0 and the boiling point of water as 100, with 100 equal divisions or degrees between.

Chemical property: Describes the behavior of a substance when it reacts or combines with another substance.

Concentric fracture: A crack in a glass that forms a rough circle around the point of impact.

Crystalline solid: A solid in which the constituent atoms have a regular arrangement.

Density: A physical property of matter that is equivalent to the mass per unit volume of a substance.

Density-gradient tube: A glass tube filled from bottom to top with liquids of successively lighter densities; used to determine the density distribution of soil.

Dispersion: The separation of light into its component wavelengths.

Fahrenheit scale: The temperature scale using the melting point of ice as 32 and the boiling point of water as 212, with 180 equal divisions or degrees between.

Intensive property: A property that is not dependent on the size of an object.

Laminated glass: Two sheets of ordinary glass bonded together with a plastic film.

Mass: A constant property of matter that reflects the amount of material present.

Mineral: A naturally occurring crystalline solid.

Physical property: Describes the behavior of a substance without having to alter the substances composition through a chemical reaction.

Radial fracture: A crack in a glass that extends outward like the spoke of a wheel from the point at which the glass was struck.

Refraction: The bending of a light wave as it passes from one medium to another.

Refractive index: The ratio of the speed of light in a vacuum to its speed in a given substance.

Tempered glass: Glass that is strengthened by introducing stress through rapid heating and cooling of the glass surfaces.

Weight: A property of matter that depends on both the mass of a substance and the effects of gravity on that mass.

Key Points:

1. Property of matter

Anything that can be used to identify a piece of matter is a called a property. If the property can be measured without changing the composition of the matter, it is a physical property. Examples of physical properties include color and density. Melting temperature and boiling temperature are also physical properties, because changing between solid and liquid and gas does not change the identity of the substance (ice, water, and steam are all still water).

A property can also describe how a sample of matter changes into a substance with different physical properties. These are known as chemical properties. Examples of chemical properties include the ability to burn (reacting with oxygen and releasing heat), how a substance reacts to a specific chemical, and acid/base properties.

2. Phases of Matter

Each phase of matter has its own chemical and physical properties. The phases of matter you need to know are:

- Solid - a solid has a definite shape and volume
- Liquid - a liquid has a definite volume, but can change shape
- Gas - the shape and volume of a gas can change

3. Phase Changes

These phases of matter can change from one to another. Remember the definitions of the following phase changes:

- Melting - melting occurs when a substance changes from a solid to a liquid
- Boiling - boiling is when a substance changes from a liquid to a gas
- Condensing - condensation is when a gas changes to a liquid
- Freezing - freezing is when a liquid changes to a solid

4. Physical & Chemical Changes

The changes that take place in substances may be categorized in two classes:

- Physical Change - does not produce a new substance (e.g., phase changes, crushing a can)
- Chemical Change - produces a new substance (e.g., burning, rusting, photosynthesis)

5. Solutions

A solution results from combining two or more substances. Making a solution can produce either a physical or chemical change. You can tell them apart this way:

- The original substances can be separated from one another if the solution produces only a physical change.
- The original substances cannot be separated from one another if a chemical change took place.

6. Basic Units Of The Metric System

The metric system is a decimalised system of measurement. It exists in several variations, with different choices of base units, though the choice of base units does not affect its day-to-day use. Over the last two centuries, different variants have been considered the metric system. Since the 1960s the International System of Units ("Systme International d'Units" in French, hence "SI") has been the internationally recognised standard metric system. Metric units are widely used around the world for personal, commercial and scientific purposes. A standard set of prefixes in powers of ten may be used to derive larger and smaller units. However, the prefixes for multiples of one thousand are the most commonly used. According to the US CIA World Factbook in 2006, the International System of Units is the primary or sole system of measurement for all nations except for Myanmar, Liberia and the United States.

6.1 Replicable

The usual way to establish a standard was to make prototypes of the base units and distribute copies. This would make the new standard reliant on the original prototypes which would be in conflict with the previous goal since all countries would have to refer to the one holding the prototypes.

The designers developed definitions of the base units such that any laboratory equipped with proper instruments should be able to make their own models of them. The original base units of the metric system could be derived from the length of a meridian of the Earth and the weight of a certain volume of pure water. They discarded the use of a pendulum since its period or, inversely, the length of the string holding the bob for the same period changes around the Earth. Likewise, they discarded using the circumference of the Earth over the Equator since not all countries have access to the Equator while all countries have access to a section of a meridian.

6.2 Decimal multiples

The metric system is decimal, in the sense that all multiples and submultiples of the base units are factors of powers of ten of the unit. Fractions of a unit are not used formally. The practical benefits of a decimal system are such that it has been used to replace other non-decimal systems outside the metric system of measurements; for example currencies.

The simplicity of decimal prefixes encouraged the adoption of the metric system. Clearly the advantages of decimal prefixes derive from our using base 10 arithmetic. At most, differences in expressing results are simply a matter of shifting the decimal point or changing an exponent; for example, the speed of light may be expressed as 299,792.458 km/s or 2.9979245810^{8} m/s.

6.3 Prefixes

All derived units would use a common set of prefixes for each multiple. Thus the prefix kilo could be used both for mass (kilogram) or length (kilometre) both indicating a thousand times the base unit. This did not prevent the popular use of names for some derived units such as the tonne which is a megagram while a quintal is accepted as 100 kilograms; both are derived from old customary units and were rounded to metric.

The function of the prefix is to multiply or divide the measure by a factor of ten, one hundred or a positive integer power of one thousand. If the prefix is Greek-derived, the measure is multiplied by this factor. If the prefix is Latin-derived, it is divided, except

from division by 10^6 (micro~) which is also Greek-derived. The Greek prefix kilo~ and the Latin prefixes centi~ and milli~ are those most familiar from everyday use.

metre		(common base unit)
kilometre	= 1000 metres	
hectometre	= 100 metres	(not commonly used)
decametre	= 10 metres	(a measure used in naval artillery)
decimetre	= $^1\!/_{10}$ of a metre	
centimetre	= $^1\!/_{100}$ of a metre	
millimetre	= $^1\!/_{1000}$ of a metre	
micrometre	= $^1\!/_{1000000}$ of a metre	
nanometre	= $^1\!/_{1000000000}$ of a metre	(a measure used in nanotechnology)
litre		(common base unit)
kilolitre	= 1000 litres	(not commonly used)
hectolitre	= 100 litres	(used for beer kegs, 1 keg is approx. $^1\!/_2$ of a hectolitre)
decalitre	= 10 litres	(not a commonly used measure)
decilitre	= $^1\!/_{10}$ of a litre	
centilitre	= $^1\!/_{100}$ of a litre	

millilitre	= $^{1}\!/_{1000}$ of a litre	

Table 1. Prefixes

A similar application of Greek and Latin prefixes can be made with other metric measurements.

6.4 Practicality

The base units were chosen to be of similar magnitude to customary units. The metre, being close to half a toise (French yard equivalent), became more popular than the failed decimal hour of the Republican Calendar which was 2.4 times the normal hour. The kilometre was originally defined as the length of an arc spanning a decimal minute of latitude, a similar definition to that of the nautical mile which was the length of an arc of one (non-decimal) minute of latitude.

Originally, units for volume and mass were directly related to each other, with mass defined in terms of a volume of water. Even though that definition is no longer used, the relation is quite close at room temperature and nearly exact at 4 C. So as a practical matter, one can fill a container with water and weigh it to get the volume. For example,

Relations:			
1000 litres	= 1 cubic metre	≈ 1 ton of water	("cubic metre" is commonly used instead of "kilolitre")
1 litre	= 1 cubic decimetre	≈ 1 kilogram of water	
1 millilitre	= 1 cubic centimetre	≈ 1 gram of water	
1 microlitre	= 1 cubic millimetre	≈ 1 milligram of water	

Table 2. Relation of Different Units

7. Coincidental similarities

Two important values, when they were expressed in the metric system, turned out to be very close to a multiple of 10. The standard acceleration due to gravity on Earth g_n has been defined to be 9.80665 m/s exactly, which is the value at about 45 north or south of the equator. Accordingly the force exerted on a mass of one kilogram in Earth gravity (F = ma) is about ten newtons (kG-M/S). THIS SIMPLIFIED THe metrication of many machines such as locomotives, which were simply re-labelled from e.g. "85 tonnes" to "850 kN". A closer approximation is π m/s, which means a one-metre pendulum has a period of almost two seconds.

Also, the standard atmospheric pressure, previously expressed in atmospheres, when given in pascals, is 101.325 kPa. Since the difference between 10 atmospheres and 1 MPa is only 1.3%, many devices were simply re-labelled by dividing the scale by ten, e.g. 1 atm was changed to 0.1 MPa.

In addition, the speed of light in a vacuum turns out to be astonishingly close (0.07% error) to 310^8 m/s.
A useful conversion used in meteorology is 1 m/s ≈ 2 knots with less than a 3% error, actually 1.94384 knots (to 5 decimal places). The equivalent conversion for distance is not so "rounded", 1 nautical mile = 1.852 km (exactly) = 1 minute of arc Latitude (approximately).

8. Density And Refractive Index

The refractive index (or index of refraction) of a medium is a measure for how much the speed of light (or other waves such as sound waves) is reduced inside the medium. For example, typical soda-lime glass has a refractive index of 1.5, which means that in glass, light travels at 1 / 1.5 = 0.67 times the speed of light in a vacuum. Two common properties of glass and other transparent materials are directly related to their refractive index. First, light rays change direction when they cross the interface from air to the material, an effect that is used in lenses. Second, light reflects partially from surfaces that have a refractive index different from that of their surroundings.

The refractive index, n, of a medium is defined as the ratio of the phase velocity, c, of a wave phenomenon such as light or sound in a reference medium to the phase velocity, v_p, in the medium itself:

It is most commonly used in the context of light with vacuum as a reference medium, although historically other reference media (e.g. air at a standardized pressure and temperature) have been common. It is usually given the symbol n. In the case of light, it equals

,

where ε_r is the material's relative permittivity, and μ_r is its relative permeability. For most materials, μ_r is very close to 1 at optical frequencies, therefore n is approximately . Contrary to a widespread misconception, n may be less than 1, for example for x-rays. This has practical technical applications, such as effective mirrors for x-rays based on total external reflection. The phase velocity is defined as the rate at which the crests of the waveform propagate; that is, the rate at which the phase of the waveform is moving. The group velocity is the rate that the envelope of the waveform is propagating; that is, the rate of variation of the amplitude of the waveform. Provided the waveform is not distorted significantly during propagation, it is the group velocity that represents the rate that information (and energy) may be transmitted by the wave, for example the velocity at which a pulse of light travels down an optical fiber.

9. Speed of light

Refraction of light at the interface between two media of different refractive indices, with $n_2 > n_1$. Since the phase velocity is lower in the second medium ($v_2 < v_1$), the angle of refraction θ_2 is less than the angle of incidence θ_1; that is, the ray in the higher-index medium is closer to the normal.

The speed of all electromagnetic radiation in vacuum is the same, approximately 310^8 meters per second, and is denoted by c. Therefore, if v is the phase velocity of radiation of a specific frequency in a specific material, the refractive index is given by

or inversely

This number is typically greater than one: the higher the index of the material, the more the light is slowed down. However, at certain frequencies (e.g. near absorption resonances, and for X-rays), n will actually be smaller than one. This does not contradict the theory of relativity, which holds that no information-carrying signal can ever propagate faster than c, because the phase velocity is not the same as the group velocity or the signal velocity.
Sometimes, a "group velocity refractive index", usually called the group index is defined:

where v_g is the group velocity. This value should not be confused with n, which is always defined with respect to the phase velocity. The group index can be written in terms of the wavelength dependence of the refractive index as

where λ is the wavelength in vacuum. At the microscale, an electromagnetic wave's phase velocity is slowed in a material because the electric field creates a disturbance in the charges of each atom (primarily the electrons) proportional to the permittivity of the medium. The charges will, in general, oscillate slightly out of phase with respect to the driving electric field. The charges thus radiate their own electromagnetic wave that is at the same frequency but with a phase delay. The macroscopic sum of all such contributions in the material is a wave with the same frequency but shorter wavelength than the original, leading to a slowing of the wave's phase velocity. Most of the radiation from oscillating material charges will modify the incoming wave, changing its velocity. However, some net energy will be radiated in other directions.

If the refractive indices of two materials are known for a given frequency, then one can compute the angle by which radiation of that frequency will be refracted as it moves from the first into the second material from Snell's law.
If in a given region the values of refractive indices n or n_g were found to differ from unity (whether homogeneously, or isotropically, or not), then this region was distinct from vacuum in the above sense for lacking Poincar symmetry.

10. Negative refractive index

Recent research has also demonstrated the existence of negative refractive index which can occur if the real parts of both ε_r and μ_r are simultaneously negative, although such is a necessary but not sufficient condition. Not thought to occur naturally, this can be achieved with so-called metamaterials and offers the possibility of perfect lenses and other exotic phenomena such as a reversal of Snell's law.

11. Dispersion and absorption

In real materials, the polarization does not respond instantaneously to an applied field. This causes dielectric loss, which can be expressed by a permittivity that is both complex and frequency dependent. Real materials are not perfect insulators either, i.e. they have non-zero direct current conductivity. Taking both aspects into consideration, we can define a complex index of refraction:

Here, n is the refractive index indicating the phase velocity as above, while κ is called the extinction coefficient, which indicates the amount of absorption loss when the electromagnetic wave propagates through the material. Both n and κ are dependent on the frequency (wavelength). Note that the sign of the complex part is a matter of convention, which is important due to possible confusion between loss and gain. The notation above, which is usually used by physicists, corresponds to waves with time evolution given by $e^{-i\omega t}$.

The effect that n varies with frequency (except in vacuum, where all frequencies travel at the same speed, c) is known as dispersion, and it is what causes a prism to divide white light into its constituent spectral colors, explains rainbows, and is the cause of chromatic aberration in lenses. In regions of the spectrum where the material does not absorb, the real part of the refractive index tends to increase with frequency. Near absorption peaks, the curve of the refractive index is a complex form given by the KramersKronig relations, and can decrease with frequency. Since the refractive index of a material varies with the frequency (and thus wavelength) of light, it is usual to specify the corresponding vacuum wavelength at which the refractive index is measured. Typically, this is done at various well-defined spectral emission lines; for example, n_D is the refractive index at the Fraunhofer "D" line, the centre of the yellow sodium double emission at 589.29 nm wavelength.

The Sellmeier equation is an empirical formula that works well in describing dispersion, and Sellmeier coefficients are often quoted instead of the refractive index in tables. For some representative refractive indices at different wavelengths.
As shown above, dielectric loss and non-zero DC conductivity in materials cause absorption. Good dielectric materials such as glass have extremely low DC conductivity, and at low frequencies the dielectric loss is also negligible, resulting in almost no absorption ($\kappa \approx 0$). However, at higher frequencies (such as visible light), dielectric loss may increase absorption significantly, reducing the material's transparency to these frequencies.

The real and imaginary parts of the complex refractive index are related through use of the KramersKronig relations. For example, one can determine a material's full complex refractive index as a function of wavelength from an absorption spectrum of the material.

12. Relation to dielectric constant

The dielectric constant (which is often dependent on wavelength) is simply the square of the (complex) refractive index in a non-magnetic medium (one with a relative magnetic permeability of unity). The refractive index is used for optics in Fresnel equations and Snell's law; while the dielectric constant is used in Maxwell's equations and electronics.

Where , ε_1, ε_2, n, and κ are functions of wavelength:

Conversion between refractive index and dielectric constant is done by:

$$\varepsilon_1 = n^2 - \kappa^2$$

$$\varepsilon_2 = 2n\kappa$$

13. Anisotropy

A calcite crystal laid upon a paper with some letters showing birefringence

The refractive index of certain media may be different depending on the polarization and direction of propagation of the light through the medium. This is known as birefringence or anisotropy and is described by the field of crystal optics. In the most general case, the dielectric constant is a rank-2 tensor (a 3 by 3 matrix), which cannot simply be described by refractive indices except for polarizations along principal axes.

In magneto-optic (gyro-magnetic) and optically active materials, the principal axes are complex (corresponding to elliptical polarizations), and the dielectric tensor is complex-Hermitian (for lossless media); such materials break time-reversal symmetry and are used e.g. to construct Faraday isolators.

14. Nonlinearity

The strong electric field of high intensity light (such as output of a laser) may cause a medium's refractive index to vary as the light passes through it, giving rise to nonlinear optics. If the index varies quadratically with the field (linearly with the intensity), it is called the optical Kerr effect

and causes phenomena such as self-focusing and self-phase modulation. If the index varies linearly with the field (which is only possible in materials that do not possess inversion symmetry), it is known as the Pockels effect.

15. Inhomogeneity

If the refractive index of a medium is not constant, but varies gradually with position, the material is known as a gradient-index medium and is described by gradient index optics. Light traveling through such a medium can be bent or focused, and this effect can be exploited to produce lenses, some optical fibers and other devices. Some common mirages are caused by a spatially-varying refractive index of air.

16. Relation to density

In general, the refractive index of a glass increases with its density. However, there does not exist an overall linear relation between the refractive index and the density for all silicate and borosilicate glasses. A relatively high refractive index and low density can be obtained with glasses containing light metal oxides such as Li_2O and MgO, while the opposite trend is observed with glasses containing PbO and BaO as seen in the diagram at the right.

17. Momentum Paradox

The momentum of a refracted ray, p, was calculated by Hermann Minkowski in 1908, where E is energy of the photon, c is the speed of light in vacuum and n is the refractive index of the medium.

In 1909, Max Abraham proposed

Rudolf Peierls raises this in his book More Surprises in Theoretical Physics. Ulf Leonhardt, Chair in Theoretical Physics at the University of St Andrews, has discussed this, including experiments to resolve it.

18. Applications

The refractive index of a material is the most important property of any optical system that uses refraction. It is used to calculate the focusing power of lenses, and the dispersive power of prisms.

Since refractive index is a fundamental physical property of a substance, it is often used to identify a particular substance, confirm its purity, or measure its concentration. Refractive index is used to measure solids (glasses and gemstones), liquids, and gases. Most commonly it is used to measure the concentration of a solute in an aqueous solution. A refractometer is the instrument used to measure refractive index. For a solution of sugar, the refractive index can be used to determine the sugar content

19. Forensic Methods For Comparing Glass Fragments

Glass fragments are frequently encountered as evidence in hitand- run, burglary, and other types of crime scenes. Previous studies and reports (13) have improved the understanding of the variation of the physical, optical, and chemical properties of glass within a single source and between sources of a population. The properties of color, thickness, density, refractive index, and elemental composition can be used to include glass fragments into a group (46) (as is used in classification schemes) as well as to characterize the glass to associate a fragment recovered from a crime scene with another fragment from a known source. One approach to associate glass fragments is to compare the fragments on the basis of their physical, optical, and chemical properties. Having found the glass sample fragments to be indistinguishable, an examiner may state the informing power of the test and draw conclusions regarding the value of the association. The use of a sensitive test (or tests) translates to a more significant association between the fragments. Some tests such as color, thickness, and density comparisons are of value for relatively large fragments, but that is not the usual situation regarding fragments recovered in

transfer evidence cases. The more frequently encountered glass sample is of a size more amenable for refractive index and, sometimes, elemental composition determinations.

20. Glass Traces

Glass is one of the most common and important substances submitted to forensic science laboratories for analysis.:It's frequently encountered at crime scenes, particularly those involving motor vehicle accidents, car theft and burglaries.:This is due, in part, to the fact that windows are a common point of entry into buildings for burglars and large quantities of broken glass are produced in traffic accidents.: Glass, fragments of which may remain on clothing for a long time, is very stable it doesn't degrade like biological evidence and doesn't alter over time.:The role of the forensic scientist analyzing glass is to unequivocally establish the origin of the sample.: In practice this involves comparing fragments obtained from a suspect with samples taken from the scene or comparing fragments obtained from the clothing of a hit-and-run victim with samples taken from a vehicle.

20.1 Windows Breaking

When struck, flat glass breaks in a very specific way.**:** Glass is weaker under tension than under compression so the window will break on the opposite side to the strike.**:** Radial fractures form initially.**:** These run out from the point of impact on the opposite surface to the applied force. Then concentric fractures form.**:** These run between the radial fractures but on the same side of the glass as the impact.

Most of the glass is projected forward, in the direction of the blow.: But some of the fragments will be projected backwards, towards the person breaking the window, up to a distance of 3 meters known as 'backscatter'.: Individuals standing close enough when the window breaks will be covered in tiny fragments of glass which will stick to their clothing and their hair.

20.2 Reading the Signs

Most of the glass encountered by forensic scientists originates from windows, headlamps, bottles and containers.: All this commercial glass is similar in composition and the usual methods of chemical analysis are of little help in distinguishing between them. The simplest method used to compare pieces of broken glass is to fit them together like a jigsaw, though this is rarely possible due to the small size of samples.:However, large fragments of glass that originated from the point of impact do show characteristic 'rib' (or 'heckle') marks along the edges.: And these marks can be used to determine the side on which the impact occurred and so help to reconstruct the window.

Edge of broken glass showing rib or heckle marks:Patterns and marks on glass surfaces are also used in the reconstruction process.:The surfaces of glass fragments can show characteristic scratch marks, revealing their origin.:For example, windscreens can be scratched by windscreen wipers and side windows can be scratched by being wound up and down past abrasive particles.

Scratches on a side window from grit caught in the rubber: Another method of analysis is density measurement.: The densities of glass fragments are measured using a technique known as the 'floatation process'.: The fragment is placed in a range of liquid mixtures of known density until the fragment just floats.: At this point the density of the fragment is the same as that of the liquid mixture. Hence the density of the glass is known.:But the most commonly used method of analysis is RI (refractive index) measurement.: Measurement of the RI of glass samples is carried out using GRIM (Glass Refractive Index Measurement) apparatus.: The fragment is immersed in silicon oil and mounted on a hot platform under a microscope.: The RI of the silicon oil varies with temperature.: The temperature of the platform is raised until the glass disappears.: At this point the refractive indices of the glass and the oil are the same so the RI of the glass

sample can be determined.: With both density and RI measurements, a sample from a suspect can be compared with a sample from the scene to see if they're from the same source.: However, there's considerable overlap between the densities and RIs of different types of glass.: Therefore such results don't identify the type of glass with total accuracy.:Furthermore, even the RIs of glass fragments taken from the same window will vary to some degree.: For these reasons, density and RI measurements can't absolutely determine the source of a glass fragment.: If the samples match they do suggest a possible link between a suspect and the scene.: But it's only when two fragments fit together that they can be said, unequivocally, to have come from the same source.

- In Section 2 of this course you will cover these topics:
- Organic Analysis
- Inorganic Analysis
- The Microscope
- Hairs, Fibers, And Paint

Topic : Organic Analysis

Topic Objective:

After studying this topic the student should be able to:

- Define and distinguish elements and compounds
- Contrast the differences between a solid, liquid, and gas
- Define and distinguish organic and inorganic compounds
- Understand the difference between qualitative and quantitative analysis
- Describe and explain the process of chromatography

- List and describe the parts of a gas chromatograph
- Explain the difference between thin-layer chromatography, gas chromatography, and electrophoresis
- Understand the differences between the wave and particle theories of light
- Describe the electromagnetic spectrum
- Name the parts of a simple absorption spectrophotometer

Definition/Overview:

Chromatography: Any of several analytical techniques for separating organic mixtures into their components by attraction to a stationary phase while being propelled by a moving phase.

Compound: A pure substance composed of two or more elements.

Electromagnetic Spectrum: The entire range of radiation energy from the most energetic cosmic rays to the least energetic radio waves.

Electrophoresis: A technique for separating molecules through migration on a support medium while under the influence of an electrical potential.

Element: A fundamental particle of matter. An element cannot be broken down into simpler substances by chemical means.

Enzyme: A type of protein that acts as a catalyst for certain specific reactions.

Fluoresce: To emit visible light when exposed to light of a shorter wavelengththat is, ultraviolet light.

Frequency: The number of waves that pass a given point per second.

Gas (Vapor): A state of matter in which the attractive forces between molecules are small enough to permit them to move with complete freedom.

Infrared: Invisible short frequencies of light before red in the visible spectrum.

Inorganic: Describes a chemical compound not based on carbon.

Ion: An atom or molecule bearing a positive or negative charge.

Laser: An acronym for light amplification by stimulated emission of radiation; light that has all its waves pulsating in unison.

Liquid: A state of matter in which molecules are in contact with one another but are not rigidly held in place.

Matter: All things of substance. Matter is composed of atoms or molecules.

Monochromatic Light: Light having a single wavelength or frequency.

Monochromator: A device for isolating individual wavelengths or frequencies of light.

Organic: Describes a substance composed of carbon and often smaller amounts of hydrogen, oxygen, nitrogen, chlorine, phosphorus, or other elements.

Periodic Table: A chart of elements arranged in a systematic fashion. Vertical rows are called groups or families; horizontal rows are called series. Elements in a given row have similar properties.

Phase: A uniform body of matter; different phases are separated by definite visible boundaries.

Photon: A small packet of electromagnetic radiation energy. Each photon contains a unit of energy equal to the product of Plancks constant and the frequency of radiation: E 5 hf.

Physical State: A condition or stage in the form of matter; a solid, liquid, or gas.

Proteins: Polymers of amino acids that play basic roles in the structures and functions of living things.

Pyrolysis: The decomposition of organic matter by heat.

Solid: A state of matter in which the molecules are held closely together in a rigid state.

Spectrophotometry: An analytical method for identifying a substance by its selective absorption of different wavelengths of light.

Sublimation: A physical change from the solid state directly into the gaseous state.

Ultraviolet: Invisible long frequencies of light beyond violet in the visible spectrum.

Visible Light: Colored light ranging from red to violet in the electromagnetic spectrum.

Wavelength: The distance between crests of adjacent waves.

X-ray: A high-energy, short-wavelength form of electromagnetic radiation.

Key Points:

1. Chromatography

Chromatography (from Greek χρώμα:chroma, color and γραφειν:graphein to write) is the collective term for a family of laboratory techniques for the separation of mixtures. It involves passing a mixture dissolved in a "mobile phase" through a stationary phase, which separates the analyte to be measured from other molecules in the mixture and allows it to be isolated. Chromatography may be preparative or analytical. Preparative chromatography seeks to separate the components of a mixture for further use (and is thus a form of purification). Analytical chromatography normally operates with smaller amounts of material and seeks to measure the relative proportions of analytes in a mixture. The two are not mutually exclusive.

2. Techniques by chromatographic bed shape

2.1 Column chromatography

Column chromatography is a separation technique in which the stationary bed is within a tube. The particles of the solid stationary phase or the support coated with a liquid stationary phase may fill the whole inside volume of the tube (packed column) or be concentrated on or along the inside tube wall leaving an open, unrestricted path for the mobile phase in the middle part of the tube (open tubular column). Differences in rates of movement through the medium are calculated to different retention times of the sample.

In 1978, W. C. Still introduced a modified version of column chromatography called **flash column chromatography** (flash). The technique is very similar to the traditional column chromatography, except for that the solvent is driven through the column by applying positive pressure. This allowed most separations to be performed in less than 20 minutes, with improved separations compared to the old method. Modern flash chromatography systems are sold as pre-packed plastic cartridges, and the solvent is pumped through the cartridge. Systems may also be linked with detectors and fraction collectors providing automation. The introduction of gradient pumps resulted in quicker separations and less solvent usage.

A spreadsheet that assists in the successful development of flash columns has been developed. The spreadsheet estimates the retention volume and band volume of analytes, the fraction numbers expected to contain each analyte, and the resolution between adjacent peaks. This information allows users to select optimal parameters for preparative-scale separations before the flash column itself is attempted.

In expanded bed adsorption, a fluidized bed is used, rather than a solid phase made by a packed bed. This allows omission of initial clearing steps such as centrifugation and filtration, for culture broths or slurries of broken cells.

2.2 Planar Chromatography

Planar chromatography is a separation technique in which the stationary phase is present as or on a plane. The plane can be a paper, serving as such or impregnated by a substance as the stationary bed (paper chromatography) or a layer of solid particles spread on a support such as a glass plate (thin layer chromatography). Different compounds in the sample mixture travel different distances according to how strongly they interact with the stationary phase as compared to the mobile phase . The specific Retardation factor (Rf) of each chemical can be used to aid in the identification of an unknown substance.

2.3 Paper Chromatography

Paper chromatography is a technique that involves placing a small dot or line of sample solution onto a strip of chromatography paper. The paper is placed in a jar containing a shallow layer of solvent and sealed. As the solvent rises through the paper, it meets the sample mixture which starts to travel up the paper with the solvent. This paper is made of cellulose, a polar substance, and the compounds within the mixture travel farther if they

are non-polar. More polar substances bond with the cellulose paper more quickly, and therefore do not travel as far.

2.4 Thin layer chromatography

Thin layer chromatography (TLC) is a widely-employed laboratory technique and is similar to paper chromatography. However, instead of using a stationary phase of paper, it involves a stationary phase of a thin layer of adsorbent like silica gel, alumina, or cellulose on a flat, inert substrate. Compared to paper, it has the advantage of faster runs, better separations, and the choice between different adsorbents. For even better resolution and to allow for quantitation, high-performance TLC can be used.

2.5 Displacement Chromatography

The basic principle of displacement chromatography is: A molecule with a high affinity for the chromatography matrix (the displacer) will compete effectively for binding sites, and thus displace all molecules with lesser affinities. There are distinct differences between displacement and elution chromatography. In elution mode, substances typically emerge from a column in narrow, Gaussian peaks. Wide separation of peaks, preferably to baseline, is desired in order to achieve maximum purification. The speed at which any component of a mixture travels down the column in elution mode depends on many factors. But for two substances to travel at different speeds, and thereby be resolved, there must be substantial differences in some interaction between the biomolecules and the chromatography matrix. Operating parameters are adjusted to maximize the effect of this difference. In many cases, baseline separation of the peaks can be achieved only with gradient elution and low column loadings. Thus, two drawbacks to elution mode chromatography, especially at the preparative scale, are operational complexity, due to gradient solvent pumping, and low throughput, due to low column loadings. Displacement chromatography has advantages over elution chromatography in that components are resolved into consecutive zones of pure substances rather than peaks. Because the process takes advantage of the nonlinearity of the isotherms, a larger column feed can be separated on a given column with the purified components recovered at significantly higher concentrations.

3. Techniques by physical state of mobile phase

3.1 Gas chromatography

Gas chromatography (GC), also sometimes known as Gas-Liquid chromatography, (GLC), is a separation technique in which the mobile phase is a gas. Gas chromatography is always carried out in a column, which is typically "packed" or "capillary" .

Gas chromatography (GC) is based on a partition equilibrium of analyte between a solid stationary phase (often a liquid silicone-based material) and a mobile gas (most often Helium). The stationary phase is adhered to the inside of a small-diameter glass tube (a capillary column) or a solid matrix inside a larger metal tube (a packed column). It is widely used in analytical chemistry; though the high temperatures used in GC make it unsuitable for high molecular weight biopolymers or proteins (heat will denature them), frequently encountered in biochemistry, it is well suited for use in the petrochemical, environmental monitoring, and industrial chemical fields. It is also used extensively in chemistry research.

3.2 Liquid chromatography

Liquid chromatography (LC) is a separation technique in which the mobile phase is a liquid. Liquid chromatography can be carried out either in a column or a plane. Present day liquid chromatography that generally utilizes very small packing particles and a relatively high pressure is referred to as high performance liquid chromatography (HPLC).

In the HPLC technique, the sample is forced through a column that is packed with irregularly or spherically shaped particles or a porous monolithic layer (stationary phase) by a liquid (mobile phase) at high pressure. HPLC is historically divided into two different sub-classes based on the polarity of the mobile and stationary phases. Technique in which the stationary phase is more polar than the mobile phase (e.g. toluene as the mobile phase, silica as the stationary phase) is called normal phase liquid chromatography (NPLC) and the opposite (e.g. water-methanol mixture as the mobile phase and C18 = octadecylsilyl as the stationary phase) is called reversed phase liquid

chromatography (RPLC). Ironically the "normal phase" has fewer applications and RPLC is therefore used considerably more.

Specific techniques which come under this broad heading are listed below. It should also be noted that the following techniques can also be considered fast protein liquid chromatography if no pressure is used to drive the mobile phase through the stationary phase.

3.3 Affinity chromatography

Affinity chromatography is based on selective non-covalent interaction between an analyte and specific molecules. It is very specific, but not very robust. It is often used in biochemistry in the purification of proteins bound to tags. These fusion proteins are labelled with compounds such as His-tags, biotin or antigens, which bind to the stationary phase specifically. After purification, some of these tags are usually removed and the pure protein is obtained.

3.4 Supercritical fluid chromatography

Supercritical fluid chromatography is a separation technique in which the mobile phase is a fluid above and relatively close to its critical temperature and pressure.

4. Techniques by separation mechanism

4.1 Ion exchange chromatography

Ion exchange chromatography utilizes ion exchange mechanism to separate analytes. It is usually performed in columns but the mechanism can be benefited also in planar mode. Ion exchange chromatography uses a charged stationary phase to separate charged compounds including amino acids, peptides, and proteins. In conventional methods the stationary phase is an ion exchange resin that carries charged functional groups which interact with oppositely charged groups of the compound to be retained. Ion exchange chromatography is commonly used to purify proteins using FPLC.

4.2 Size exclusion chromatography

Size exclusion chromatography (SEC) is also known as **gel permeation chromatography** (GPC) or **gel filtration chromatography** and separates molecules according to their size (or more accurately according to their hydrodynamic diameter or

hydrodynamic volume). Smaller molecules are able to enter the pores of the media and, therefore, take longer to elute, whereas larger molecules are excluded from the pores and elute faster. It is generally a low resolution chromatography technique and thus it is often reserved for the final, "polishing" step of a purification. It is also useful for determining the tertiary structure and quaternary structure of purified proteins, especially since it can be carried out under native solution conditions.

5. Electromagnetic (Em) Spectrum

The electromagnetic (EM) spectrum is the range of all possible electromagnetic radiation frequencies. The "electromagnetic spectrum" (usually just spectrum) of an object is the characteristic distribution of electromagnetic radiation from that particular object.

The electromagnetic spectrum extends from below the frequencies used for modern radio (at the long-wavelength end) through gamma radiation (at the short-wavelength end), covering wavelengths from thousands of kilometers down to a fraction the size of an atom. It is thought that the short wavelength limit is in the vicinity of the Planck length, and the long wavelength limit is the size of the universe itself, although in principle the spectrum is infinite and continuous.

6. Range of the spectrum

EM waves are typically described by any of the following three physical properties: the frequency, f, and wavelength, λ, and photon energy, E. Frequencies range from about a million billion Hertz (gamma rays) down to a few Hertz (radio waves). Wavelength is inversely proportional to the wave frequency, so gamma rays have very short wavelengths that are fractions of the size of atoms, whereas radio wavelengths can be as long as a several thousand kilometers. Photon energy is directly proportional to the wave frequency, so gamma rays have the highest energy around a mega electron volt and radio waves have very low energy around femto electron volts (femto = 10^{-15}). These relations are illustrated by the following equations:

: or: : or:

Where:

c = 299,792,458 m/s (speed of light in vacuum) and

h = $6.62606896(33)10^{-34}$ Js (Planck's constant).

Whenever light waves (and other electromagnetic waves) exist in a medium (matter), their wavelength is decreased. Wavelengths of electromagnetic radiation, no matter what medium they are traveling through, are usually quoted in terms of the vacuum wavelength , although this is not always explicitly stated.

Generally, EM radiation is classified by coiled wavelength into radio wave, microwave, infrared, the visible region we perceive as light, ultraviolet, X-rays and gamma rays.

The behavior of EM radiation depends on its wavelength. When EM radiation interacts with single atoms and molecules, its behavior also depends on the amount of energy per quantum (photon) it carries. Electromagnetic radiation can be divided into octaves as sound waves are. Spectroscopy can detect a much wider region of the EM spectrum than the visible range of 400 nm to 700 nm. A common laboratory spectroscope can detect wavelengths from 2 nm to 2500 nm. Detailed information about the physical properties of objects, gases, or even stars can be obtained from this type of device. It is widely used in astrophysics. For example, many hydrogen atoms emit a radio wave photon which has a wavelength of 21.12 cm. Also, frequencies of 30 Hz and below can be produced by and are important in the study of certain stellar nebulae and frequencies as high as 2.910^{27} Hz have been detected from astrophysical sources.

7. Absorption Spectrophotometer

A spectrophotometer consists of two instruments, namely a spectrometer for producing light of any selected color (wavelength), and a photometer for measuring the intensity of light. The instruments are arranged so that liquid in a cuvette can be placed between the spectrometer beam and the photometer. The amount of light passing through the tube is measured by the

photometer. The photometer delivers a voltage signal to a display device, normally a galvanometer. The signal changes as the amount of light absorbed by the liquid changes.

If development of color is linked to the concentration of a substance in solution then that concentration can be measured by determining the extent of absorption of light at the appropriate wavelength. For example hemoglobin appears red because the hemoglobin absorbs blue and green light rays much more effectively than red. The degree of absorbance of blue or green light is proportional to the concentration of hemoglobin.
When monochromatic light (light of a specific wavelength) passes through a solution there is usually a quantitative relationship (Beer's law) between the solute concentration and the intensity of the transmitted light, that is,

where I sub 0 is the intensity of transmitted light using the pure solvent, I is the intensity of the transmitted light when the colored compound is added, c is concentration of the colored compound, l is the distance the light passes through the solution, and k is a constant. If the light path l is a constant, as is the case with a spectrophotometer, Beer's law may be written,

where k is a new constant and T is the transmittance of the solution. There is a logarithmic relationship between transmittance and the concentration of the colored compound. Thus,

The O.D. is directly proportional to the concentration of the colored compound. Most spectrophotometers have a scale that reads both in O.D. (absorbance) units, which is a logarithmic scale, and in % transmittance, which is an arithmetic scale. As suggested by the above relationships, the absorbance scale is the most useful for colorimetric assays.

Topic : Inorganic Analysis

Topic Objective:

After studying this topic the student should be able to:

- Describe the usefulness of trace elements for forensic comparison of various types of physical evidence
- Distinguish continuous and line emission spectra
- Understand the parts of a simple emission spectrograph
- List the parts of a simple atomic absorption spectrophotometer
- Define and distinguish protons, neutrons, and electrons
- Define and distinguish atomic number and atomic mass number
- Appreciate the phenomenon of how an atom absorbs and releases energy in the form of light
- Describe why an X-ray diffraction pattern is useful for chemical identification

Definition/Overview:

Alpha Ray: A type of radiation emitted by a radioactive element. The radiation is composed of helium atoms minus their orbiting electrons.

Atomic Mass Number: The sum of the number of protons and neutrons in the nucleus of an atom.

Atomic Number: The number of protons in the nucleus of an atom. Each element has its own unique atomic number.

Beta Ray: A type of radiation emitted by a radioactive element. The radiation consists of electrons.

Continuous Spectrum: A type of emission spectrum showing a continuous band of colors all blending into one another.

Electron: A negatively charged particle that is one of the fundamental structural units of the atom.

Electron Orbital: The path of electrons as they move around the nuclei of atoms; each orbital is associated with a particular electronic energy level.

Emission Spectrum: Light emitted from a source and separated into its component colors or frequencies.

Excited State: The state in which an atom absorbs energy and an electron moves from a lower to a higher energy level.

Gamma Ray: A high-energy form of electromagnetic radiation emitted by a radioactive element.

Isotope: An atom differing from another atom of the same element in the number of neutrons in its nucleus.

Line Spectrum: A type of emission spectrum showing a series of lines separated by black areas. Each line represents a definite wavelength or frequency.

Neutron: A particle with no electrical charge that is one of the basic structures in the nucleus of an atom.

Nucleus: The core of an atom containing the protons and neutrons.

Proton: A positively charged particle that is one of the basic structures in the nucleus of an atom.

Radioactivity: The particle and/or gamma-ray radiation emitted by the unstable nucleus of some isotopes.

X-ray diffraction: An analytical technique for identifying crystalline materials.

Key Points:

1. Trace evidence

Trace evidence is collected at the scene and is also collected from the deceased post mortem. This is done by scraping the fingernails, checking clothing for fibres and also checking footwear for soil samples that might allude to whether or not the victim's last living moments were spent somewhere else before being moved.

It is not uncommon for the perpetrators of the act of murder to move their victim to try and slow down the process of identification and also to remove suspicion from themselves. In many murder investigations it is common for the victim to have known the killer so their surroundings can sometimes be something of a giveaway and therefore moving the body post mortem to another locale is an attempt - albeit mostly a futile one - to case doubt elsewhere.

As mentioned already there are many different types of trace evidence that can be collected; for the most part a forensic scientist or pathologist will look for signs of a struggle which can lead to the discovery of skin particles, blood flecks, hairs or fibres being transferred by contact from the perpetrator to the victim.

Where hair has been found it can be tested not only for a DNA match but also for trace elements of various chemicals which are found in hair care products; identifying such products can give an indication as to the sex of the assailant.
Grass, glass and soil traces are also an important element of the crime scene environment and each of these trace elements should be given due care and attention as they can often lead to

surprising revelations and also bring avenues of investigation to the fore that would have not previously been considered as viable options.

2. Atomic Absorption Spectrophotometer

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It relies therefore heavily on Beer-Lambert law.

In short, the electrons of the atoms in the atomizer can be promoted to higher orbitals for an instant by absorbing a set quantity of energy (i.e. light of a given wavelength). This amount of energy (or wavelength) is specific to a particular electron transition in a particular element, and in general, each wavelength corresponds to only one element. This gives the technique its elemental selectivity.

As the quantity of energy (the power) put into the flame is known, and the quantity remaining at the other side (at the detector) can be measured, it is possible, from Beer-Lambert law, to calculate how many of these transitions took place, and thus get a signal that is proportional to the concentration of the element being measured.

3. Instrumentation

In order to analyze a sample for its atomic constituents, it has to be atomized. The sample should then be illuminated by light. The light transmitted is finally measured by a detector. In order to reduce the effect of emission from the atomizer (e.g. the black body radiation) or the environment, a spectrometer is normally used between the atomizer and the detector.

4. Types of Atomizer

The technique typically makes use of a flame to atomize the sample, but other atomizers such as a graphite furnace or plasmas, primarily inductively coupled plasmas, are also used.

When a flame is used it is laterally long (usually 10 cm) and not deep. The height of the flame above the burner head can be controlled by adjusting the flow of the fuel mixture. A beam of light passes through this flame at its longest axis (the lateral axis) and hits a detector.

4.1 Analysis of liquids

A liquid sample is normally turned into an atomic gas in three steps:

- Desolvation (Drying) the liquid solvent is evaporated, and the dry sample remains
- Vaporization (Ashing) the solid sample vaporises to a gas
- Atomization the compounds making up the sample are broken into free atoms.

4.2 Radiation Sources

The radiation source chosen has a spectral width narrower than that of the atomic transitions.

4.3 Hollow cathode lamps

Hollow cathode lamps are the most common radiation source in atomic absorption spectroscopy. Inside the lamp, filled with argon or neon gas, is a cylindrical metal cathode containing the metal for excitation, and an anode. When a high voltage is applied across the anode and cathode, gas particles are ionized. As voltage is increased, gaseous ions acquire enough energy to eject metal atoms from the cathode. Some of these atoms are in an excited states and emit light with the frequency characteristic to the metal. Many modern hollow cathode lamps are selective for several metals.

4.4 Diode lasers

Atomic absorption spectroscopy can also be performed by lasers, primarily diode lasers because of their good properties for laser absorption spectrometry. The technique is then either referred to as diode laser atomic absorption spectrometry (DLAAS or DLAS), or, since wavelength modulation most often is employed, wavelength modulation absorption spectrometry.

5. Background Correction methods

The narrow bandwidth of hollow cathode lamps make spectral overlap rare. That is, it is unlikely that an absorption line from one element will overlap with another. Molecular emission is much broader, so it is more likely that some molecular absorption band will overlap with an atomic

line. This can result in artificially high absorption and an improperly high calculation for the concentration in the solution. Three methods are typically used to correct for this:

- Zeeman correction - A magnetic field is used to split the atomic line into two sidebands. These sidebands are close enough to the original wavelength to still overlap with molecular bands, but are far enough not to overlap with the atomic bands. The absorption in the presence and absence of a magnetic field can be compared, the difference being the atomic absorption of interest.
- Smith-Hieftje correction (invented by Stanley B. Smith and Gary M. Hieftje) - The hollow cathode lamp is pulsed with high current, causing a larger atom population and self-absorption during the pulses. This self-absorption causes a broadening of the line and a reduction of the line intensity at the original wavelength.
- Deuterium lamp correction - In this case, a separate source (a deuterium lamp) with broad emission is used to measure the background emission. The use of a separate lamp makes this method the least accurate, but its relative simplicity (and the fact that it is the oldest of the three) makes it the most commonly used method.

6. Proton

Protons are spin-1/2 fermions and are composed of three quarks, making them baryons. The two up quarks and one down quark of the proton are held together by the strong force, mediated by gluons.

Protons and neutrons are both nucleons, which may be bound by the nuclear force into atomic nuclei. The nucleus of the most common isotope of the hydrogen atom is a single proton (it contains no neutrons). The nuclei of heavy hydrogen (deuterium and tritium) contain neutrons. All other types of atoms are composed of two or more protons and various numbers of neutrons. The number of protons in the nucleus determines the chemical properties of the atom and thus which chemical element is represented; it is the number of both neutrons and protons in a nuclide which determine the particular isotope of an element.

6.1 Stability

Protons are observed to be stable and their theoretical minimum half-life is 110^{36} years. Grand unified theories generally predict that proton decay should take place, although experiments so far have only resulted in a lower limit of 10^{35} years for the proton's

lifetime. In other words, proton decay has never been witnessed and the experimental lower bound on the mean proton lifetime ($2.1 10^{29}$ years) is put by the Sudbury Neutrino Observatory.

However, protons are known to transform into neutrons through the process of electron capture. This process does not occur spontaneously but only when energy is supplied. The equation is:

where

- p is a proton,
- e is an electron,
- n is a neutron, and
- ve is an electron neutrino

The process is reversible: neutrons can convert back to protons through beta decay, a common form of radioactive decay. In fact, a free neutron decays this way with a mean lifetime of about 15 minutes.

7. Electron

The **electron** is a subatomic particle that carries a negative electric charge. It is an elementary particle with no known substructure and is believed to be a point particle. Each electron participates in gravitational, electromagnetic and weak interactions. The mass of an electron is approximately $1/1836$ that of a proton. Like its rest mass and elementary charge, the intrinsic angular momentum (or spin) of an electron has a constant value. In the collision of an electron and a positron, the electron's antiparticle, both are annihilated. An electronpositron pair can be produced from gamma ray photons with a combined energy at least equal to the rest energy of the particles.

Electrons are identical particles that belong to the first generation of the lepton particle family. Electrons have quantum mechanical properties of both a particle and a wave, so they can collide with other particles and be diffracted like light. Each electron occupies a quantum state that

describes its random behavior upon measuring a physical parameter, such as its energy or spin orientation. Because they are a type of fermion, no two electrons can occupy the same quantum state; a property known as the Pauli exclusion principle.

Electrons play an essential role in many physical phenomena such as electricity, magnetism, and thermal conductivity. When an electron is in motion, it both generates a magnetic field and is deflected by external magnetic fields. While an electron is undergoing acceleration, it can absorb or radiate energy in the form of photons. Electrons, together with atomic nuclei made of protons and neutrons, make up atoms. The attractive Coulomb force between an electron and a proton is what causes electrons to be bound into atoms. The exchange, sharing or interaction of the electrons in two or more atoms is the main cause of chemical bonding.

Electrons were formed during the early stages of the big bang, and they can be annihilated as the result of stellar nucleosynthesis. Electrons are created by Hawking radiation at the event horizon of a black hole and by cosmic rays entering the atmosphere. Radioactive isotopes can release an electron from an atomic nucleus as a result of negative beta decay. Laboratory instruments are capable of containing and observing individual electrons, while telescopes can detect electron plasma by its energy emission. Electron plasma has multiple applications, including welding, cathode ray tubes, electron microscopes, radiation therapy, lasers and particle accelerators.

8. Neutron

The **neutron** is a subatomic particle with no net electric charge and a mass slightly larger than that of a proton.

Neutrons are usually found in atomic nuclei. The nuclei of most atoms consist of protons and neutrons, which are therefore collectively referred to as nucleons. The number of protons in a nucleus is the atomic number and defines the type of element the atom forms. The number of neutrons determines the isotope of an element. For example, the carbon-12 isotope has 6 protons and 6 neutrons, while the carbon-14 isotope has 6 protons and 8 neutrons.

While bound neutrons in stable nuclei are stable, free neutrons are unstable; they undergo beta decay with a lifetime of just under 15 minutes (885.7 0.8 s). Free neutrons are produced in nuclear fission and fusion. Dedicated neutron sources like research reactors and spallation sources produce free neutrons for the use in irradiation and in neutron scattering experiments. Even though it is not a chemical element, the free neutron is sometimes included in tables of nuclides. It is then considered to have an atomic number of zero and a mass number of one.

9. X-ray diffraction pattern

X-ray diffraction finds the geometry or shape of a molecule using X-rays. X-ray diffraction techniques are based on the elastic scattering of X-rays from structures that have long range order. The most comprehensive description of scattering from crystals is given by the dynamical theory of diffraction.

- Single-crystal X-ray diffraction is a technique used to solve the complete structure of crystalline materials, ranging from simple inorganic solids to complex macromolecules, such as proteins.
- Powder diffraction (XRD) is a technique used to characterize the crystallographic structure, crystallite size (grain size), and preferred orientation in polycrystalline or powdered solid samples. Powder diffraction is commonly used to identify unknown substances, by comparing diffraction data against a database maintained by the International Centre for Diffraction Data. It may also be used to characterize heterogeneous solid mixtures to determine relative abundance of crystalline compounds and, when coupled with lattice refinement techniques, such as Rietveld refinement, can provide structural information on unknown materials. Powder diffraction is also a common method for determining strains in crystalline materials. An effect of the finite crystallite sizes is seen as a broadening of the peaks in an X-ray diffraction as is explained by the Scherrer Equation.
- Thin film diffraction and grazing incidence X-ray diffraction may be used to characterize the crystallographic structure and preferred orientation of substrate-anchored thin films.
- High-resolution X-ray diffraction is used to characterize thickness, crystallographic structure, and strain in thin epitaxial films. It employs parallel-beam optics.
- X-ray pole figure analysis enables one to analyze and determine the distribution of crystalline orientations within a crystalline thin-film sample.

- X-ray rocking curve analysis is used to quantify grain size and mosaic spread in crystalline materials.

10. Scattering techniques

10.1 Elastic scattering

Materials that do not have long range order may also be studied by scattering methods that rely on elastic scattering of monochromatic X-rays.

- Small angle X-ray scattering (SAXS) probes structure in the nanometer to micrometer range by measuring scattering intensity at scattering angles 2θ close to 0.
- X-ray reflectivity is an analytical technique for determining thickness, roughness, and density of single layer and multilayer thin films.
- Wide angle X-ray scattering (WAXS), a technique concentrating on scattering angles 2θ larger than 5.

10.2 Inelastic scattering

When the energy and angle of the inelastically scattered X-rays are monitored scattering techniques can be used to probe the electronic band structure of materials.

- Compton scattering
- Resonant inelastic X-ray scattering (RIXS)
- X-ray Raman scattering
- X-ray diffraction pattern

Topic : The Microscope

Topic Objective:

After studying this topic the student should be able to:

- List and understand the parts of the compound microscope
- Define magnification, field of view, working distance, and depth of focus
- Contrast the comparison and compound microscopes

- Understand the theory and utility of the stereoscopic microscope
- Appreciate how a polarizing microscope is designed to characterize polarized light
- Appreciate how a microspectrophotometer can be used to examine trace physical evidence
- Compare and contrast the image formation mechanism of a light microscope to that of a scanning electron microscope
- Outline some forensic applications of the scanning electron microscope

Definition/Overview:

Binocular: Describes a microscope with two eyepieces.

Condenser: The lens system under the microscope stage that focuses light onto the specimen.

Depth of focus: The thickness of a specimen that is entirely in focus under a microscope.

Eyepiece lens: The lens of a microscope into which the viewer looks; same as the ocular lens.

Field of view: The area of the specimen that can be seen after it is magnified.

Microspectrophotometer: An instrument that links a microscope to a spectrophotometer.

Monocular: Describes a microscope with one eyepiece.

Objective lens: The lower lens of a microscope, which is positioned directly over the specimen.

Parfocal: Describes a microscope such that when an image is focused with one objective in position, the other objective can be rotated into place and the field will remain in focus.

Plane-polarized light: Light confined to a single plane of vibration.

Polarizer: A device that permits the passage of light waves vibrating in only one plane.

Real image: An image formed by the actual convergence of light rays on a screen.

Transmitted illumination: Light that passes up from the condenser and through the specimen.

Vertical or reflected illumination: Illumination of a specimen from above; in microscopy it is used to examine opaque specimens.

Virtual image: An image that cannot be seen directly. It can be seen only by a viewer looking through a lens.

Key Points:

1. Microscopes

Microscopes trace their history back almost 1200 years with Abbas Ibn Firnas's corrective lenses, and it was Ibn al-Haytham's Book of Optics written between 1011 and 1021 that laid the foundation for optical research on the magnifying glass. Also, a device called the reading stone by an unknown inventor (thought to be Ibn Firnas) magnified text when laid on top of reading materials.

The first true microscope was made around 1595 in Middelburg, Holland. Three different eyeglass makers have been given credit for the invention: Hans Lippershey (who also developed the first real telescope); Hans Janssen; and his son, Zacharias. The coining of the name "microscope" has been credited to Giovanni Faber, who gave that name to Galileo Galilei's compound microscope in 1625. (Galileo had called it the "occhiolino" or "little eye".)

The most common type of microscopeand the first to be inventedis the optical microscope. This is an optical instrument containing one or more lenses that produce an enlarged image of an

object placed in the focal plane of the lens(es). There are, however, many other microscope designs.

2. Types

"Microscopes" can largely be separated into three classes: optical theory microscopes (Light microscope), electron microscopes (e.g.,TEM), and scanning probe microscopes (SPM).

Optical theory microscopes are microscopes which function through the optical theory of lenses in order to magnify the image generated by the passage of a wave through the sample. The waves used are either electromagnetic (in optical microscopes) or electron beams (in electron microscopes). The types are the Compound Light, Stereo, and the electron microscope.

2.1 Optical microscopes

Optical microscopes, through their use of visible wavelengths of light, are the simplest and hence most widely used type of microscope.

Optical microscopes typically use refractive lenses of iron and occasionally of plastic or quartz, to focus light into the eye or another light detector. Mirror-based optical microscopes operate in the same manner. Typical magnification of a light microscope, assuming visible range light, is up to 1500x with a theoretical resolution limit of around 0.2 micrometres or 200 nanometers. Specialized techniques (e.g., scanning confocal microscopy) may exceed this magnification but the resolution is diffraction limited. Using shorter wavelengths of light, such as the ultraviolet, is one way to improve the spatial resolution of the microscope as are techniques such as Near-field scanning optical microscope. A stereo microscope is often used for lower-power magnification on large subjects.

Various wavelengths of light, including those beyond the visible range, are sometimes used for special purposes. Ultraviolet light is used to enable the resolution of smaller features as well as to image samples that are transparent to the eye. Near infrared light is used to image circuitry embedded in bonded silicon devices as silicon is transparent

in this region. Many wavelengths of light, ranging from the ultraviolet to the visible are used to excite fluorescence emission from objects for viewing by eye or with sensitive cameras.

phase contrast microscope:Phase contrast microscopy is an optical microscopy illumination technique in which small phase shifts in the light passing through a transparent specimen are converted into amplitude or contrast changes in the image. A phase contrast **microscope** does not require staining to view the slide. This microscope made it possible to study the cell cycle.

2.2 Compound Microscope

A compound microscope uses a very short focal length objective lens to form a greatly enlarged image. This image is then viewed with a short focal length eyepiece used as a simple magnifier. The image should be formed at infinity to minimize eyestrain. The general assumption is that the length of the tube L is large compared to either f_o or f_e so that the following relationships hold.

The limitations on resolution (and therefore magnifying power) imposed by the constraints of a simple microscope can be overcome by the use of a compound microscope, in which the image is relayed by two lens arrays. One of them, the objective, has a short focal length and is placed close to the object being examined. It is used to form a real image in the front focal plane of the second lens, the eyepiece or ocular. The eyepiece forms an enlarged virtual image that can be viewed by the observer. The magnifying power of the compound microscope is the product of the magnification of the objective lens and that of the eyepiece.

In addition to these two lens arrays, a compound microscope consists of a body tube, in which the lenses can be housed and kept an appropriate distance apart; a condenser lens

that lies beneath the specimen stage and focuses light upon the specimen; and an illumination system, which either transmits light through or reflects light from the object being examined. A method for focusing the microscope, usually with coarse and fine focusing controls, must also be provided.

The basic form of a compound microscope is monocular: a single tube is used, with the objective at one end and a single eyepiece at the other. In order to permit viewing with two eyes and thereby increase comfort and acuity, a single objective can be employed in a binocular tube fitted with a matched pair of eyepieces; beam-splitting prisms are used to send half of the light from the image formed by the objective to each eye. These prisms are mounted in a rotating mechanical assembly so that the separation between the eyepieces can be made to match the required interpupillary distance for the observer. A true stereoscopic microscope is configured by using two objectives and two eyepieces, enabling each eye to view the object separately, making it appear three-dimensional.

2.3 Electron Microscope

Two major variants of electron microscopes exist:

- Scanning electron microscope (SEM): looks at the surface of bulk objects by scanning the surface with a fine electron beam and measuring reflection. May also be used for spectroscopy.
- Transmission electron microscope (TEM): passes electrons completely through the sample, analogous to basic optical microscopy. This requires careful sample preparation, since electrons are scattered so strongly by most materials.This is a scientific device that allows people to see objects that could normally not be seen by the naked or unaided eye.
- Scanning Tunneling Microscope (STM): is a powerful technique for viewing surfaces at the atomic level.
- The SEM, TEM, STM are include in the scanning probe microsocpy.

3. Visible microspectrophotometry

Visible microspectrophotometry is a very useful tool in the forensic analysis of many kinds of trace evidence. It combines a microscope with a spectrophotometer so that the light absorption properties of a very small sample can be recorded. The technique is particularly valuable in the investigation of hair, textile fibers, and paint, which are typically of microscopic dimensions. A fiber, for instance, may have a diameter of only around 20 micrometers.

The chemical bonds within the molecular components of trace evidence interact with light in a characteristic manner. They will absorb, transmit, or reflect specific frequencies of visible light. When human eyes see a piece of cloth as blue, for example, this means that although white light falls upon the material, all the color frequencies making it up except blue are absorbed by the dye molecules in the material. It is therefore the blue frequencies of light that are reflected back. A yellow fiber contains different dye molecules, which reflect back only yellow frequencies. Visible spectrophotometry is a more sophisticated and highly accurate way of recording exactly what color an object is.

When an opaque or translucent item of trace evidence is inserted into the visible microspectrophotometer, it is exposed to a range of visible frequencies. The frequencies where it reflects, absorbs, or transmits, depending on the mode of the instrument, are recorded at a detector as a spectrum, or fingerprint, of that material. Comparisons can be made with materials whose visible spectra are held in reference databases. It is also possible to compare a piece of trace evidence with a control sample. A textile fiber found at the scene of the crime can be compared with one found on a suspect's clothing, for instance. If their visible spectra are identical, then they likely come from the same source. The same is true of hairs and paint flakes. Visible microspectrophotometry is also a useful and non-destructive way of analyzing colored inks in the investigation of questioned documents.

4. Microspectrophotometer

From a Forensic scientists point of view, few instruments present in a crime laboratory can match the versatility of the forensic comparison microscopy. The forensic comparison microscopes magnifying power is an essential necessity for searching and finding very small

traces of physical evidence. Once found, many items of physical evidence may be characterized by a forensic comparison microscopic examination of their morphological features. Likewise, the forensic comparison microscopy can be used to study how light interacts with the material under investigation, or it can be used to observe the effects that other chemical substances are having on such evidence. Each of these features will allow the forensic examiner to better characterize and identify physical evidence. Recently, by attaching it to a computerized spectrophotometer, a new element has been added to the capability of the forensic comparison microscope. This combination has given rise to a new instrument called the microsectrophotometer.

In many respects, this is an ideal discovery from the forensic scientists viewpoint. The chemist can take advantage of the selective absorption of light materials in order to characterize them. In particular, light in the ultraviolet, visible, and infrared regions of the electromagnetic spectrum has proved mot helpful for this purpose. But sadly in the past forensic chemists were unable to take full advantage of the capabilities of spectrophotometry for examining trace evidence, as most spectrophotometer are not well suited for examining the very small particles commonly encountered as evidence. However, with the development of the microspectrophotometer, a forensic analyst can now view a particle under a forensic comparison microscope while, at the same time, abeam of light is directed at the particle in order to obtain its absorption spectrum. Depending on the type of light employed, an examiner can acquire either a visible or an IR spectral pattern of substance being viewed under the microscope. The obvious advantage of this approach is to provide the forensic scientist with added information that will characterize trace quantities of evidence. A microspectrophotometer designed to measure the uptake of visible light by materials.

The visual comparison of color is usually one of the first step in examining paint, fiber, and ink evidence. Such comparisons are easily obtained by means of a forensic comparison microscope. Now, with the use of microspectrophotometer, not only can the color of materials be compared visually but, at the same time, an absorption spectrum can be plotted for each item under examination to display the exact wavelengths at which it absorbs in the visible light spectrum. Sometimes, colors that appear similar by using the visual examination will show significant differences in their absorption spectra. The microspectrophotometer is used to distinguish counterfeit and authentic currency by comparing the spectral patterns of inked lines on currency.

Another emerging technique in forensic science is the utilization of the infrared microspectrophotometer for the forensic comparison examination of fibers and paints. The fingerprint IR spectrum is unique for each chemical substance. Therefore, if such a spectrum can be obtained either a fiber or a paint chip, it will allow the analyst to better identify and compare the type of chemical from which these materials are manufactured. With a microspectrophotometer, a forensic analyst can view a substance by means forensic comparison microscopy and at the same time have the instrument plot the infrared absorption spectrum for that material.

Topic : Hairs, Fibers, And Paint

Topic Objective:

After studying this topic the student should be able to:

- Recognize and understand the cuticle, cortex, and medulla areas of hair
- List the three phases of hair growth
- Appreciate the distinction between animal and human hairs
- List hair features that are useful for the microscopic comparison of human hairs
- Explain the proper collection of forensic hair evidence
- Describe and understand the role of DNA typing in hair comparisons
- Understand the differences between natural and manufactured fibers
- List the properties of fibers that are most useful for forensic comparisons
- Describe the proper collection of fiber evidence
- List the most useful examinations for performing a forensic comparison of paint
- Describe the proper collection and preservation of forensic paint evidence

Definition/Overview:

Anagen phase: The initial growth phase during which the hair follicle actively produces hair.

Catagen phase: A transition stage between the anagen and telogen phases of hair growth.

Cortex: The main body of the hair shaft.

Cuticle: The scale structure covering the exterior of the hair.

Follicular tag: A translucent piece of tissue surrounding the hairs shaft near the root. It contains the richest source of DNA associated with hair.

Macromolecule: A molecule with a high molecular mass.

Manufactured fibers: Fibers derived from either natural or synthetic polymers; the fibers are typically made by forcing the polymeric material through the holes of a spinneret.

Medulla: A cellular column running through the center of the hair.

Mitochondrial DNA: DNA present in small structures (mitochondria) outside the nucleus of a cell. Mitochondria supply energy to the cell. This form of DNA is inherited maternally (from the mother).

Molecule: Two or more atoms held together by chemical bonds.

Monomer: The basic unit of structure from which a polymer is constructed.

Natural fibers: Fibers derived entirely from animal or plant sources.

Nuclear DNA: DNA present within the nucleus of a cell. This form of DNA is inherited from both parents.

Polymer: A substance composed of a large number of atoms. These atoms are usually arranged in repeating units or monomers.

Telogen phase: The final growth phase in which hair naturally falls out of the skin.

Key Points:

1. Hairs

Hairs, which are composed primarily of the protein keratin, can be defined as slender outgrowths of the skin of mammals. Each species of animal possesses hair with characteristic length, color, shape, root appearance, and internal microscopic features that distinguish one animal from another. Considerable variability also exists in the types of hairs that are found on the body of an animal. In humans, hairs found on the head, pubic region, arms, legs, and other body areas have characteristics that can determine their origin. On animals, hair types include coarse outer hairs or guard hairs, the finer fur hairs, tactile hairs such as whiskers, and other hairs that originate from the tail and mane of an animal.

Because hairs can be transferred during physical contact, their presence can associate a suspect to a victim or a suspect/victim to a crime scene. The types of hair recovered and the condition and number of hairs found all impact on their value as evidence in a criminal investigation. Comparison of the microscopic characteristics of questioned hairs to known hair samples helps determine whether a transfer may have occurred.

2. Hair Microscopy

The examination of human hairs in the forensic laboratory is typically conducted through the use of light microscopy. This examination routinely involves a two-step processthe identification of

questioned hairs and the comparison of questioned and known hairs. The purpose for conducting this examination is to ascertain whether two or more individuals could have come into contact or whether one or more individuals could have come into contact with an object. This associative evidence is particularly useful in crimes of violence, such as homicide, sexual assault, and aggravated assault, where physical contact may have occurred. Crimes such as burglary and armed robbery typically involve the recovery of debris and articles of clothing which may contain hairs useful for the identification of suspects.

The value of hair evidence is related to the variability of hair characteristics between individuals in the population, which can be visualized through the use of comparison microscopy. There are many factors that impact on the reliability of a hair association, including experience, training, suitability of known hair standards, and adequacy of equipment. Although hair evidence is a valuable tool in human identification, it is difficult to establish a statistical probability for a particular association due in part to the lack of reliable quantitative assessments of the microscopic characteristics present in hairs.

The comparison microscope consists of two compound light microscopes connected by an optical bridge that allows for the simultaneous viewing of questioned hairs and known hairs. Typically, a glass microscope slide containing known or reference hairs is positioned on the stage of one microscope, and a glass microscope slide containing a questioned hair or hairs is positioned on the stage of the other microscope. This enables the hair examiner to compare the microscopic characteristics of the known and questioned hairs in one field. The range of magnification used is approximately 40X to 400X.

The hair examination process involves many different steps, the first of which is to determine whether the hair in question originated from an animal or a human being. If the hair originated from an animal, it is possible to further identify it to a particular type of animal. Although certain hairs can be attributed to species, it is not possible to identify hairs to a specific animal to the exclusion of other similar animals. An example of this occurs when dog hairs can be associated to a particular breed but cannot be identified to a specific dog within that breed.

3. Hair Anatomy and Growth

Hair is present on many different regions of the body. Each region, such as the head, pubic area, chest, axillae, and limbs, has hairs with microscopical characteristics attributable to that region. Although it is possible to identify a hair as originating from a particular body area, the regions of the body that are primarily used in forensic comparisons are the head and pubic areas. As hairs undergo a cyclical growth (anagen) and resting phase (telogen), the visible microscopic characteristics are sufficient to determine the phase of growth of the hair.
During the anagen phase, the hair is actively growing, and materials are deposited in the hair shaft by cells found in the follicle. Metabolically active and dividing cells above and around the dermal papilla of the follicle grow upward during this phase, to form the major components of the hairthe medulla, cortex, cuticle, and accompanying root sheath. In the telogen phase, the follicle is dormant or resting. The transition period between the anagen and telogen phases is referred to as the catagen phase.

Hairs are routinely lost during the telogen phase and often become a primary source of evidentiary material. An example of this natural shedding process can be seen when one combs through the hairs on the head. It is not uncommon for hairs of this type to be transferred to another individual or to an object during physical contact. Hairs can also become dislodged from the body while they are in an actively growing state, such as by pulling or by striking with an object. The microscopical appearance of the root area will allow for the determination of the growth phase.

On a healthy head, 80 to 90 percent of the hair follicles are in the anagen phase, 2 percent are in the catagen phase, and 10 to 18 percent are in the telogen phase. Once the hair reaches the telogen phase, the follicles have achieved a mature, stable stage of quiescence. During the telogen phase, the hair is anchored in the follicle only by the root, which is club-shaped. The germ cells below the club-shaped root will give rise to the next generation of an anagen hair. The

replacement of human scalp hair occurs in a scattered mosaic fashion with no apparent wave-like or seasonal pattern. The average period of growth for scalp hair is approximately 1,000 days; the resting phase lasts about 100 days. Approximately 10 percent of the hairs on a human head (100/1000), therefore, are in the quiescent telogen phase, and a minimal amount of forcesuch as that from combingis required to dislodge the hairs from the dormant follicle.

The basic morphology of human hairs is shared by each individual in the population, but the arrangement, distribution, and appearance of individual microscopic characteristics within different regions of hair routinely allow a skilled hair examiner to differentiate hairs between individuals. An analogy would be the ability of an individual to recognize the face of a friend or relative in a crowd even though each person in the crowd possesses ears, eyes, a nose, and a mouth.

4. Animal Hairs

Animal hairs discovered on items of physical evidence can link a suspect or location to a crime of violence. A victim placed in a vehicle or held at a location where animals are routinely found often results in the transfer of animal hairs to the victim's clothing. Cat or dog hairs can be found on the adhesive portions of ransom and extortion notes prepared by pet owners. The transfer of pet hairs to the victim or crime scene may also occur when the suspect is a pet owner and has animal hairs on his or her clothing when the contact occurs. This is referred to as a secondary transfer of trace material.

When an animal hair is found, it is identified to a particular type of animal and microscopically compared with a known hair sample from either an animal hair reference collection or a specific animal. If the questioned hair exhibits the same microscopic characteristics as the known hairs, it is concluded that the hair is consistent with originating from that animal. It is noted, however,

that animal hairs do not possess enough individual microscopic characteristics to be associated with a particular animal to the exclusion of other similar animals.

The collection of a suitable known animal hair standard is necessary before a meaningful comparison can be conducted. Because hairs can vary widely in color and length on different areas of the body of an animal, hairs should be collected from each area. While a minimum number of hairs is difficult to determine, good judgment should be used in collecting enough hairs to represent the various types and colors of hairs found on the animal. The sample should contain full-length hairs and should include combings as well as pluckings. If the animal is not available for sample collection, a brush or comb used for the animal may be substituted. Sometimes hair samples collected from a dog or cat bed may be useful when actual samples from the animal cannot be obtained.

Animal hairs found at crime scenes or on the clothing of suspects and victims may also have originated from a fur coat or pelt. These hairs may have been artificially colored or trimmed and often do not have a root. It is preferred that the entire fur garment be obtained so that suitable known samples can be submitted for comparison.

5. Fiber Evidence

A fiber is the smallest unit of a textile material that has a length many times greater than its diameter. Fibers can occur naturally as plant and animal fibers, but they can also be man-made. A fiber can be spun with other fibers to form a yarn that can be woven or knitted to form a fabric. The type and length of fiber used, the type of spinning method, and the type of fabric construction all affect the transfer of fibers and the significance of fiber associations. This becomes very important when there is a possibility of fiber transfer between a suspect and a victim during the commission of a crime.

As discussed previously, fibers are considered a form of trace evidence that can be transferred from the clothing of a suspect to the clothing of a victim during the commission of a crime.

Fibers can also transfer from a fabric source such as a carpet, bed, or furniture at a crime scene. These transfers can either be direct (primary) or indirect (secondary). A primary transfer occurs when a fiber is transferred from a fabric directly onto a victim's clothing, whereas a secondary transfer occurs when already transferred fibers on the clothing of a suspect transfer to the clothing of a victim. An understanding of the mechanics of primary and secondary transfer is important when reconstructing the events of a crime.

When two people come in contact or when contact occurs with an item from the crime scene, the possibility exists that a fiber transfer will take place. This does not mean that a fiber transfer will always take place. Certain types of fabric do not shed well (donor garments), and some fabrics do not hold fibers well (recipient garments). The construction and fiber composition of the fabric, the duration and force of contact, and the condition of the garment with regard to damage are important considerations.

An important consideration is the length of time between the actual physical contact and the collection of clothing items from the suspect or victim. If the victim is immobile, very little fiber loss will take place, whereas the suspect's clothing will lose transferred fibers quickly. The likelihood of finding transferred fibers on the clothing of the suspect a day after the alleged contact may be remote, depending on the subsequent use or handling of that clothing.

6. Natural Fibers

Many different natural fibers originating from plants and animals are used in the production of fabric. Cotton fibers are the plant fibers most commonly used in textile materials, with the type of cotton, fiber length, and degree of twist contributing to the diversity of these fibers. Processing techniques and color applications also influence the value of cotton fiber identifications.
Other plant fibers used in the production of textile materials include flax (linen), ramie, sisal, jute, hemp, kapok, and coir. The identification of less common plant fibers at a crime scene or on the clothing of a suspect or victim would have increased significance.
The animal fiber most frequently used in the production of textile materials is wool, and the most common wool fibers originate from sheep. The end use of sheep's wool often dictates the fineness or coarseness of woolen fibers: Finer woolen fibers are used in the production of

clothing, whereas coarser fibers are found in carpet. Fiber diameter and degree of scale protrusion of the fibers are other important characteristics. Although sheep's wool is most common, woolen fibers from other animals may also be found. These include camel, alpaca, cashmere, mohair, and others. The identification of less common animal fibers at a crime scene or on the clothing of a suspect or victim would have increased significance.

7. Man-Made Fibers

More than half of all fibers used in the production of textile materials are man-made. Some man-made fibers originate from natural materials such as cotton or wood; others originate from synthetic materials. Polyester and nylon fibers are the most commonly encountered man-made fibers, followed by acrylics, rayons, and acetates. There are also many other less common man-made fibers. The amount of production of a particular man-made fiber and its end use influence the degree of rarity of a given fiber.

The shape of a man-made fiber can determine the value placed on that fiber. The cross section of a man-made fiber can be manufacturer-specific: Some cross sections are more common than others, and some shapes may only be produced for a short period of time. Unusual cross sections encountered through examination can add increased significance to a fiber association.

8. Fiber Color

Color influences the value given to a particular fiber identification. Often several dyes are used to give a fiber a desired color. Individual fibers can be colored prior to being spun into yarns. Yarns can be dyed, and fabrics made from them can be dyed. Color can also be applied to the surface of fabric, as found in printed fabrics. How color is applied and absorbed along the length of the fiber are important comparison characteristics. Color-fading and discoloration can also lend increased value to a fiber association.

9. Fiber Number

The number of fibers on the clothing of a victim identified as matching the clothing of a suspect is important in determining actual contact. The greater the number of fibers, the more likely that contact actually occurred between these individuals.

10. Fiber Location

Where fibers are found also affects the value placed on a particular fiber association. The location of fibers on different areas of the body or on specific items at the crime scene influences the significance of the fiber association.