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Preface:

Why teach a course in Forensic Science at the High School level? Simple; there was a demand for it. With the success of TV shows such as CSI and NCIS, forensic science has been thrust into the mainstream media and entered into the homes of America’s youth. Also inundating our culture is the use of forensic science to solve real-life criminal investigations. Shows such as A&E’s Forensic Files and Tru Crime give us an authentic look into the world of criminal investigative efforts to bring offenders to justice. Forensic Science is front page news now, where ever you look, therefore it became apparent that a course of this nature was needed at the high school level; to address the real science and to also discuss the abstract science so to differentiate reality from fiction.

This course was spawned by the curiosity of Marty Sewell, a veteran high school science teacher at Forbush High School. Based upon a curriculum module Sewell interacted with at the National Science Teacher’s Convention, he pitched the idea to his principal who was more than accommodating to Sewell’s enthusiasm. What you have here is a work in progress. After teaching the course for one semester, Sewell saw the immediate need to consolidate the teaching material into a cohesive study guide. Within these pages you will find teaching notes, activities, web links and practically everything else you will need to complete this course successfully.

“Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as silent evidence against him. Not only his fingerprints or his footprints, but also his hair, the fibers from his clothes, the glass he breaks, the tool marks he leaves, the paint he scratches, the blood or semen that he deposits or collect—all of these and more bear mute witness against him.

This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence. Physical evidence cannot be wrong; it cannot perjure itself; it cannot be wholly absent. Only its interpretation can err.

Only human failure to find it, study and understand it, can diminish its value.”

From Kirk, Paul L.
Crime Investigation.
New York: Interscience Publishers, 1953
Laboratory and Safety Guidelines

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

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

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

Laboratory Cleanup
- Keep work, lab, and balance areas clean, limiting the amount of easily ignitable materials.
- Turn off all burners, water faucets, probeware, and calculators before leaving the lab.
- Carefully dispose of waste materials as instructed by your teacher.
- With your goggles on, wash your hands thoroughly with soap and warm water after each activity.
Chapter 1: Introduction to Forensic Science:

…when you have eliminated the impossible, whatever remains, however improbable, must be the truth?
-Sherlock Holmes

Definition and Description

At its most broad definition, forensics is the application of science to law. “Forensics” means forum (public place where, in Roman times, senators and others debated and held judicial proceedings).

As society has become increasingly complex, it has become more dependent on the rules and regulations of society to administer a system of order that people can live harmoniously in. But as there is that element of society that refuses to live by these rules, there must be part of society willing to enforce the rules and administer judgment to the law breakers. In being dedicated to do this, law enforcement has had to continue to modify itself as criminal tendencies have become ever increasingly sophisticated. One would think that crime rates would eventually subside and level off, but the opposite is actually true. As new technologies are introduced to society, new crimes are devised to use it. Consider identity theft; this is a modern day crime that seems to more rampant than ever as our digitized world contains our personal information, bank accounts, credit reports…etc., in cyberspace accessible to anyone who has a computer. This type of crime did not exist 25 years ago. Forensic science has had to not only keep up with the different types of crimes, investigative techniques have had to surpass the criminals’ ability so as to stay a step ahead.

Forensics draw on every type of science to assist in the investigation of crimes, however forensics does not offer the final solutions of how to deal with the presented problems of society. Forensic science is only one facet of the giant machine called justice. The scientists solve the problems, and then must turn the results over to other legal authorities to interpret the scientific findings and apply them to specific legal situations. Therefore it is no wonder that forensic scientists work closely with police investigators and lawyers to bring about a solution to some infraction of law that is acceptable to society.

Refining the definition of FS, one might come up with the following:

“The application of science to those criminal and civil laws that are enforced by police agencies in a criminal justice system.”

But even this definition is not quite adequate to describe the scope and magnitude of all that FS entails.

Forensic Science (FS) draws on many disciplines, including but not limited to: Chemistry, Physics, Biology, Earth Sciences, Mathematics, Psychology, Anthropology, Computer Science,…etc. along with every possible subdivision of each science. FS’s usually specialize in a particular discipline as it would be literally impossible to master all of them.

The term criminalistics would be more applicable in most situations as this term is relegated to the science and not the application to law.

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Vocabulary: Chapter 1
Make sure you can identify these concepts for your midterm exam:

- Forensic Science
- Locard’s Exchange Principle
- Physical Science Unit
- Biology Unit
- Firearms Unit
- Document Examination Unit
- Photography Unit
- Toxicology Unit
- Latent Fingerprint Unit
- Polygraph Unit
- Voiceprint Analysis Unit
- Evidence Collection Unit
- Forensic Pathology
- Myocardial Infarction
- Arrhythmia
- Huypoventilatory Hypoxia
- Exsanguination
- Homicide
- Suicide
- Postmortem
- Rigor Mortis
- Livor Mortis
- Desiccation
- Putrefaction
- Laceration
- Incised Wound
- Puncture
- Abrasion
- Contusion
- Contact Wound
- Coronary Artery Disease
- Pulmonary Embolus
- Myocarditis
- Aortic Valvular Stenosis
- Berry Aneurysm
- Intercerebral Aneurysm
- Perforated Peptic Ulcer
- Anaphylaxis
- Forensic Anthropology
- Forensic Osetology
- Forensic Taphonomy
- Forensic Odontology
- Forensic Psychiatry
History and Development of Forensic Science

There are many individuals that can be cited as having contributed to FS. The following list is definitely a brief listing:

- 700s AD—Chinese used fingerprints to establish identity of documents and clay sculptures
- ~1000—Roman courts determined that bloody palm prints were used to frame a man in his brother’s murder
- 1149—King Richard of England introduced the idea of the coroner to investigate questionable death
- 1200s—A murder in China is solved when flies were attracted to invisible blood residue on a sword of a man in the community
- 1670—Anton Van Leeuwenhoek constructed the first high-powered microscope
- 1776—Paul Revere identified the body of General Joseph Warren based on the false teeth he had made for him
- 1784—John Toms convicted of murder on basis of torn edge of wad of paper in pistol matching a piece of paper in his pocket
- 1859—Gustav Kirchhoff and Robert Bunsen developed the science of spectroscopy.
- 1864—Crime scene photography developed
- 1879—Alphonse Bertillon developed a system to identify people using particular body measurements
- 1896—Edward Henry developed first classification system for fingerprint identification
- 1900—Karl Landsteiner identified human blood groups
- 1904—Edmond Locard formulated his famous principle, “Every contact leaves a trace.”
- 1922—Francis Aston developed the mass spectrometer.
- 1959—James Watson and Francis Crick discover the DNA double helix
- 1977—AFIS developed by FBI, fully automated in 1996
- 1984—Jeffreys developed and used first DNA tests to be applied to a criminal case

Noted individuals will be discussed in greater detail.

1. **Mathieu Orfelia** (1787-1853) – considered to be the father of forensic toxicology. In 1814, published the first scientific treatise on the detection of poisons and their effects on animals.

2. **Francis Galton** (1822-1911) – Developed the first system of using fingerprints as a standard for personal identification.
3. **Alphonse Bertillon** (1853-1914) – developed a system of personal identification based upon body measurements (Fig 1.2). This system, termed anthropometry, was used for two decades before finally being replaced by fingerprinting.

4. **Leone Lattes** (1887-1954) – discovered that blood can be grouped into different categories. These categories today are recognized as type A, B, AB and O.

5. **Calvin Goddard** (1881-1955) – An army colonel, Goddard refined the technique of examining bullets to see if they had been fired from a particular gun. Using the comparison microscope, he revolutionized the science of ballistics.

6. **Albert S. Osborn** (1858-1946) – considered to be the final authority on document examination, published “Questioned Documents” in 1910, and is still considered by some to be the primary resource for document examiners.

7. **Walter C. McCrone** (1916-2002) – One of the world foremost authorities in microscopy, particularly as applied to forensic science. Dr. McCrone was well known and respected throughout the scientific world and was responsible for educating thousands of forensic scientists in the application of microscopic techniques.

8. **Hans Gross** (1847-1915) – Author of the first work to coalesce various branches of science into a single volume that described how they could be used in forensic science. A public prosecutor and judge in Graz, Austria, he spent many years developing his understanding of the various disciplines to publish them in his work, *Criminal Investigations*. 
9. **Edmond Locard** (1877-1966) – Locard pioneered the use of forensic science in practical application to criminal cases. Beginning in an attic above the police department in Lyons with only a microscope and a simple spectrometer, Locard quickly advanced the use of forensics to police cases. He was eventually lifted to the office of founder and director of the Institute of Criminalistics at the University of Lyons, a leading international facility for study and research in forensic science. It was Locard’s belief that every criminal that came in contact with another object or person, that cross transfer occurred. This became known as **Locard’s Exchange Principle** and is still a standard in forensic science today.

![Edmond Locard hard at work in the laboratory. Considered by many to be the Father of modern forensics.](image)

**The Organization of the Crime Laboratory**

Crime laboratory development in the United States has been characterized by rapid growth without national and regional planning and coordination.

- There are currently about 350 public crime laboratories operate at various levels of government—federal (national), state, county, and municipal (city).
- With a large diversity of crime laboratories nationwide, it is impossible to use a general model that describes all.

Laboratory staff sizes range from 1 - 100 people, and the services offered can be diverse or specialized.

- There has been an unparalleled growth of crime laboratories in the last 35 years, due to three things:
  1) Supreme Court decisions in the 1960's that are responsible for police placing greater emphasis on scientifically evaluated evidence. The advent of “Miranda Rights” has eliminated confessions as routine investigative tools.
  2) Crime laboratories are inundated with drug and other evidence specimens due to accelerated drug abuse and increased crime rates.
  3) The advent of DNA profiling. Crime laboratories have had to increase staff and laboratory space. DNA profiling has influenced how the general public perceives modern crime laboratories.
- There are a variety of independent crime laboratories in the United States that precludes (keeps from happening) a national system. There is no single agency that has unlimited jurisdiction.
- There are four major federal crime laboratories that have been created to assist in cases that extend beyond state and local jurisdictions. They offer their expertise to any local agency that requests it.
  1) The **Federal Bureau of Investigation** (FBI) maintains the largest crime laboratory in the world.
  2) The **Drug Enforcement Administration** (DEA) is responsible for analyzing drugs seized in violation of laws.
  3) The **Bureau of Alcohol, Tobacco, Firearms, and Explosives** (ATF) analyze alcoholic beverages, explosive devices, weapons, and related evidence.
  4) The **U.S. Postal Inspection Service** is concerned with crimes relating to the postal service.
• Most states maintain crime laboratories to provide service to local and regional agencies that don’t have their own laboratories.

• Alabama and several other states have a comprehensive statewide system of regional and satellite laboratories.

• Statewide systems are operated under a central facility and provide services to most areas of the state.

• Regional laboratories have greatly increased the accessibility of law enforcement agencies to a laboratory while minimizing duplication of services.

• Local crime laboratories provide services to county and municipal (city) agencies, and are financed by local government. These operate independently of the state crime laboratories. Most of the larger cities in the U.S. maintain their own crime laboratories.

• More than 100 countries around the world have created and maintain crime laboratories.

**Services of the Crime Laboratory**

Different crime laboratories have a variety of services due to local laws, the capabilities of the agency, and budget limitations.

• Many crime laboratories have been created solely for the purpose of processing drug evidence.

• A “full-service” crime laboratory would include the following:

  • **Physical Science Unit** – Incorporates the principles of chemistry, physics, and geology to identify and compare physical evidence. May be further divided into Drug Identification, Soil & Mineral Analysis, and Trace Evidence sections.

  • **Biology Unit** – Applies the knowledge of biological sciences in order to investigate blood samples, body fluids, botanical samples, hair, and fiber samples. Includes DNA profiling.

  • **Firearms Unit** – Investigates discharged bullets, cartridge cases, shotgun shells, and ammunition. Also includes comparison of tool marks, tire treads, and shoe prints.

  • **Document Examination Unit** – Provides the skills needed for handwriting analysis and other questioned document issues. Also analyzes paper and ink, indentations, obliterations, erasures, and burned or charred documents.
- **Photography Unit** – Applies special photographic techniques for recording and examining physical evidence. Special techniques include digital imaging, infrared & ultraviolet, and X-ray photography. Some crime laboratories may offer the optional services of toxicology, fingerprint analysis, voiceprint analysis, evidence collection, and polygraph administration.
- **Toxicology Unit** – Examines body fluids and organs for the presence of drugs and poisons. Also responsible for training Breathalyzer operators as well as maintenance of the instruments.
- **Latent Fingerprint Unit** – Processes and examines evidence for latent fingerprints.
- **Polygraph Unit** – Conducts polygraph (lie detector) tests, administered by people trained in investigation and interrogation.
- **Voiceprint Analysis Unit** – Attempts to tie a recorded voice to a particular suspect. An instrument called a *sound spectrograph* makes a visual graphic display called a *voiceprint*.
- **Evidence-Collection Unit** – Dispatches specially trained personnel to the crime scene to collect and preserve physical evidence.

- A laboratory’s specialized units must not impede coordination of services for the criminal investigator.
- Forensic investigation requires the implementation of skills from many individuals in many of the units a crime laboratory has to offer.

### Additional Services:

### Forensic Pathology

#### I. Introduction

Forensic pathology, which for practical purposes deals with the postmortem investigation of sudden and unexpected death, is about as far from the mainstream of medicine as one can get, short of actually becoming Surgeon General or a medical school dean. The training of a forensic pathologist generally entails a complete five-year residency in anatomic and clinical pathology, followed by one or more years of fellowship training in a medical examiner’s office in a large city “fortunate” enough to have hundreds of homicides per year. A completely credentialed forensic pathologist is certified by the American Board of Pathology as both a general pathologist and as a sub-specialist, following successful completion of the Board examinations in anatomic, clinical, and forensic pathology.

The good forensic pathologist is an amalgamation of pathologist, detective, politician, and public relations person. Not only must one know the technical aspect of the discipline, but he/she needs to have the communication skills to acquire supportive information from law enforcement officers and explain the results of medical examinations to juries (which are specifically selected for technical ignorance) and other laypeople. Also, mediocre media operatives, desperate for exposees when news is slow, find medical examiners to be quick and easy targets. Forensic pathology, because it involves no mean amount of educated guessing, lends itself well to glib Monday morning quarterbacking by amateurs.

![Fig 1-5. Reconstruction of the flight of a bullet through a victim’s skull.](image)

[There are a few peculiar incidental advantages to being in the world of forensic pathology. 1) In many jurisdictions, the forensic pathologist, as a criminal investigator, may acquire a permit to carry a handgun. This is
perfect for those just macho enough to wish to go armed, but not so macho as to want to go to jail for it. 2) Since forensic pathologists typically work in nonmedical institutions, such as city morgues and county medical examiner's offices, they may be exempt from licensing/certifying agencies and may thumb their noses at even the most basic laboratory safety practices. It is something of a tradition for a lot of eating and smoking to be going on while actually performing autopsies. On the other hand, forensic pathologists are not known for their longevity.

II. Role of the Forensic Pathologist

Forensic determinations go beyond those of patient-oriented medicine, as they involve legal as well as medical considerations:

A. Cause of death

This is a specific medical diagnosis denoting a disease or injury (e.g., myocardial infarction, strangulation, gunshot wound). In particular,

- 1. Proximate cause of death. The initial injury that led to a sequence of events which caused the death of the victim.
- 2. Immediate cause of death. The injury or disease that finally killed the individual.

Example: A man burned extensively as a result of a house fire dies two weeks later due to sepsis. The proximate cause of death is his burns, leading to sepsis, which is the immediate cause of death.

B. Mechanism of death

This term describes the altered physiology by which a disease or injury produces death (e.g., arrhythmia, hypoventilatory hypoxia, exsanguination).

C. Manner of death

This determination deals with the legal implications superimposed on biological cause and mechanism of death:

1. Homicide. Someone else caused the victim's death, whether by intention (robber shoots convenience store clerk) or by criminal negligence (drunk driver, going 55 mph on Fondren, runs red light at Bellaire and strikes pedestrians in crosswalk). After the forensic determination is made, it may of course be altered as a result of a grand jury or other legal inquiry. For instance, when one child shoots another, the forensic examination may conclude from the body that homicide was the manner of death, but after considering all evidence, a grand jury may conclude that the gun discharged accidentally.

2. Suicide. The victim caused his/her own death on purpose. This may not always be straightforward. For instance, a victim may strangle himself accidentally during autoerotic behavior (apparently some people find a certain amount of hypoxia very stimulating). If the examiner were not to consider all of the evidence (such as erotic literature found near the body), an incorrect determination of "suicide by hanging" might be made. This error may be financially disastrous for the victim's survivors, since many life insurance policies do not award benefits when the insured is a suicide. Also, in some cultures suicide is a social stigma or a sin against its deity.

3. Accidental. In this manner of death, the individual falls victim to a hostile environment. Some degree of human negligence may be involved in accidental deaths, but the magnitude of the negligence falls short of that reasonably expected in negligent homicide. Whereas the negligence of the speeding drunk, above, would
be considered gross by a reasonable observer, a pedestrian killed at the same intersection by a sober driver, not speeding or running a red light, would be reasonably considered a victim of accidental death.

4. Natural causes. Here, the victim dies in the absence of an environment reasonably considered hostile to human life. Most bodies referred for forensic examination represent this manner of death. We will consider the major diseases producing sudden death below.

III. "Normal" postmortem changes

These are important to be familiar with, as they may otherwise mislead the examiner into thinking trauma or other foul play led to the victim's death.

A. Rigor mortis, familiar to any aficionado of horror films, begins earlier in small muscles and muscles exercised vigorously prior to death. An extreme example is "cadaveric spasm," a great literary/cinematic device, in which a person dying following extreme exertion "freezes" in place virtually in a photographic pose of the moment of death. I would imagine that this occurs a lot more often in movies than in reality. Rigor mortis passes as muscle decomposition begins and is usually gone in 36 hours. It can also be mechanically "broken" by stretching the rigid muscles by force.

B. Livor mortis, (see image right) or hypostasis, a purplish discoloration of the body and organ surfaces, results when blood settles to dependent parts of the body. It becomes visible between one-half hour and two hours after death. Early on, the blood remains in the vessels, so the livor can be blanched by applying pressure to the affected part. Later, the blood hemolyzes, and the hemoglobin breakdown pigment leaches out into the extravascular interstitium. At this point, the livor cannot be blanched by pressure and is said to be "fixed." The period over which livor becomes fixed is so variable that whether it is fixed or not offers little information in trying to determine the time of death.

C. Desiccation occurs most prominently on the mucous membranes, which during life are kept moist (by blinking, lip licking, etc) and are not protective by water repellant keratin in cornified skin. The membranes may look "burned," and the conjunctiva may actually be black ("tache noire").

D. Putrefaction is the sequence of physicochemical events that begins with death and ends with dissolution of the nondurable parts of the body. It begins with a greenish discoloration of the skin and mucous membranes. The epidermis becomes detached from its basement membrane, and flaccid cutaneous bullae form. Overgrowth of bacteria (which normally seed the entire body via the bloodstream at or immediately before the time of death) cause gas production, resulting in gaseous distension of the body cavities, which may then rupture. The soft tissues may also puff up and appear swollen, also as a result of gas release. Finally, autolysis and bacterial lysis hydrolyze proteins and fats, to produce frank liquefaction of the soft tissues. The proteins get broken down into amino acids, which then are decarboxylated and become "biogenic amines" with such memorable and apt names as "putrescine" and "cadaverine." Other protein-derived products of putrefaction are amino acid residues with sulfhydryl (-SH) groups; these are also mighty rank. The sulfhydryl groups are often further cleaved off, then released as hydrogen sulfide, which also has the ability to put your olfactory neurons into overload.
E. Alternatives to putrefaction include **mummification**, in which the body dries out faster than decomposition takes place, and **adipocere formation**, in which by some unknown mechanism the adipose tissues become chemically transformed into a waxy substance that acts as a preservative. As might be expected, mummification typically occurs in dry environments. Adipocere formation, which is much rarer, tends to occur in moist environments, such as caves. A good example of adipocere can be viewed at Philadelphia's Mutter Museum, where the "Soap Lady" is on exhibit.

IV. Trauma

This is the cornerstone of forensic pathology. Terms used to describe traumatic lesions are somewhat more specific than analogous terms used in surgery and internal medicine.

A. **Laceration** is a tearing injury due to friction or impact with a blunt object. The typical laceration has edges which are ragged, bruised, and/or abraded. Generally, surgeons and ER physicians do not make a distinction between lacerations and incised wounds, calling them both "lacerations."

B. **Incised wound** is a cutting injury due to slicing action of a bladelike object. The wound edges are smooth. Serrated blades produce the same smooth edges as do nonserrated blades.

C. **Puncture** is a penetrating injury due to pointed object without a blade, such as an ice pick.

D. **Abrasion** is a friction injury removing superficial layers of skin, allowing serum to exude and form a crust. Abrasions may not be visible on wet skin; therefore, an abrasion not apparent when a body is first examined may appear the next day, after the wet body has had a chance to dry out in the morgue refrigerator.

E. **Contusion** is a bruise due to rupture or penetration of small-caliber blood vessel walls. Contusions may be seen on the surfaces of internal organs (such as the brain or heart) as well as the skin and mucous membranes.

F. **Gunshot wounds** represent a special form of trauma very important to forensic pathology. The types of determinations made on bodies include 1) type of firearm used (shotgun, handgun/rifle, or high-powered rifle), 2) distance of the gun from the victim at the time of firing, 3) whether a given wound is an entrance wound or an exit wound, and 4) track of the projectile through the body. Wounds may be classified by distance as follows:

1. **Contact wound**: Muzzle of gun was applied to skin at time of shooting. Classic features include an impression of the muzzle burned around the entrance wound and absence of fouling and stippling (see below). Contact wounds over the skull may have a stellate appearance because of expulsion of hot gases from the barrel which are trapped against the outer table of the skull and blow back toward the exterior, ripping apart the skin around the entrance wound.

2. **Close range (6 - 8 inches)**: The entrance wound is surrounded by fouling, which is soot that travels for a short distance from the gun barrel to be deposited on the skin. There may also be stippling (see below).

3. **Intermediate range (6 - 8 inches to 1.5 - 3.5 feet)**: This is too far for soot to travel, so there is no fouling, but hot fragments of burning propellant (gunpowder) follow the bullet to the victim and produce stippling by causing pinpoint burns around the entrance wound. Of the two type of propellant, "ball" and "flake," the former will produce stippling at a greater distance.

4. **Distant (greater than 1.5 - 3.5 feet)**: This is too far for either soot or burning propellant to travel, so the wound margins are clean, with neither fouling nor stippling. Entrance versus exit wounds represents an important distinction for the forensic pathologist to make. A grand jury may look with more favor on an assailant alleging self defense, if the victim has the entrance wound on the front and
the exit wound on the back, rather than vice versa. Classically, the entrance wound has a rim of abrasion surrounding the wound, because the projectile "drags" the surrounding skin into the wound a bit, abrading it along the way. The exit wound lacks this abrasion, unless the victim was braced against a wall or other solid object that may secondarily abrade the margin of the exit wound as the projectile penetrates the skin and pushes it into the wall.

The following images were taken by a forensic pathologist;

Image A (left) – deep laceration of the right arm. Indicative of a defensive wound receive from an attacker with a knife.

Image B (left) – an abrasion ring and muzzle imprint from a shooting victim. The gun was pressed into the victim before firing. This would be classified as a contact wound.

Image C (left) – electrocution burns. A man, inadvertantly grabbed high voltage electrical line producing an electrical burn seen in the palm of the hand. The subsequent soft tissue damage and swelling are similar to a localized burn.

Check out this website for a “Time of Death” program that you can plug data into.
http://www.pathguy.com/TimeDead.htm
V. Death by Natural Causes

Perhaps having a bit more relevance to patient-oriented medicine is the problem of sudden and unexplained death by natural causes. Careful attention to the autopsy and the patient's history usually establish the cause of death, but a few cases, like that of Elvis Presley, will remain mysteries indefinitely.

A. Coronary artery disease is the most common cause of nontraumatic sudden death. Autopsy typically shows occlusion of at least 60% of the luminal cross-section of one or more of the three major branches of the coronary arterial system. The occlusion may be all atheroma, or thrombus superimposed on atheroma. It is likely that spasm of the coronary artery, which cannot be demonstrated at autopsy, plays a role in a significant proportion of these cases. The myocardium itself may be perfectly normal, death having resulted from ischemia-induced arrhythmia before anatomic changes of infarction have time to develop.

B. Pulmonary embolus, typically a saddle thromboembolus, stops the heart by some type of reflex action. At autopsy all that may be found is the embolus itself, as the patient dies before anatomic changes of pulmonary infarction have time to develop. Emboli may occur in previously normal individuals, but one may find in some cases a history of recent immobilization (like a truck driver on a long haul, or a person recently discharged from the hospital).

C. Myocarditis, typically of viral etiology, may cause sudden death, often in association with vigorous physical activity. There may be history of a recent acute viral upper respiratory infection.

D. Aortic valvular stenosis physiologically resembles coronary artery disease in a patient with essential hypertension. The coronary ostia are poorly supplied due to the marked pressure differential across the aortic valve. Also, the myocardium demands more blood supply as a result of having to pump against that pressure gradient. Most cases nowadays are due to a congenital bicuspid aortic valve, but a history of old rheumatic fever should be sought.

E. Berry aneurysms of the arteries at the base of the brain may rupture, producing fatal subarachnoid hemorrhage. The typical victim is a young or middle-aged female. There may be history of complaints of a very severe headache immediately before the collapse.

F. Intracerebral hemorrhage is usually seen in older, typically hypertensive patients. Embolic or atherosclerotic strokes usually do not produce sudden death.

G. Perforated peptic ulcer is common, as about 10% of peptic ulcers present with perforation and no previously documented manifestations. Fortunately, only rarely do they produce sudden death. The mechanism of death is unknown but probably involves some sort of autonomic reflex (which is what is typically invoked when the cognoscenti have absolutely no idea about what the pathogenetic mechanism is).

H. Anaphylaxis, better known as Type I Immunologic Hypersensitivity Reaction From Hell, may cause sudden death by laryngeal edema, causing asphyxiation. Usually, the inciting stimulus (bee sting, penicillin injection, etc.) is apparent from the history.
Forensic Anthropology

Anthropology is the study of humans. This diverse field is traditionally divided into three subfields: cultural (social) anthropology, archeology, and physical (biological) anthropology. Cultural anthropologists study the beliefs and customs of people in different (usually third world) societies. Archeologists excavate and study the artifacts and architecture of ancient peoples. Physical anthropologists study the anatomy, growth, adaptation, and evolution of the human body. All of anthropology is comparative in its approach, examining the differences and similarities between people across the globe and through time.

Forensic anthropology is the application of anthropological research and techniques to the resolution of medicolegal issues, drawing primarily from physical anthropology and archeology. The critical distinction between a forensic anthropologist and a general anthropologist is the former’s focus on human identification. The subfields of forensic anthropology are:

- forensic osteology
- forensic archeology
- forensic taphonomy

Osteology is the study of the skeleton. Archeology involves the controlled collection and excavation of human remains and other evidence from the scene. Taphonomy is the study of changes occurring to human remains at the time of and after death, including trauma, decomposition, and environmental modification.

Fig. 1-7 (above) shows a gunshot wound on the skull of a victim. Fig 1-8 (left) shows Dr. William Bass, the founder of ARF (Anthropological Research Facility), otherwise known as the “Body Farm”, at the University of Tennessee at Knoxville. Dr. Bass is studying the effect of decomposition on the human body to help investigators gather information about discovered human remains.
Forensic Entomology

Forensic Entomology is the use of the insects, and their arthropod relatives that inhabit decomposing remains to aid legal investigations. The broad field of forensic entomology is commonly broken down into three general areas: medicolegal, urban, and stored product pests. The medicolegal section focuses on the criminal component of the legal system and deals with the necrophagous (or carrion) feeding insects that typically infest human remains. The urban aspect deals with the insects that affect man and his immediate environment. This area has both criminal and civil components as urban pests may feed on both the living and the dead. The damage caused by their mandibles (or mouthparts) as they feed can produce markings and wounds on the skin that may be misinterpreted as prior abuse. Urban pests are of great economic importance and the forensic entomologist may become involved in civil proceedings over monetary damages. Lastly, stored product insects are commonly found in foodstuffs and the forensic entomologist may serve as an expert witness during both criminal and civil proceedings involving food contamination.

Forensic Psychiatry

Basically forensic psychiatry is a branch of medicine that focuses on the interface of mental health as well as law. Forensic psychiatry includes psychiatric consultation in a wide range of legal matters as well as clinical work with perpetrators as well as victims.

A Forensic psychiatrist is a medical doctor with the additional training of a psychiatrist and then specialized training and experience in the application of psychiatric knowledge to questions posed by the legal system is called a forensic psychiatrist. In the scenario when a forensic psychiatrist acts in the capacity of a forensic specialist, he/she does not provide therapy to alleviate the patient’s suffering or to help the patient be healthy, but instead provides an objective evaluation that can be used by the retaining institution, attorney or court.

When does forensic psychiatry prove useful to the legal process?

In cases when legal matters involve issues that are outside the expertise of lawyers and judges, consultation from professionals in a wide variety of fields, including medical specialties is sought. This is when forensic psychiatrists work with courts in evaluating an individual’s competency to stand trial, defenses based on mental diseases or defects and sentencing recommendations.

Basically there are two major areas in criminal evaluations in forensic psychiatry, which have been listed below.

1. Competency to Stand Trial (CST)

This competency evaluation is used to determine whether a defendant has the mental capacity to understand the charges and assist his/her attorney. This law that is seated in the Fifth Amendment to the US constitution ensures the right to be present at your trial, to face the accusers and to seek help from an attorney. Often, as a witness forensic psychiatrists are called to be expert witnesses in civil and criminal proceedings. Here the forensic psychiatrist has to give his/her opinion about a specific issue often from a detailed report, prepared beforehand. It is the duty of the expert witness to provide an independent opinion to the court.
2. Mental State at the Time of the Offence (MSO)

This evaluation is used to give the court an opinion, which states whether the defendant was able to understand what he/she was doing at the time of the crime. Many states word this very differently, whereas in some, it has been rejected altogether. Despite that, in every setting the intent to do a criminal act and the understanding that it was a criminal act bear on the final disposition of the case. Forensic psychiatry is mostly guided by laws of significant court rulings that bear on this area. These laws include three standards which have been listed below.

- **Durham Rule**: This court ruling excuses a defendant whose conduct is because of mental disease or some defect.

- **M’Naghten Rules**: This rule excuses a defendant who does not know the quality of the act, or does not know that the act is wrong, because of a defect of reason or disease of the mind.

- **ALI Test**: This test is used to excuse a defendant who lacks substantial capacity to appreciate the criminality of his conduct or to conform his conduct to those required by law because of a mental disease or defect.

Forensic psychiatrists also take care of prisoners in prisons as well as jails.

**Forensic Odontology**

Forensic odontology (which is also called forensic dentistry or bitemark evidence expertise) mainly involves the identification of an assailant by comparing a record of their dentition (set of teeth) with a record of a bite mark left on a victim. Other uses in law for dentists include the identification of human remains, medico-legal assessment of trauma to oral tissues, and testimony about dental malpractice. The forensic dentist, however, is to an ordinary dentist what the forensic pathologist is to an ordinary physician. They are board-certified specialists who deal primarily with bite mark evidence. Although one doesn’t have to be a board-certified specialist to become an expert witness in this area, it does help to lend validity to any scientific opinions rendered. Courts have been remarkably generous in granting qualification to experts, regardless if they are a forensic dentist or a non-specialist dentist.

It should be remembered that it was bite mark evidence back in 1975 that gave us the *Marx* standard of admissibility, and it’s probably worth quoting that standard at length (People v. Marx 1975):

> “In making their painstaking comparisons and reaching their conclusions, the experts did not rely on untested methods, unproven hypotheses, intuition or revelation. Rather, they applied scientifically and professionally established techniques -- x-rays, models, microscopy, photography -- to the solution of a particular problem which, though novel, was well within the capability of those techniques. In short, *in admitting the evidence, the court did not have to sacrifice its independence and common sense in evaluating it.*”

All dental records are based on a universal numbering system, and contain an amazing amount of information. For example, they note:

1. fillings
2. extractions
3. surface structure/root configuration
4. adjacent teeth
5. twisted/tilted teeth

- Antemortem/Postmortem match determines identity.
Reading Assignment #1:

A Summarized History of Forensic Science!
By Leanne Perry.

No crime is more frightening than serial murder. Not only are these crimes most brutal and sickening, but the serial killer usually targets a particular type of person, (i.e. children, prostitutes, women, elderly women, young boys, male hustlers, hitchhikers), then selects his victims at random from this category, so none of us are safe, really, because we all belong to one or more particular group. How long has mankind put up with this heartache? Probably for as long as the race has existed. Below we take a closer look at the terms ‘Serial Killer’, ‘Forensic Medicine or Science’ and follow the progress of ‘detection’ through to modern times:

The term ‘Serial Killer’ was invented in the early 1980s, by American F.B.I. Agent Robert Ressler. He was describing a killer who killed repeatedly and obsessively, on separate occasions. Those who kill many victims all at one time, come under the term: ‘Mass Murderer’. It was noted by Lesser and his colleagues that a ‘Serial Killer’ chooses his particular victims at random, and the most common motive is sexual, but it’s not necessarily always the case. Serial Killers are usually white, heterosexual males, of above average intelligence, aged in their 20s or 30s. They were probably once commonly considered attractive by those around them, and most were bed-wetters, animal torturers and/or from violent households as children. After their crimes, many enjoy cannibalism, necrophilia and/or take away body parts as ‘trophies’. The percentage of Male Serial Killers far outweighs that of Female ones.

An examination of known Serial Killers, reveals that:
Peter Sutcliffe, (‘The Yorkshire Ripper’), Ted Bundy, (‘The Campus Killer’), Albert DeSalvo, (‘The Boston Strangler’), Norman John Collins, (‘The Ypsilanti Killer’), and others were all considered nice, decent, honest and handsome men, by family members and those who knew them best.

HISTORY OF FORENSICS:

Prehistoric rock carvings and an early human painting of a hand with ridge patterns, show evidence of the use of fingerprints. Few records of serial killings from mere centuries ago, still exist today. Examination of the earliest records, tells us that crime detection depended largely on finding a link between the crime and the criminal, (i.e. a clear motive). Looking back at the oldest recorded incident, Gilles de Rais, a French nobleman, fought alongside Joan of Arc at Orleans and killed hundreds of children in the 15th century. He was a satanist and alchemist who, in addition to killing and molesting children for his own pleasure, used their blood in an attempt to turn lead into gold. He was strangled to death and burned by the church after a trial. In ancient Rome, Locusta the Poisoner killed five or six people, for profit and some for her own enjoyment. She killed and molested children for her own pleasure, then used their blood in an attempt to turn lead into gold. She was strangled and burned by the church after a trial in 69 A.D.

In the 18th and early 19th century, the usual motive for any crime was robbery. Over a twenty year period, beginning in 1830, Frenchwoman Helene Jegado, poisoned around 60 people, then was executed in 1852. In 1862, Frenchman Martin Dumollard was found guilty of murdering 6 girls, so was sentenced to death. In 1871, Frenchman Eusebius Piedagnelle stabbed 6 young women. In 1858, Englishman Sir William Hershel began using fingerprints on native contracts. In 1877, American Thomas Taylor, suggested that markings from the tips of a persons fingers could be used
for identification in criminal cases. In 1880, Scotsman Henry Faulds used fingerprints to eliminate an innocent suspect.

In 1888, while the Whitechapel murderer was in full swing, Sir Francis Gaton was merely making observations of fingerprints as a means of identification and didn’t publish his book on the topic, until 1892. In that same year, Argentinean police researcher Juan Vucetich developed a fingerprint classification system that was used in Latin America. The system came into use in Europe and North America in 1896, developed by Sir Edward Richard Henry.

In 1901, Dr. Paul Uhlenhuth developed a method of testing blood stains, to determine if they were human. Fingerprinting was introduced to Scotland Yard in 1902.

In the 1960s the ‘serial’ type of killings became known amongst the American police as 'Stranger-to-Stranger' murders. This type increased in occurrence in the U.S., from 6% of all crimes, to 18% by the mid-1970s. At that time, there were more than 4000 cases per year.

In 1978, the Yorkshire Ripper case taught detectives a valuable lesson. If Peter Sutcliffe’s details, (his shoes size, blood type, etc.), had have been stored on a computer, he probably would have been questioned further, sooner, saving a few lives. It would have also told detectives working on the case, that he’d been interviewed before. The Surrey Police began investigating the next Serial Killer case, with the use of the computer print-out of the names of 4900 sex offenders. On this list was a man named John Duffy, who’d been charged with loitering near railway stations. A study of this loiterer’s ‘mental map’, (of committing crimes near railway lines), led to the development of ‘Psychological Profiling’ techniques in the 1980s.

It was soon discovered that Serial Killers were likely to have experienced environmental problems, (dysfunctional family relations, aggressive parents, etc.), and/or behavioral traits, (bedwetting beyond age 12, violence, arson, etc). Moors murderer Ian Brady, threw cats from windows. Ed Kemper cut the family cat into pieces with his boy scout’s knife.

In 1984, Sir Alec Jefferies developed the first DNA profiling test. He published his findings in 1985. ('DNA' stands for: DeoxyriboNucleic Acid, which is the stuff that living genes are made up of. 'DNA profiling', is identifying people by visual representations of regions of their genes. It can determine whether or not a suspect has similar DNA characteristics, to evidence found at the scene of a crime. With the exception of identical twins, the DNA of each individual is unique to him or her.)

In 1986, 'DNA Profiling' was first used to identify Colin Pitchfork as the murderer of two girls in England. In 1987, 'DNA Profiling' was introduced to the U.S.A., to convict Tommy Lee Andrews of a series of sexual assaults.

Today’s advancement in computers has greatly simplified tasks that were once considered very complicated. In 1999 Dr. Lawrence Farwell developed the technique of ‘Farwell Brain Fingerprinting’, a new computer-based method of identifying criminals by measuring brain-wave responses to viewing relevant pictures.

Three-dimensional laser scanners will soon replace microscopes. As technology advances into the future, forensic sciences like: pathology, toxicology, anthropology and odontology will follow.

SOURCES:

1. ‘What Makes A Serial Killer?’
2. ‘Forensic Clues To Murder’  
   - Brian Marriner.

3. The Giant Book of World Famous Murders’  
   - Colin Damon & Rowan Wilson.

4. ‘The Serial Killers’  
   - Colin Wilson & Donald Seaman.

5. ‘The History of Forensic Science’  
   - http://www.forensicdna.com/Forensictimeline.htm

6. ‘Brain Fingerprinting’  
   — http://www.forensic-evidence.com/site/Behv_Evid/Farwell_sum6_00.html

Questions Based on the Reading:

Answer these questions and email to Mr. Sewell at marty.sewell@yadkin.k12.nc.us. Make sure that you put in the “Subject” line of the email [Forensics-Chapter 1-Reading Assignment (your name)].

1. Where did the term “serial killer” come from?

2. Describe the “typical” serial killer. Be sure to include not only physical characteristics, but psychological characteristics as well.

3. Based upon the earliest forensic records, how were criminals associated to their crime?

4. How did the Yorkshire Killer case influence how forensics was done?

5. Explain how DNA profiling works and give an example of a case that used DNA evidence to convict someone.
Research Assignment-1:

Vocab: Define and describe how this term or concept relates to forensics.
1. Criminalistics
2. Forensic Science
3. Quantitative Research
4. Qualitative Research
5. Scientific Method
6. Statutory Submission
7. Anthropometry
8. Canonical Law
9. Code of Hammurabi
10. Dactylography
11. The Dauber Decision
12. Forensic Pathology
13. Forensic Toxicology
14. Justinian Code
15. Law of the 12 Tables
16. M’Naughten Rule
17. Mores of society
18. Roman Law

Questions: (You may have to look outside of this document to find these answers; thus the title “Research Assignment”)
1. Why don’t all crimes receive the same amount of investigative effort?
2. Why are cases that deal with drugs and alcohol given more priority in Forensic Science?
3. What is the CSI effect and how has it lead to an increased interest in forensics?
4. Why can increased media exposure of criminal justice have a negative impact on forensic science?

Notes:
Use whatever means you need to find the answers to these questions. Use each other and divide and conquer.

First Grading Period Project:

Directions:
Pick any topic in forensic science. You will be presenting this topic to the class in the form of a 5 minute power point presentation. The object is to familiarize yourself, as well as your classmates, on this topic. The power point should include all necessary pictures, drawings, vocabulary etc. You will provide the narrative. Remember this is a presentation; you are not using the power point as a teleprompter to read from. Provide your resources on one of the last slides. Write 5 test questions on your presentation; either fill-in or short answer style with the answers. No two people can have the same topic.

You will submit your topic and an abstract of the topic on a date specified by Mr. Sewell.
Activity: Can you solve the mystery?

In the Sherlock Holmes’ mystery *The Adventure of the Dancing Men* by Sir Arthur Conan Doyle, Elsie Patrick received several disturbing messages that were written using figures of dancing men. To decode the messages that she received (as well as the message that she sent to the criminal),

Sherlock Holmes used two facts:
• The letter E is the most common letter in the English language.
• It was likely that Elsie’s name appeared in one of the messages.

Can you decode the following messages?

Criminal’s first message to Elsie

Criminal’s Second Message to Elsie:

Criminal’s Third Message to Elsie:

Elsie’s Message to the Criminal:

Criminal’s Fourth Message to Elsie:

Sherlock Holmes’ Message to the Criminal:
**Lab Activity #1: Forensic Anthropology**

Forensic anthropology is a unique forensic discipline that studies the human skeleton to answer various questions about an individual’s race, sex, age, height, illness, and trauma. In this particular exercise students will explore 1) how a single bone can reveal a person’s overall height and 2) how this information can be used to make presumptive identifications.

A person’s height can be affected by several variables: age, sex, race, health, etc. Anthropologists have compiled several formulas for determining the approximate height of an individual given the length of any of the long bones of the human body. It is important to stress to the students that these formulas only give approximations of height—they are not exact.

One of the main factors affecting a person’s height is age. The formulas provided were designed for individuals between 23 – 30 years old. Before the ages of 18-23 a person’s bones have yet to full ossify. **Ossification** is the natural replacement of cartilage with bone; it is responsible for nearly all bone growth. Because these bones are still growing, the relationship between bone length and an individual’s height is extremely variable. Be sure that your class realizes that the data they collect from each other is only applicable to their same age group. It would NOT apply to adults.

**Assignment:** Identify these two bones and discuss the anatomy/pathology of each.
Lab Materials:
- Metric Ruler
- Calculator

No Bones About It (Part 1)
When a body is discovered, it is important to learn as much as possible from the remains. Forensic anthropologists use mathematical formulas to estimate someone’s height from the lengths of certain bones in their body. But where do these formulas come from?

1. Using a metric ruler, measure the length of your femur (thigh bone) in centimeters. This is the large bone that runs from your hip socket to your knee cap. Record this information in the table below.

2. Have a partner measure your actual height in centimeters. Record this information in the table below.

3. Collect the same information (femur length and height) from several of your classmates. Leave the “calculated height” row blank for now.

Table 1: Classroom Measurements

<table>
<thead>
<tr>
<th>Name</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur Length (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated Height (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Use the graph paper on the next page to graph the data you’ve collected. Use Femur Length for the x-axis and Height for the y-axis.

5. Use your graph to answer the following question: What relationship is there between the length of someone’s femur bone and their height?
No Bones About It (Part 2)

Anthropologists have performed hundreds of calculations like the one we just did. Their calculations showed that a person’s height can be estimated using the lengths of the long bones of the body—the femur, tibia, and fibula in the leg, and the ulna, radius, and humerus of the arm. However, the relationship between the length of these bones and a person’s height is different for men and women and for people from different races. The table below lists all the different equations forensic anthropologist use to estimate a person’s height.

Table 2: Formulas for calculating height

<table>
<thead>
<tr>
<th>BONE</th>
<th>RACE</th>
<th>MALE EQUATION</th>
<th>FEMALE EQUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur</td>
<td>Caucasian</td>
<td>2.32 * length + 65.53 cm</td>
<td>2.47 * length + 54.13 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>2.10 * length + 72.22 cm</td>
<td>2.28 * length + 59.76 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>2.15 * length + 72.57 cm</td>
<td>Not Available</td>
</tr>
<tr>
<td>Tibia</td>
<td>Caucasian</td>
<td>2.42 * length + 81.93 cm</td>
<td>2.90 * length + 61.53 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>2.19 * length + 85.36 cm</td>
<td>2.45 * length + 72.56 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>2.39 * length + 81.45 cm</td>
<td>Not Available</td>
</tr>
<tr>
<td>Fibula</td>
<td>Caucasian</td>
<td>2.60 * length + 75.50 cm</td>
<td>2.93 * length + 59.61 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>2.34 * length + 80.07 cm</td>
<td>2.49 * length + 70.90 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>2.40 * length + 80.56 cm</td>
<td>Not Available</td>
</tr>
<tr>
<td>Humerus</td>
<td>Caucasian</td>
<td>2.89 * length + 78.10 cm</td>
<td>3.36 * length + 57.97 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>2.88 * length + 75.48 cm</td>
<td>3.08 * length + 64.67 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>2.68 * length + 83.19 cm</td>
<td>Not Available</td>
</tr>
<tr>
<td>Ulna</td>
<td>Caucasian</td>
<td>3.76 * length + 75.55 cm</td>
<td>4.27 * length + 57.76 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>3.20 * length + 82.77 cm</td>
<td>3.31 * length + 75.38 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>3.48 * length + 77.45 cm</td>
<td>Not Available</td>
</tr>
<tr>
<td>Radius</td>
<td>Caucasian</td>
<td>3.79 * length + 79.42 cm</td>
<td>4.74 * length + 54.93 cm</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>3.32 * length + 85.43 cm</td>
<td>3.67 * length + 71.79 cm</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>3.54 * length + 82.00 cm</td>
<td>Not Available</td>
</tr>
</tbody>
</table>

*These formulas are calculated for adult males and females. (from Bass, W.M. (1987) Human Osteology: A Laboratory and Field Manual (3rd ed.). Missouri Archeological Society, Columbia.)*

Use the table to fill in the “Calculated Height” row on Table 1. Are the results close to the actual heights? What are some possible sources of error?
LONG BONES OF THE HUMAN SKELETON

- Humerus
- Radius
- Ulna
- Femur
- Fibula
- Tibia
No Bones About It (Part 3)
The following bones were recovered from the construction site. A fellow forensic anthropologist has already classified the bones by sex and race. Using the mathematical formulas from Table 2, calculate the approximate height of each individual.

Table 3: Analysis of bones from construction site

<table>
<thead>
<tr>
<th>Bone#</th>
<th>Type of Bone</th>
<th>Length(cm)</th>
<th>Race</th>
<th>Sex</th>
<th>Calculated Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Humerus</td>
<td>38.2</td>
<td>Caucasian</td>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Femur</td>
<td>44.0</td>
<td>African-American</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ulna</td>
<td>25.4</td>
<td>Caucasian</td>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Femur</td>
<td>52.4</td>
<td>Caucasian</td>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Femur</td>
<td>43.9</td>
<td>African-American</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Tibia</td>
<td>43.7</td>
<td>Caucasian</td>
<td>Male</td>
<td></td>
</tr>
</tbody>
</table>

Questions:
1. Is it possible any of these bones came from the same person? Which bones?

2. What is the minimum number of bodies buried at this site? What is the maximum number of bodies?

3. Do all bones from the same body give exactly the same height? If not, why would the heights be different?
No Bones About It (Part 4)

Another forensic anthropologist on the team estimates the remains have been buried three to four years. A search of the local missing person’s database shows that the following people disappeared during that time:

MISSING PERSONS DATABASE

| Missing Person #1 | Name: Dana Grant                  | Height: 5’0” |
|                  | Age: 27                           | Hair Color: Black |
|                  | Sex: F                            | Eye Color: Brown |
|                  | Race: African-American            |
|                  | Distinguishing Marks: Small rose tattoo on left ankle; appendectomy scar |

| Missing Person #2 | Name: Rosalyn Fairbanks           | Height: 5’7” |
|                  | Age: 36                           | Hair Color: Black |
|                  | Sex: F                            | Eye Color: Green |
|                  | Race: Caucasian                   |
|                  | Distinguishing Marks: Wears glasses or corrective lenses |

| Missing Person #3 | Name: Devon Bailey                | Height: 5’8” |
|                  | Age: 45                           | Hair Color: Black |
|                  | Sex: M                            | Eye Color: Brown |
|                  | Race: African-American            |
|                  | Distinguishing Marks: None         |
Missing Person #4

Name: Wayne Aughney
Age: 36
Sex: M
Race: Caucasian
Distinguishing Marks: Tattoo of a dragon on upper right arm

Height: 6’2”
Hair Color: Black
Eye Color: Brown

Missing Person #5

Name: Crystal Wilson
Age: 47
Sex: F
Race: African-American
Distinguishing Marks: Large birthmark on upper back

Height: 5’3”
Hair Color: Black
Eye Color: Brown

Missing Person #6

Name: Jessie Anderson
Age: 46
Sex: M
Race: African-American
Distinguishing Marks: Surgical scars on the back and legs due to injuries in an automobile accident

Height: 5’4”
Hair Color: Black
Eye Color: Brown

Missing Person #7

Name: Herman Arbas
Age: 29
Sex: M
Race: Caucasian
Distinguishing Marks: Scars on the forehead and right cheek from construction accident

Height: 5’8”
Hair Color: Blond
Eye Color: Brown
Final Analysis:

1. Using the database, can you determine the possible identities of the people buried at the site?

2. Are the heights exactly what you expected them to be? Why or why not?

3. What are some possible sources of error in your identification?

4. What other forensic tests could you do to test your deductions?
Lab Activity #2: Where did they drown?

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

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

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

All substances, including water, can diffuse. However, the diffusion of water across a selectively permeable membrane has a different name, osmosis. Suppose you have two solutions of sugar of different concentrations (high and low) in a clear box. A membrane that is permeable to water but not to sugar separates the two solutions. High concentration is on side 2, and low concentration is on side 1, as shown in Figure 1-4 below. The solution on the left has a lower sugar concentration relative to the one on the right and is said to be hypotonic to the one on the right. The solution on the right has a higher sugar concentration compared to the one on the left and is said to be hypertonic to the solution on the left.

![Figure 1-4](image-url) This diagram shows how water will move from an area of greater concentration to an area of lesser concentration.
The more sugar that is dissolved in water, the less concentrated the water becomes; in other words, pure water is 100% water, and the concentration of water decreases as you add sugar. Therefore, the concentration of water on the left side is greater than that on the right side. As a result, water will diffuse from the left to the right until the concentrations of water on both sides of the membrane are equal, as shown in Part B of Figure 1-4. At that time, the concentrations of sugar on both sides of the membrane will also be equal, or isotonic. Solutions in your body behave the same way.

Diffusion in the Lungs
Your lungs form a compartment of air separated from a compartment of water (your blood) by cells that take up the air sacs called alveoli. When you breathe, gases diffuse from one compartment to another. Oxygen diffuses from the air into the blood, and carbon dioxide from the blood diffuses into the air. When a person drowns, the lungs fill with freshwater or salt water, depending on the type of water in which he or she drowned. The blood and lungs become two water filled compartments (similar to Figure 1-4) in which water can move across the membranes separating the blood and the lungs. Salts in the compartments do not move across the membranes.

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

Everyday Materials
- string (optional)
- tissues
- marker

Lab Materials
- sucrose solutions (1%, 5%, 10%, 20%, 40%)
- 250-mL beakers (7)
- 2.5 cm x 30 cm pieces of water-soaked dialysis tubing (7)
- distilled water
- 250-mL graduated cylinder
- 25-mL graduated cylinder
- balance that is sensitive to at least 0.1 g

Safety
- Never eat or drink anything in the lab.

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

5. Allow each bag to stay in the beaker for 30 minutes.

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

7. Calculate the change in each bag’s mass (final mass – initial mass) and the percent change: (Mass change/initial mass) x 100. Record the values in the table below and use the data to answer the questions.

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

Analysis and Application

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

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

3. Explain the changes observed in Bags A and B in terms of the concentrations of solutions inside and outside the bags and the movement of water.
4. What happened to the mass of Bag C?

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

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

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

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

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

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

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

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

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

13. Should you look for murderers or did the victims drown accidentally? Explain your answer.
Chapter 2: Processing the Crime Scene

In the endeavor of completing a work task certain criteria to complete the work task is needed. Crime scene processing is no different in that respect than to other work related tasks such as exchanging a motor in a car, painting a landscape scene or preparing a meal. There are certain tasks related to each work objective. In the field of crime scene processing several books have been written on what these tasks are and how they should be incorporated into the field of crime scene processing. Yet each book varies only in the technique used, not in a change of the basic protocol used for the processing of crime scenes.

How do you explain to someone the mechanics of thoroughly processing a crime scene? It sounds simple, but in fact crime scene processing is a very intricate and interwoven multiple task function. It is difficult to explain to someone the exact protocol that will be used at every crime scene. Each crime scene is different and may require a different approach to processing the scene. However there is a basic crime scene protocol that should be adhered to in all crime scenes. These basic functions or tasks are as follows:

1. INTERVIEW
2. EXAMINE
3. PHOTOGRAPH
4. SKETCH
5. PROCESS

**Interview** is the first step in processing a crime scene. The crime scene technician must interview the first officer at the scene or the victim to ascertain the "theory" of the case. Basically what allegedly happened, what crime took place, and how was the crime committed. This information may not be factual information but it will give the crime scene technician a base from which to start.

**Examine** the crime scene as the second step in the protocol. Examine the scene for what? To ascertain if the "theory" of the case is substantiated by what the crime scene technician observes. Examining the scene to identify possible items of evidentiary nature, identify point of entry and point of exit, and getting the general layout of the crime scene.

**Photograph** the crime scene is the third step in the protocol. Photographing the crime scene to record a pictorial view of what the scene looks like and to record items of possible evidence. Crime scene photographs are generally taken in two categories, overall views and items of evidence.

**Sketch** the crime scene is the fourth step in the protocol. A rough sketch is completed by the crime scene technician to demonstrate the layout of the crime scene or to identify the exact position of the deceased victim or evidence within the crime scene. A crime scene sketch may not be completed on every case, however some form of sketching usually occurs in most cases, i.e., on a fingerprint lift card to identify exactly where the latent was recovered.

The last step in the protocol is to **process** the crime scene. Process the scene for what? The crime scene technician will process the crime scene for evidence, both physical and testimonial evidence. It is the crime scene technician’s responsibility to identify, evaluate and collect physical evidence from the crime scene for further analysis by a crime laboratory.

The above five steps in the protocol of crime scene processing is intermingled with each other step. If the "theory" of the case dictates that the intruder forcibly entered the residence through a window then the crime scene technician will
need to examine the window area for footwear patterns, toolmarks, trace evidence and latent fingerprints. Upon finding such items of evidence the technician will need to photograph their location and possibly complete a sketch showing the exact location of the evidence or perhaps a sketch of the footwear pattern. This intermingling of the steps in the protocol will continue throughout the processing of the crime scene. Of course interwoven throughout these five steps is the recording of the crime scene by photographs, sketches, and field notes.

This protocol should be used in all crime scenes. Whether the crime scene is a recovered stolen vehicle or a multiple homicide where several crime scenes are involved the basic protocol is the same.

**Vocabulary for Chapter 2:**
Make sure you can utilize these vocabulary terms by your midterm exam.

- **Interview**
- **Examine**
- **Photograph**
- **Sketch**
- **Process**
- **Chain of Custody**
  - **Algor Mortis** - the cooling of the body that follows death. Generally 1-1.5 degrees per hour.
  - **Anthropometrical** - the measurement of the size and proportions of the human body.
- **Autopsy** - inspection and dissection of a body after death, as for determination of the cause of death; postmortem examination.
- **Cephalometer** – an instrument for measuring the human head.
- **Chain of Custody** - the order in which a piece of criminal evidence should be handled by persons investigating a case, specifically the unbroken trail of accountability that ensures the physical security of samples, data, and records in a criminal investigation.
- **Circumstantial Evidence** - proof of facts offered as evidence from which other facts are to be inferred.
- **Coroner** - an officer, as of a county or municipality, whose chief function is to investigate by inquest, as before a jury, any death not clearly resulting from natural causes.
- **Criminalistics** - the scientific study and evaluation of physical evidence in the commission of crimes.
- **Dactyloscopy** - a method of studying fingerprints to establish identification.
- **Dermatoglyphics** - the patterns of ridges on the inner surface of the hands and feet.
- **Distillation** - the volatilization or evaporation and subsequent condensation of a liquid.
- **Epiphyses** - a part or process of a bone separated from the main body of the bone by a layer of cartilage and subsequently uniting with the bone through further ossification.
- **Erythrocyte** - a red blood cell.
- **Evidence** - that which tends to prove or disprove something; ground for belief; proof.
- **Fingerprint** - an impression of the markings of the inner surface of the last joint of the thumb or other finger.
- **Footprint** - a mark left by the shod or unshod foot, as in earth or sand.
- **Forensic** - pertaining to, connected with, or used in courts of law or public discussion and debate.
- **Hemosiderin** - a yellowish-brown protein containing iron, derived chiefly from hemoglobin and found in body tissue and phagocytes, especially as the result of disorders in iron metabolism and the breakdown of red blood cells.
- **Hypothesis** - a proposition, or set of propositions, set forth as an explanation for the occurrence of some specified group of phenomena, either asserted merely as a provisional conjecture to guide investigation.
- **Latents** - Present or potential but not evident or active.
- **Lesion** - an injury; hurt; wound.
- **Leukocyte** - a white blood cell
- **Livor Mortis** - hypostasis of the blood following death that causes a purplish red discoloration of the skin.
- **Melanin** - any of a class of insoluble pigments, found in all forms of animal life, that account for the dark color of skin, hair, fur, scales, feathers, etc.
- **Morphology** - the branch of biology dealing with the form and structure of organisms.
- **Petechia** - a minute, round, nonraised hemorrhage in the skin or in a mucous or serous membrane.
- **Postmortem** - of, pertaining to, or occurring in the time following death.
- **Rigor Mortis** - the stiffening of the body after death.
- **Serum** - the clear, pale-yellow liquid that separates from the clot in the coagulation of blood; blood serum.
- **Somatometry** - a branch of anthropometry that is concerned with measurement of parts of the body other than the head.
Activity: Sketching the Crime Scene:

After the scene has been photographed, then the scene should be rough sketched, and a legend included. The following is an example of a rough sketch of a crime scene.
Guidelines for the rough sketch:

1. First a rough sketch is made at the scene containing accurate depiction of the dimensions at the scene and the location of important objects to the case (body, weapon, etc.)
2. All objects are measured from two fixed points (triangulation method) accurately with a tape measure (DO NOT GUESS)
3. Each object is then given a letter and a legend or list will correlate the letter to the item
4. The sketch should always designate North
5. A finished sketch will be made from the rough sketch and will then be done to scale using the measurements provided in the rough sketch (see image below). This is what will be used as evidence in court.

Mr. Sewell will provide you with a mock crime scene. You are to make a rough sketch of the scene. Be sure to follow the procedures outlined above.
Legal, ethical and human dignity considerations

Legal

While there are general principles related to crime scene investigations, local laws, rules and regulations govern many activities of the crime scene investigation and forensic process. They relate to issues such as how to obtain authority to enter the scene, to conduct the investigation, to handle evidence (e.g. the type of sealing procedure required) and to submit physical evidence to the forensic laboratory. They ultimately determine the admissibility of the evidence collected at the crime scene. Failure to comply with existing laws, rules and regulations can result in a situation where the evidence cannot be used in court. It is therefore of importance for personnel working at the scene to be aware of, and ensure proper compliance with, these rules. If adequate laws, regulations and rules to enable the forensic process do not exist, their establishment may be a matter of necessity.

Ethics and human dignity

Regardless of the local laws, rules and regulations, codes of professional conduct outline ethical obligations of personnel working at crime scenes. Such codes typically stress the importance of acting with care and professionalism (due diligence), objectivity (“treat evidence for what it shows not what you think it shows”), open-mindedness and impartiality (“you may not be independent from the police but you are impartial”). If there is a conflict between preservation of evidence and the possibility of saving a human life, priority is always given to emergency medical care.

Codes of conduct also address the need to respect individuals and their human dignity when examining and collecting physical evidence from dead bodies or the living, and for the victims’ privacy. This includes the control and management of the media.

Processing Protocol:

Evidence Collection

Investigators should perform the evidence collection process in a systematic and careful manner. The process begins with the preliminary crime scene survey/walk-through, followed by a determination of the evidence collection sequence to be used. It cannot be stressed enough that you should take your time with your initial observations so as not to miss minute details that may be important to the scene. As you approach the scene, just observe for several minutes; use all your powers of observation before you begin to collect any data.

The evidence collection sequence may be based on the following information:
1. The scene location: interior, exterior, within a vehicle.
2. The condition of the evidence: either fragile or stable.
3. Weather conditions which might affect the scene or evidence within.
4. Scene management considerations which may alter or contaminate the evidence.
5. Additional processing techniques that may need to be conducted at the scene with specialized personnel. Investigators should use the appropriate equipment when collecting evidence. Collection equipment that may come into contact with evidence should be sterile.
The following equipment may be used in the evidence collection process:

- Latex gloves/nitrile gloves (N-DEX, nonlatex).
- Forceps.
- Tweezers.
- Scalpels.
- Swabs.
- Paper bags.
- Plastic bags.
- Cardboard boxes.
- Wrapping paper.
- Hand tools.
- Thermometer.
- Plastic 5 gallon bucket with lid

**Collection Methods**

The swabbing collection technique should be used for the recovery of biological evidence in a dried or liquid state. Best practice techniques include the following:

**Dried Material Collection Technique**

- With gloved hands, slightly moisten the swab with distilled water. (The swab should be damp but not overly wet.)
- Thoroughly rub the stained area using a single moistened swab for a small stain and multiple swabs for a large stain. When only a small amount of the stain is available, concentrate as much of the stain as possible on the tip of the swab.
- Air-dry the swabs.
- Place each swab into separate package.
- This package may be placed inside a paper envelope.
- Collect a substrate/control sample from an unstained area using the same techniques.

**Liquid Material Collection Technique**

A. When suspected biological evidence is found on clothing or other absorbent surfaces, transport it to the laboratory in an appropriate container. Wet evidence should not be folded over on itself. Use paper wrapping to prevent contamination during the transfer. This will protect bloodstain patterns and prevent cross-contamination between stains on one item. The item should be air-dried thoroughly in a drying locker and packaged in a container suitable for dried evidence.

B. If the suspected biological evidence is in a liquid form on a fixed surface that cannot be transported (i.e., concrete floor), the substance should be recovered using the following swab technique:
   1. With gloved hands, swab the liquid material allowing the swab to absorb as much of the substance as possible. Multiple swabs should be obtained when a large quantity is available.
   2. Thoroughly air-dry each swab. Package the swab inside an appropriate container.
   3. Collect a substrate/control sample from an unstained area using the same techniques.
Evidence Marking and Packaging
All evidence collected at a crime scene, or received at or during a crime scene investigation, is inventoried and packaged prior to leaving the scene to prevent loss or cross-contamination. Mark the item of evidence when possible. Evidence which cannot be marked, such as soil, hair and stains, should be placed in an appropriate container or envelope. Marking some items directly may interfere with forensic analysis of the item. Always mark the outer packaging.

When marking evidence directly, include the following:
- Agency case number.
- Item number.
- Date recovered or received.
- Investigator’s initials.

Evidence that has been inventoried, marked and prepared for submittal (or to be returned to the investigating agency) is packaged in an appropriate container and labeled per agency protocol.

All outer packaging is marked with the following information:
- Agency case number.
- Item number.
- Description of the item(s).
- Investigator’s name or initials.

Containers that have been inventoried and marked are sealed with agency-approved evidence tape prior to submittal or release to the custody of the investigating agency. Evidence tape is used to seal the packaging and is marked with the investigator’s name or initials and the date sealed.

Establishing the Chain of Custody
The chain of custody is a tracking document beginning with detailed scene notes that document where the evidence was received from or collected. The chain of custody is initially established when an investigator takes custody of evidence at a crime scene, or when evidence is received from an officer or detective at, or from, the crime scene.

The chain of custody is established through a process that includes the following:
- Take notes, including documenting the recovery location, the time and date recovered or received, description of the item, condition of the item and any unusual markings or alterations to the item.
- Collect, preserve, mark and package the evidence.
- Seal the evidence.
- Create the inventory list.
- Prepare the chain-of-custody documentation.

Transfer of Evidence to Property Room
Many agencies transfer evidence to a property room prior to submission to a crime laboratory. Property room documentation or secure electronic transfer is used when the investigator submits evidence to the property room.

The associated information may include the following:
- Agency case number.
- Type of evidence.
- Officer responsible for the investigation: the name, rank and identification number of the officer for whom the evidence was recovered. The official laboratory report is addressed to this officer.
- Transporting officer: the name, rank, identification number and assignment of the investigator.
• Signature or other identifier of responsible officer and date prepared; the date the evidence is submitted to the property room.

• Comment: the address where the incident was located, or where the evidence was recovered.

The list of the evidence/property may include:
• Number each evidence item sequentially.
• Quantity of items included, e.g., 10 spent shell casings.
• Serial number of the item, e.g., VCR, handgun.
• Item description.
• Status: e.g., Submit for analysis, Hold, or RTC (releasable, return to claimant or owner).

**Chain of Custody**

The chain of custody documents the transfer of evidence/property from an investigator to another individual, location or agency.

The following information is included in the chain of custody:
• List of evidence: the item number and a brief description.
• All transfers must include the date and time of transfer.
• The signature of the individual releasing the evidence to another individual or location.
• The signature of the individual transporting the evidence.
• The signature of the individual receiving the evidence from another individual or location.
• Reason for the transfer as needed.

**Reporting**

Two reporting formats may be used by an agency. The crime scene report is used to report crime scene activities and processing results. The second is used when analyzing evidence in the laboratory.

• A crime scene report may be used for reporting scene activities. Investigators may prepare a draft/outline of their scene report per agency policy and later prepare a final report.

• A laboratory examination report is used for reporting evidence analysis performed by laboratory personnel.

Both types of reports are reviewed. The process may include an administrative and a technical review. Generally, a copy of the completed report is distributed to the prosecutor and the submitting agency.

**The following pages are a sample report of evidence submission.**
**CASE SUBMISSION FORM**

1525 Falcon Rd  
East Bend, NC 27018  
336-961-4644

**Forbush Case # FHS-FH-S10**  
(To be assigned by FHS Forensics)

**CASE INFORMATION**

<table>
<thead>
<tr>
<th>New Case</th>
<th>Name of Suspect(s)</th>
<th>Bobby Badguy w-m, age 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑️</td>
<td>Name of Victim(s)</td>
<td>Pearl Poorgirl w-f, age 18</td>
</tr>
</tbody>
</table>

**CLIENT**

<table>
<thead>
<tr>
<th>Name</th>
<th>Yadkin County Schools</th>
<th>Case Number</th>
<th>01378-S11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency</td>
<td>Yadkin County Forensic Examiners</td>
<td>Phone</td>
<td>336-679-2051</td>
</tr>
<tr>
<td>Address</td>
<td>121 Washington St.</td>
<td>Fax</td>
<td></td>
</tr>
<tr>
<td>City/State/Zip</td>
<td>Yadkinville, NC 27055</td>
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**AGENCY SHIPPING EVIDENCE**

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<tbody>
<tr>
<td>Name</td>
<td>Forbush Forensics Class</td>
<td>Case Number</td>
</tr>
<tr>
<td>Agency</td>
<td>Forbush High School</td>
<td>Phone</td>
</tr>
<tr>
<td>Address</td>
<td>1525 Falcon Rd.</td>
<td>Fax</td>
</tr>
<tr>
<td>City/State/Zip</td>
<td>East Bend, NC 27018</td>
<td>E-Mail</td>
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</table>

**ADDITIONAL PERSONS AUTHORIZED TO DISCUSS CASE**

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<th>☑️ No</th>
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<tbody>
<tr>
<td>Name</td>
<td>M.Sewell</td>
<td>Name</td>
</tr>
<tr>
<td>Agency</td>
<td>Forbush Forensics Class</td>
<td>Agency</td>
</tr>
<tr>
<td>Title</td>
<td>Instructor</td>
<td>Title</td>
</tr>
<tr>
<td>Phone</td>
<td>336-961-4644</td>
<td>Phone</td>
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</table>

**REPORT SENT TO**

<table>
<thead>
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<tbody>
<tr>
<td>Name</td>
<td>John Q. Public</td>
<td>Title</td>
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<tr>
<td>Agency</td>
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</tr>
<tr>
<td>Address</td>
<td>All over Yadkin County</td>
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<td>City/State/Zip</td>
<td>East Bend, NC 27018</td>
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<td>0145-0333-6998-5678</td>
<td>Expiration</td>
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**EVIDENCE RETURN**

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<tr>
<td>Return upon delivery of case</td>
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<tr>
<td>☑️ Return upon written request</td>
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<tr>
<td>☑️ Return after 60 days</td>
<td>Return to Shipping Agency</td>
<td></td>
</tr>
<tr>
<td>☑️ Destroy</td>
<td>☑️ Return to other (listed below)</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
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</tr>
<tr>
<td>Agency</td>
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<td>Address</td>
<td>Phone</td>
<td></td>
</tr>
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<td>City/State/Zip</td>
<td>Fax</td>
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**BILLING INFORMATION**

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<tbody>
<tr>
<td>☑️ No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All non-government agencies must submit pre-payment by Purchase Order, Check, or Credit Card</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
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</tr>
<tr>
<td>Agency</td>
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<td>Address</td>
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<tr>
<td>Name of Card Holder</td>
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<td>Signature</td>
</tr>
</tbody>
</table>
### CASE BACKGROUND
Provide a brief summary and what questions you are trying to answer. Attach any relevant documents (ie. a letter of consumption permission for limited DNA items such as hairs or touched items).

Victim found dead in bed, apt, 9-A, Yadkinville Arms Apts. Face of the victim bruised around cheek bones. Pink bedspread crumpled on floor next to bed. On night table, (1) prescription bottle containing 2 blue pills (pharmacy check, prescript Amo-barbital). Bits of pink thread found in victim’s mouth. Apt door forced. Suspect was seen in the general area the night in question, wearing pink sweater, screwdriver in pocket.

1) #1&2: Gen. toxicology for narcotics, poisons, alcohol.
2) Verify (#3) pill ID
3) Compare threads, removed from vic mouth(#4) w/ fibers from bedspread (#5).
4) Compare #5 w/ #6 – threads from suspect sweater
5) Comparison, blade of #7 w/ mark #8.
6) #'s 9-19 for the presence of semen or stains.

### EVIDENCE DESCRIPTION

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Description</th>
<th>Type of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blood- 25 cc from victim</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>2</td>
<td>Urine- 20 cc from victim bladder</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>3</td>
<td>Prescription bottle containing 2 blue pills, labeled “Bardley Pharmacy- Prescription #56789 – Dr. S. Johnson – Patient Pearl Poorgirl.</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>4</td>
<td>Four strands pink thread taken from victim’s mouth.</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>5</td>
<td>One pink bedspread (home of vic).</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>6</td>
<td>One blue “Darwin” sweater with pink threads. Suspect’s.</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>7</td>
<td>One “handyman” screwdriver. Suspect’s.</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
<tr>
<td>8</td>
<td>Door latch from front door of vic apartment w/ possible toolmarks on same.</td>
<td>☑ Serology-Blood, Semen, or Saliva</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Y-STR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☑ Mini-STR</td>
</tr>
</tbody>
</table>

### NOTES:
For samples 9-19, see attached sheet.

### SPECIAL STORAGE REQUIREMENTS
None.
### PRICE SUMMARY FORM

Please enter the quantity of each item submitted in the space provided, and calculate the Total Cost and Grand Total in the right hand column. Once our Forensic Laboratory Director has reviewed your submission, we may recommend additional testing. If so, we will contact you.

<table>
<thead>
<tr>
<th>Service</th>
<th>Description/Comments</th>
<th>Quantity</th>
<th>Cost/Sample (each cutting)</th>
<th>Total Cost (Quantity x Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swabbing or Biological Screening and/or DNA Quantification Only</td>
<td>Any item of evidence, up to two stains</td>
<td>2</td>
<td>$350</td>
<td>$700.00</td>
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<tr>
<td></td>
<td>Additional stains (&gt;2) tested on an item or sub-item</td>
<td>10</td>
<td>$50</td>
<td>$500.00</td>
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<tr>
<td>STR DNA Testing†</td>
<td>Sample (Known or Evidence)</td>
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<td>$985</td>
<td>$0.00</td>
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<tr>
<td></td>
<td>Bone/Tooth sample</td>
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<td>$1385</td>
<td>$0.00</td>
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<tr>
<td>MiniFiler DNA Testing†</td>
<td>Sample (Known or Evidence)</td>
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<td>$1085</td>
<td>$0.00</td>
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<tr>
<td></td>
<td>Bone/Tooth sample</td>
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<td>$1485</td>
<td>$0.00</td>
</tr>
<tr>
<td>YSTR DNA Testing†</td>
<td>Sample (Known or Evidence)</td>
<td>0</td>
<td>$1085</td>
<td>$0.00</td>
</tr>
<tr>
<td></td>
<td>Bone/Tooth sample</td>
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<td>$0.00</td>
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<tr>
<td>Mitochondrial DNA Testing</td>
<td>Sample (Known or Evidence)</td>
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<td>$2485</td>
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<tr>
<td>Criminal Paternity</td>
<td>Trio Buccal-Samples from Mother, child, alleged father. Prenatal samples acceptable. (Products of Conception are $200 additional; non-standard samples are $100 additional)</td>
<td>0</td>
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<tr>
<td>Consultation</td>
<td>Case review; Deposition; Comparison to previously generated DNA profiles (one hour minimum)</td>
<td>0</td>
<td>$250/hr</td>
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<tr>
<td>Expert Witness Testimony</td>
<td>Per day, plus expenses</td>
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<td>$1800</td>
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### Add-On Services (Must be added to a service listed above)

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<tr>
<th>Add-On Services</th>
<th>Quantity</th>
<th>Cost/Sample</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>Expedited DNA sample*</td>
<td>10 business day turnaround time</td>
<td>$750/sample</td>
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<td></td>
<td>15 business day turnaround time</td>
<td>$500/sample</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

| GRAND TOTAL | Sum of “Total Cost” column | $1,200.00 |

† No charge for “Cutting / Screening / Serology and/or DNA Quantification Only” if DNA Analysis is conducted on tested item or sub-item.

### CLIENT AUTHORIZATION

I authorize Forbush Forensics to conduct testing on the samples listed above according to the listed specifications.

Signature: ______ Marty Sewell__________ Date: ______05/29/10_____

Print Name: ______ Marty Sewell__________

Please submit this completed Case Submission form along with items of evidence. All items must be shipped to the address below via delivery using a traceable carrier (i.e. FedEx, UPS of Priority Mail).

**SHIP TO:**
ATTN: EVIDENCE TECHNICIAN
FORBUSH FORENSICS
1525 FALCON RD.
EAST BEND, NC 27018
Chapter 2 Review questions:
Answer these questions and email to Mr. Sewell at marty.sewell@yadkin.k12.nc.us. Make sure that you put in the “Subject” line of the email [Forensics-Chapter 2-Review Questions (your name)].

1. What term encompasses all objects that can establish whether a crime has been committed or can provide a link between a crime and its victim or perpetrator?

2. Scientific evaluation of crime-scene evidence can usually overcome the results of a poorly conducted criminal investigation. (True or False)

3. What is the most important thing to do when approaching a crime scene?

4. List the crime scene processing protocol in order.

5. Whose responsibility is it to identify, evaluate and collect physical evidence from the crime scene for further analysis by a crime laboratory?

6. Explain why it is necessary for a CSI to be aware of any local laws regarding evidence collection.

7. If there is a conflict between preserving evidence and saving a human life, which is given priority?

8. Why should wet evidence not ever be folded over on itself?

9. Explain the “Chain of Custody” procedures.
Reading Assignment #2:

List of the Evidence in the O.J. Simpson Double-Murder Trial:

Key evidence and testimony in the O.J. Simpson murder trial, with explanations of how the prosecution has used it against Simpson thus far and how the defense has challenged it:

**Crime scene blood:**

Blood drops were found alongside bloody shoe prints leading away from the bodies of Nicole Brown Simpson and Ronald Goldman; blood was found on a gate at the back of the murder scene condominium; blood from both places contained Simpson's genetic markers. Simpson had a cut on his left middle finger when interviewed by police the day after the killings.

Prosecution: one of the most important parts of the case, claiming it placed Simpson at the crime scene; said Simpson dripped blood after wounding his finger with a knife during the murders; said scientific controls and testing by different labs thwarted any possibility of contamination or tampering.

Defense: mounted vigorous counterattack, alleging samples were sloppily collected and poorly handled, rendering DNA results unreliable; raised possibility that blood was planted by someone who took it from a police crime lab vial that contained Simpson's blood and a blood preservative; most compelling evidence was bloodstains on paper wrapping that was supposed to be holding dry blood samples; wound on Simpson's left hand was only a minor one he suffered in his house - not enough to drip as much blood as prosecutors found - and that Simpson re-injured the finger when he cut it on a glass in a Chicago hotel room the morning after killings, before police interviewed him.

**Bloody shoe prints:**

The bloody shoe prints matched a size 12 Bruno Magli shoe, a relatively rare Italian-made model. Simpson wears size 12 shoes.

Prosecution: tried to place Simpson at the murder scene by showing that Bloomingdale's in New York, where Simpson sometimes shopped, carried such shoes.

Defense: Thousands of people bought such shoes; noted that no murder shoes were ever recovered and that the prosecution had no evidence that Simpson ever purchased such shoes; raised the possibility that unexplained "imprints" that didn't match the Bruno Magli sole also were at the crime scene.

**Crime scene hairs and fibers:**

Hairs found in a dark knit cap were similar to Simpson's hairs; fibers on a cap were similar to those in the carpeting of Simpson's Ford Bronco; dark blue cotton fibers were found on Goldman.

Prosecution: Evidence places Simpson at the crime scene; noted that a witness said Simpson wore a dark sweat suit the night of the murders.

Defense: Hairs mean nothing more than assailant may have been black, as is roughly 10 percent of Los Angeles' population; also pointed to hairs that appeared to contain no dandruff, while Simpson's hair
sample had some dandruff; no dark blue sweat suit was ever found; evidence could have been cast about the scene when a detective unfurled a blanket from Ms. Simpson's home to cover her body.

**Bloody gloves:**

One dark, cashmere-lined Aris Light leather glove, size extra large, was found at the murder scene, another behind Simpson's guest house, near where Brian "Kato" Kaelin heard bumps in the night. Ms. Simpson bought Simpson two pair of such gloves in 1990. DNA tests showed blood on glove found on Simpson's property appeared to contain genetic markers of Simpson and both victims; a long strand of blond hair similar to Ms. Simpson's also was found on that glove.

Prosecution: Simpson lost the left glove at his ex-wife's home during the struggle and, in a rush, inadvertently dropped the right glove while trying to hide it; explained that evidence gloves didn't fit Simpson in a courtroom demonstration because the gloves shrunk from being soaked in blood and Simpson had rubber gloves on underneath.

Defense: glove behind guest house was planted by Detective Mark Fuhrman, a racist cop trying to frame Simpson; blood on glove may have been planted by police; gloated that evidence gloves didn't fit; hair analysis isn't sophisticated enough to be trusted.

**Bloody socks:**

Pair of dark, crumpled socks found at the foot of Simpson's bed; DNA tests found the genetic markers of Simpson and his ex-wife.

Prosecution: contended this directly linked a victim to Simpson.

Defense: suggested socks were planted at house by police, then blood was put on socks later at the police lab to frame Simpson; most compelling evidence of tampering is that some blood soaked all the way through one sock to other side, which it shouldn't have done if a foot was in it.

**Bloody Bronco:**

Small spot of blood found near driver's outside door handle of Simpson's Ford Bronco; other blood found smeared inside on console, door, steering wheel and carpeting; DNA tests showed some of the blood apparently a mixture with genetic markers of Simpson and the victims.

Prosecution: said Simpson drove Bronco to and from crime scene.

Defense: challenged interpretation of DNA tests, particularly those suggesting a genetic match to Goldman in a mixture; noted that the genetic material of an unknown person was found in the steering wheel blood; suggested police planted some of the blood; elicited testimony that the Bronco was entered at least twice by unauthorized people while it sat in a police impound yard.

**Timeline:**

Murders occurred between 10:15 p.m. and 10:40 p.m., based on testimony from prosecution and defense witnesses who heard barking from the area of the crime scene. Ms. Simpson's blood-covered pet Akita was found shortly before 11 p.m.

Prosecution: Simpson lacked an alibi or even plausible story for what he was doing alone during this period; pointed to testimony of a neighbor who saw a vehicle similar to a Bronco racing away from the
crime scene at 10:35 p.m.; suggested that Simpson would still have had time to make the approximately five-minute drive home in time for Kaelin to hear bumps behind guest house at about 10:40 p.m.; suggested that the shadowy figure seen by a waiting limousine driver slipping into Simpson's house just before 11 p.m. was Simpson returning from the murders.

Defense: Simpson didn't have enough time from when he was last seen by Kaelin about 9:40 p.m. to drive to Ms. Simpson's home, kill two people, hide bloody clothing and murder weapon, drive home, drop glove behind guest house and clean up before greeting the limo driver about 11 p.m.; told jurors during opening statements that Simpson was home practicing his golf swing at the hour of the murders.

Violent past:

Through 911 calls to police and testimony, prosecutors allege a history of Simpson hitting, degrading and stalking Ms. Simpson.

Prosecution: pointed to motive, showing Simpson was prone to jealous rages and capable of hurting his ex-wife; suggested Goldman died because he was in the wrong place at the wrong time, and Simpson may have seen him as a potential suitor.

Defense: irrelevant, isolated events that were poorly supported by what little evidence the prosecution presented.

By The Associated Press

Questions Based on the Reading:

Answer these questions and email to Mr. Sewell at marty.sewell@yadkin.k12.nc.us. Make sure that you put in the “Subject” line of the email [Forensics-Chapter 2-Reading Assignment (your name)].

1. Explain point by point the mistakes made by the prosecution and how the defense was able to capitalize on them to invalidate their arguments. (You may have to do some research outside of this article to effectively complete this assignment.)
Reading Assignment #3:

Marking Evidence at Crime Scenes: Developing a System
By Dick Warrington

One of the most basic—and most important—tasks a crime scene officer has is locating, collecting, packaging, and marking evidence found at a crime scene. In this article, I’ll address the marking of evidence collected. No matter the type of scene, you must carefully mark and record every piece of evidence you find. This may seem pretty straightforward, but it becomes more complicated when you have multiple crime scenes or incidents. Then the question becomes, how do you coordinate evidence marking across crime scenes? By developing a system for marking evidence before you arrive at your crime scenes, you will avoid confusion and build stronger cases.

There are many possible systems that you can use to mark evidence. Some departments use a combination of numbers and letters, or include a breakdown that specifies locations such as bedroom 1, bedroom 2, outdoors, vehicle, etc. It doesn’t matter what system you use as long as you are clear and consistent—that’s the key. Your system must be clear to anyone working on the case, including other crime scene officers, lab technicians, and other experts. The clarity of your system is especially important when you go to court. You don’t want to get confused because of the way you marked your evidence. You need your evidence to be so clear and easy to understand that you can go back to your notes and follow what you did whether your case just happened in the last few months or 10–15 years ago. If your system of marking evidence is confusing, you could confuse everyone else, too. If the jury gets lost in the shuffle and misses the points you are trying to make, your case could fall apart.

Whatever system you decide to use, you need to make sure that it will work if you are dealing with multiple crime scenes, locations, or incidents. The LA shootout a couple of years ago is a good example of this type of situation. About 1,500 rounds were fired between law enforcement and the suspects, the scene moved across multiple locations, and the two suspects died. Six different crime scene teams were assigned to this case, and they all needed to be on the same page while working their separate scenes. This was a very complicated case, but many cases will also have more than one scene. Homicides, in general, often include an initial crime scene but then expand to include multiple scenes at different times and different locations. There may even be different officers working each scene. How do you keep the evidence straight? You can’t simply start at the first scene, assign a case number, number the first piece of evidence as “1,” and then have other officers at the other scenes also labeling the first piece of evidence they find as “1.” If you do it this way, you end up with a number of evidence sheets, each with item number 1 and no way to distinguish them. Somehow you need to develop a system that will differentiate the scenes and the incidents so that you and everyone else who deals with the evidence will be able to tell exactly where each piece of evidence was found.

When I worked on the Major Crime Squad, we developed a system that worked well for keeping track of evidence over multiple incidents or scenes. In our system, each incident or scene included the year, the case number, and a dash plus a number to indicate the scene or incident. Each piece of evidence collected would then include this incident number and item number, which would make it unique from other items collected in this case. The list would continue in this way for each item from that scene. Meanwhile, any evidence found from the second scene would share the same date and case number, but would be listed as part of incident -2. If we had multiple teams, the lead officer, who kept the master list for the case, would give each team its own incident number to use. Having one person responsible for the master list prevented any confusion. Our system also allowed us to keep track of fingerprint evidence. If we did the fingerprinting at the scene, we numbered the print with an “L” to indicate latent and also made sure to match the number to the item it came from. If the fingerprinting was done at the lab, we would start a new incident number and then number the print as before.
We found this system worked really well because it was easy to use and to understand, which made it easy for us to use consistently. When you correctly follow the same system over and over again, it becomes habit, and makes your job even easier.

Whatever system you adopt, remember that at every crime scene you go to, every piece of evidence must have a number that corresponds to the evidence custody sheet. For multiple scenes, each piece of evidence must have a unique number that corresponds with its own evidence custody sheet. Also, anything you use to document the crime scene must be marked so that it properly coordinates to the scene you are working on. This includes the evidence markers you place at the scene, the photographs you take, the legends on the diagrams you create, the search warrants connected to the case, etc. Everything must be marked correctly, and it must match the evidence on the log sheet. If you’re not careful, you could end up with a negative trickle-down effect: if you mess up with the first marker, you mess up all the way through and ruin your case.

Taking the time to develop a clear system that is easy to use will be well worth the effort. Once you find a system that is easy to understand and follow, and that allows you to coordinate your evidence across your crime scenes, be sure to use it consistently. Nowadays, the courts are quick to jump on any mistakes in a case. Before you know it, the evidence is out, and your case is in serious trouble. If you can eliminate mistakes by being conscientious in handling your evidence, you’ll be in very good shape.

Dick Warrington is in research and development and a crime scene consultant and training instructor for the Lynn Peavey Company.

Questions based on your reading:
A crime has occurred at FHS. It began in Mr. Sewell’s room and took in all the rooms in J-building. Each room has items taken and transfer evidence found. You have been asked to investigate these crimes. How will you keep the crime scenes straight? How will you be able to record the information in one room so that it does not become confused with another? Write up your proposal, including any special forms you would design to help you in this investigation.
Lab #3: Collection of Evidence at the Crime Scene

Background Information:

RECOGNITION
The first step in collecting evidence is learning how to recognize evidence. There will not always be a smoking gun left behind at a crime scene covered with the fingerprints of the guilty party. Crime scene investigators have to consider all kinds of evidence. From obvious evidence such as fingerprints and blood, to evidence that may seem to be, at first glance, garbage, such as a toothpick or cigarettes. Even these small, seemingly useless items may carry DNA evidence through saliva.

COLLECTION
Collecting evidence is a very delicate, fragile process that requires great care. Precautions must be taken in order to protect not only the evidence being gathered, but also the person gathering the evidence. Biological evidence can contain contaminates that could be harmful to an investigator. Latex gloves, and in some cases, masks, ought to be worn to keep investigators safe from harm. These precautions not only protect the investigator from harm, but protect the evidence from becoming contaminated by the investigator themselves.

All non-liquid evidence (hair, weapons, powder, etc.) needs to be collected in paper bags or envelopes. Even in cases where liquid blood is present, it needs to be collected in a way that it can be transported in paper. If a pool of liquid blood is found on a crime scene, a cotton swab or a cloth towel needs to be used to dry the blood so that it can be transported in paper. Blood is best transported in paper is because static electricity can cause the blood to stick to the side of plastic containers. Blood should be transported dry in order to prevent bacteria to grow or enzymatic degradation to occur, both of which can happen to liquid blood contained in plastic. Of course, deterioration can occur over time no matter what preservation techniques are to be used. To help prevent complications in analysis of blood, test should be run as soon as possible. If tests cannot be conducted immediately, blood ought to be refrigerated or even frozen, to slow decomposition.

CHAIN OF CUSTODY
The chain of custody refers to the journey that evidence takes as it is being paced from place to place. It keeps track of who had the evidence, where it has been, and when it was passed along. The chain of custody is a very important part of the legal process.

METHODS AND PROCEDURES:
You are to play the role of a crime team. Your team leader is to assign the following roles to the team:

1. **Team Leader** – the decision maker and ultimately the responsible one.
2. **First Responder** – will interview any witnesses and/or suspects. Secure the scene with CSI Tape.
3. **Physical Evidence Collector** – will collect any other evidence.
4. **Photographer** – Make a photographic log of the crime scene (use a video camera instead of taking individual photos if costs are a concern).
5. **Sketching Artist** – will diagram the area of the scene and record measurements of the area.

If your group has more roles than people, you will have to double up on responsibilities. Any and all evidence collected must be properly catalogued and passed along to the forensic lab personnel (Mr. Sewell).

Your grade will come from your ability to be very thorough and exact. Mr. Sewell will have an inventory of all the materials that you should turn in, so be thorough. Your investigation should also produce a time of death.
EVIDENCE

Date: __________________________ Case # __________________________

Crime: __________________________________________________________

Date of Crime: ________________ Time of Crime: _________________

Crime Scene Investigators: _________________________________

________________________________

________________________________

________________________________

Evidence Description: ___________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Location: ______________________________________________________

________________________________________________________________

CHAIN OF CUSTODY

Received From: By: Date/Time:

_________________________ ____________________________

_________________________ ____________________________

_________________________ ____________________________

_________________________ ____________________________

_________________________ ____________________________

_________________________ ____________________________
Crime Scene Photography:

1. The crime scene should be unaltered, unless injured people are involved, objects must not be moved until they have been photographed from all necessary angles.
   a. If things are removed, added, or positions changed the photographs may not be admissible evidence.
2. Photograph completely
   a. Area where crime took place & adjacent areas
   b. Various angles
3. If crime scene includes a body:
   a. Take photos to show body’s location & position relative to the whole crime scene
   b. Take close-up photos of injuries & weapons lying near the body
   c. After the body is removed, photograph the surface underneath.
4. When size is significant, use a ruler or other measuring scale
5. Digital cameras allow for enhancement & examination in fine detail.
   a. Videotaping a scene is also becoming popular.
**Sketching:**
1. Once photos are taken, sketch the scene.
2. A rough sketch is a sketch, drawn at the crime scene that contains an accurate depiction of the dimensions of the scene & shows the location of all objects having a bearing on the case.
   a. All measurements are made with tape measure
   b. Show all items of physical evidence
   c. Assign each item a number or letter and list it in the legend
   d. Show a compass heading designating north
3. A finished sketch is a precise rendering of the crime scene, usually drawn to scale.
   e. Computer-aided drafting (CAD) has become the standard.

A rough sketch of a crime scene from an actual murder case in Youngsville, NC.
The finished crime scene diagram after using the CAD system.
Chapter 3: Using the Tools of the Lab

The Metric System

Now that you have your feet wet in the Forensic Science course, it is time to introduce you to the system of measurement that is the standard in the field; The Metric System.

Some things to remember when converting any type of measures:
- To convert from a larger to smaller metric unit you always multiply
- To convert from a smaller to larger unit you always divide
- The Latin prefixes used in the metric system literally mean the number they represent.

Example:
1 kilo gram = 1000 grams
A kilo is 1000 of something just like a dozen is 12 of something.

This is the metric conversion stair chart. You basically take a place value chart turn it sideways and expand it so it looks like stairs. The Latin prefixes literally mean the number indicated. Meter, liter or gram can be used interchangeably.

You use this chart to convert metric measurements like this:
- If you are measuring length use meter.
- If you are measuring dry weight use grams.
- If you are measuring liquid capacity use liter

For every step upward on the chart you are dividing by 10 or moving the decimal one place to the left.
Pretend you are standing on the milli-gram stair tread and to get to the 1-gram stair tread you move up 3 steps dividing by 10 each time.

\[
\frac{1000}{10} = 100 \quad \frac{100}{10} = 10 \quad \frac{10}{10} = 1 \\
\text{or} \\
\frac{1000}{1000} = 1
\]

or use the shortcut and just move the decimal place one place to the left with each step

1000 milligrams = 1 gram.

When you move down the stairs you are multiplying by 10 for each step. SO you are adding a zero to your original number and moving the decimal one place to the right with each step.

Example:
To convert 2 kilometers to meters you move 3 steps down on the chart so you add 3 zeros to the 2.

2 kilometers = 2000 meters

Conversion factors to know / memorize
- 2.2 pounds equals 1 kilogram
- 2.54 centimeters equals 1 inch
- \[ F = (C \times 1.8) + 32 \]
- \[ C = \frac{F - 32}{1.8} \]

Problems:
1.) 3 meters = _______ centimeters
2.) 40 liters = ______ Dekaliters
3.) 600 milligrams = _______ grams
4.) 5 kilometers = __________ Hectometers
5.) 70 centimeters = _________ meters
6.) 900 deciliters = _______ Dekaliters
7.) John's pet python measured 600 centimeters long. How many meters long was the snake?
8.) Faith massed 5 kilograms at birth. How many grams did she mass?

As the course proceeds, we will continue to reinforce the correct usage of the metrics system to gather numerical data.
Chapter 3 Vocabulary and Conversion Factors

- **Gram** (g) - there are 453.6 grams in a pound and 1000 g in a kilogram. It is a unit of mass.
- **Centimeter** (cm) - there are 2.54 cm in an inch and 100 cm in a meter. It is a unit of length.
- **Second** (sec) - there are 60 seconds in a minute. It is a unit of time.
- **Area** - area is a length squared. If you know the conversion factors for units of length (2.54 cm/inch or 12 inches/foot), you can calculate the area conversion factors so you don't have to learn them. For example, how many square centimeters are there in one square mile? The answer is: 
  \[(\text{2.54 cm/inch})^2 \times (\text{12 inch/foot})^2 \times (\text{5280 feet/mile})^2 = 2.59 \times 10^{10} \text{ cm}^2/\text{mile}^2\].
  
  One square mile is a section, which contains 640 acres. Therefore, an acre contains 43,560 square feet.
- **Volume** - length cubed is volume. Common units are cm\(^3\) which is a ml (There are 1000 milliliters in a liter) and gallons (there are 231 inch\(^3\) in a gallon.). Therefore, there are (2.54 cm/inch)\(^3\) x 231 in\(^3\) /gal = 3784 cm\(^3\)/gal or about 3.8 liters per gallon. In Europe, a liter of gasoline costs about the same as a gallon costs in the U.S. Engineers commonly use the acre-foot (one acre covered to a depth of one foot) as a measure for large volumes (flow of the Ohio and Mississippi Rivers, capacity of a lake). An **acre-foot** is 43560 cubic feet.
- **Velocity** - length (or distance) per unit time is velocity. The common units are cm/sec and miles/hour.
- **Acceleration** - the change in velocity per unit of time is acceleration. So the units are length/time squared. The common units are cm/sec\(^2\) and feet/sec\(^2\).
- **Force** is mass times acceleration. (F = ma which is Newton's second law of motion). The common units are the dyne (g cm/sec\(^2\)) and the Newton (kg m/sec\(^2\))
- **Energy** - Work and heat are forms of energy. Energy is a force acting through a distance or force x length. The units of measure are the erg (cm x dyne or a cm times g cm/sec\(^2\) = g cm/sec\(^2\)), the joule (kg m\(^2\)/sec\(^2\)), the calorie (there are 4.184 joules in a calorie) and the British Thermal `Unit or BTU (one BTU will increase the temperature of one pound of water one Fahrenheit degree.). The student should also recall that energy may be related to the frequency of electromagnetic radiation via Planck's constant or $E = h\gamma$ (ergs = 6.62 x 10\(^{-27}\)γ) where $γ$ is the frequency in cycles per second.
- **Power** - power is the rate of doing work. Therefore, the units are work per unit time such as a joule/sec (which is one watt) and which is also equal to one volt multiplied by one amp.
- **Coulomb** - A coulomb is a unit of electrical charge. An amp is a unit of electrical current and is a flow of one coulomb per second. Since the charge on an electron is 1.6 x 10-19 coulombs then Avogadro's number of electrons will have a charge of (1.6 x 10\(^{19}\) coulombs/electron x 6.023 x 10\(^{23}\) electrons/mole) = about 96485 coulombs/mole. This number is one Faraday. It may be used as a conversion factor between chemical mass units and electrical units of measure.
- **Concentration**: You should know about molarity, ppm and ppb and how to prepare solutions.
- **Kilo**
- **Hecto**
- **Deka**
- **Deci**
- **Centi**
- **Milli**
- **Physical Properties**
- **Chemical Properties**
- **Intensive properties**
- **Extensive Properties**
- **Physical Changes**
- **Chemical Changes**
- **Scanning Electron Microscope**
- **Compound Light Microscope**.
Physical and Chemical Properties and Changes

The properties of a substance are those characteristics that are used to identify or describe it. When we say that water is "wet", or that silver is "shiny", we are describing materials in terms of their properties. Properties can be divided into the categories of physical properties and chemical properties. **Physical properties** are readily observable, like; color, size, luster, or smell. **Chemical properties** are only observable during a chemical reaction. For example, you might not know if sulfur is combustible unless you tried to burn it.

Another way of separating kinds of properties is to think about whether or not the size of a sample would affect a particular property. No matter how much pure copper you have, it always has the same distinctive color. No matter how much water you have, it always freezes at zero degrees Celsius under standard atmospheric conditions. Methane gas is combustible, no matter the size of the sample. Properties, which do not depend on the size of the sample involved, like those described above, are called **intensive properties**. Some of the most common intensive properties are; density, freezing point, color, melting point, reactivity, luster, malleability, and conductivity.

**Extensive properties** are those that do depend on the size of the sample involved. A large sample of carbon would take up a bigger area than a small sample of carbon, so volume is an extensive property. Some of the most common types of extensive properties are; length, volume, mass and weight.

Pieces of matter undergo various changes all of the time. Some changes, like an increase in temperature, are relatively minor. Other changes, like the combustion of a piece of wood, are fairly drastic. These changes are divided into the categories of Physical and Chemical change. The main factor that distinguishes one category form the other is whether or not a particular change results in the production of a new substance.

**Physical changes** are those changes that do not result in the production of a new substance. If you melt a block of ice, you still have H₂O at the end of the change. If you break a bottle, you still have glass. Painting a piece of wood will not make it stop being wood. Some common examples of physical changes are; melting, freezing, condensing, breaking, crushing, cutting, and bending. Special types of physical changes where any object changes state, such as when water freezes or evaporates, are sometimes called **change of state operations**.

**Chemical changes**, or chemical reactions, are changes that result in the production of another substance. When you burn a log in a fireplace, you are carrying out a chemical reaction that releases carbon. When you light your Bunsen burner in lab, you are carrying out a chemical reaction that produces water and carbon dioxide. Common examples of chemical changes that you may be somewhat familiar with are; digestion, respiration, photosynthesis, burning, and decomposition.
Check Your Understanding:

Name__________________________ Date____________________________

Directions: Answer the questions in complete sentences. Make a copy and turn in to Mr. Sewell on the date specified.

**Part I. Classification** - Describe each of the following properties as either intensive or extensive.

<table>
<thead>
<tr>
<th>1) Mass</th>
<th>2) Density</th>
<th>3) Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>4) Color</td>
<td>5) Reactivity</td>
<td>6) Volume</td>
</tr>
<tr>
<td>7) Malleability</td>
<td>8) Luster</td>
<td>9) Weight</td>
</tr>
</tbody>
</table>

**Part II. Define** - Use your own words to define the following terms.

<table>
<thead>
<tr>
<th>10) Intensive Properties -</th>
</tr>
</thead>
<tbody>
<tr>
<td>11) Extensive Properties -</td>
</tr>
</tbody>
</table>
**Part III. Classification** - State whether each of the following changes would be physical or chemical.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1) melting ice</td>
<td>2) burning wood</td>
<td>3) breaking glass</td>
</tr>
<tr>
<td>4) painting wood</td>
<td>5) cooking</td>
<td>6) burning propane</td>
</tr>
</tbody>
</table>

**Part IV. Define** - Use your own words to define each of the following terms in the space provided.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7) Chemical Change -</td>
<td></td>
</tr>
<tr>
<td>8) Physical Change -</td>
<td></td>
</tr>
<tr>
<td>9) Change of State Operation -</td>
<td></td>
</tr>
</tbody>
</table>
**Lab #4: Using Flame Test to Determine an Unknown**

**Using Flame Tests**

Forensic scientists use various approaches to distinguish substances. In this lab, you will observe the flame colors of several substances and use the data to determine the identity of an unknown substance.

**Problem:** How can the color of a flame be used to distinguish substances?

**Materials:**
- solutions of calcium chloride, boric acid, potassium chloride, copper(II) sulfate, sodium chloride, and an unknown
- Bunsen burner
- nichrome wire loop
- dilute solution of hydrochloric acid
- wash bottle with distilled water

**Procedure**

**Part A: Observing Flame Colors**

1. Light the Bunsen burner. **CAUTION:** Put on safety goggles and a lab apron. Tie back loose hair and clothing before working with a flame.
2. Dip the wire loop into the calcium chloride solution and then place the loop in the flame. Observe and record the color of the flame in the data table.

**DATA TABLE**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Flame Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride</td>
<td></td>
</tr>
<tr>
<td>Potassium chloride</td>
<td></td>
</tr>
<tr>
<td>Boric acid</td>
<td></td>
</tr>
<tr>
<td>Copper(II) sulfate</td>
<td></td>
</tr>
<tr>
<td>Sodium chloride</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Identity of unknown</td>
<td></td>
</tr>
</tbody>
</table>

3. Clean the loop by dipping it into hydrochloric acid. Then, while holding the loop over a sink, rinse away the acid with distilled water. **CAUTION:** Keep hydrochloric acid away from your skin and clothing. Do not breathe in its vapor.

4. Repeat Steps 2 and 3 with each of the other solutions. Be careful not to transfer any solution from one container to another. **CAUTION:** These chemicals are poisonous. Do not let them get on your skin.
Part B: Examining an Unknown Solution

5. Obtain the unknown solution from your teacher.

6. Repeat Steps 2 and 3, using the unknown solution. Compare your observations with the other data that you recorded to identify the unknown.

CAUTION: Wash your hands thoroughly before leaving the laboratory.

Analyze and Conclude

1. Comparing and Contrasting Is there a relationship between the color of the flame and the color of the solution?

2. Formulating Hypotheses How do these substances produce light of different colors?

3. Drawing Conclusions A forensic scientist does a flame test on a substance that was found at a crime scene. What might the scientist conclude if the flame turns green?
The compound Light Microscope:

Label the parts of a typical light microscope with the following terms:

- Arm
- Base
- Body Tube
- Coarse Adjustment Knob
- Diaphragm
- Fine Adjustment Knob
- Light Source
- Nosepiece
- Objective Lenses
- Ocular Lens
- Stage
- Stage Clips

**Activity:** Using the supplied slides, make a sketch of the images under scanning, low and high powers.
The Scanning Electron Microscope:

What is a SEM?

SEM stands for scanning electron microscope. The SEM is a microscope that uses electrons instead of light to form an image. Since their development in the early 1950's, scanning electron microscopes have developed new areas of study in the medical and physical science communities. The SEM has allowed researchers to examine a much bigger variety of specimens.

The scanning electron microscope has many advantages over traditional microscopes. The SEM has a large depth of field, which allows more of a specimen to be in focus at one time. The SEM also has much higher resolution, so closely spaced specimens can be magnified at much higher levels. Because the SEM uses electromagnets rather than lenses, the researcher has much more control in the degree of magnification. All of these advantages, as well as the actual strikingly clear images, make the scanning electron microscope one of the most useful instruments in research today.

How does a SEM work?

The SEM is an instrument that produces a largely magnified image by using electrons instead of light to form an image. A beam of electrons is produced at the top of the microscope by an electron gun. The electron beam follows a vertical path through the microscope, which is held within a vacuum. The beam travels through electromagnetic fields and lenses, which focus the beam down toward the sample. Once the beam hits the sample, electrons and X-rays are ejected from the sample.
Detectors collect these X-rays, backscattered electrons, and secondary electrons and convert them into a signal that is sent to a screen similar to a television screen. This produces the final image.

How is a sample prepared?

Because the SEM utilizes vacuum conditions and uses electrons to form an image, special preparations must be done to the sample. All water must be removed from the samples because the water would vaporize in the vacuum. All metals are conductive and require no preparation before being used. All non-metals need to be made conductive by covering the sample with a thin layer of conductive material. This is done by using a device called a "sputter coater."

The sputter coater uses an electric field and argon gas. The sample is placed in a small chamber that is at a vacuum. Argon gas and an electric field cause an electron to be removed from the argon, making the atoms positively charged. The argon ions then become attracted to a negatively charged gold foil. The argon ions knock gold atoms from the surface of the gold foil. These gold atoms fall and settle onto the surface of the sample producing a thin gold coating.

SEM Sample Images

Fig. 3-5 (left). A hair shaft. Forensic analysis of hair samples is a standard for crime scene investigation.
Fig 3-6 (right). The layered structure of paint.

Fig 3-7 (left). The foot of a fruit fly.

Fig 3-6 (right). Pollen on fibers.
Web sites: Go to the website and perform the activity.

1. The Bones and the Badge: A forensic webquest adventure.
   http://projects.edtech.sandi.net/kearny/forensic/
Chapter 4: Physical Evidence

Physical evidence is one of the most common types of evidence found at a crime scene. Physical evidence consists of the actual physical objects found at the scene. This can mean large items such as damaged cars, broken glass or smashed doors. It also includes items that are minuscule in size, such as hair or clothing fibers. An investigator may also collect weapons such as knives or guns, or fired bullets and spent casings. Depending on the scene, physical impressions may also be found, including tire tracks or footprints. A suspected burglary may lead the investigator to look for tool marks on the doors or windows. Finally, physical evidence also includes fingerprints and lipstick impressions left on glasses or cigarettes. If it can be touched, picked up or moved it constitutes physical evidence.

Types of Physical Evidence

PAINT - Physical and chemical analysis of paint can indicate its class or what type of paint it is (auto, house, nail polish, etc.) Individual characteristics, such as the color, number of layers, chemical composition, or features of paint chips, can be analyzed and used for matching evidence to a suspect.

GLASS - Particles found at various crime scenes (breaking and entering, hit and run, vandalism, or murder) will be analyzed to determine its properties, such as color, tint, thickness, density, chemical composition, and refractive index (RI).

EXPLOSIVES - Chemical analysis can determine the type of explosive used in a device. Traces of explosives found on a suspect or materials from a suspect's home, work, or car can be analyzed to establish a connection to explosives from a crime scene.

BALLISTICS - Characteristics of ammunition, firearms, and gunshot residue (GSR) are examined to find matches between suspects and evidence found at a crime scene. Rifling in a gun barrel causes distinctive marks on fired bullets. The Integrated Ballistics Identification System (IBIS) is a database used for this type of evidence.

DUST & DIRT - This type of evidence can reveal where a person has traveled as it may be picked up at a crime scene or left behind. Investigators examine samples for chemical composition, pollen, plants, and other organic matter to find links to a specific crime scene.

IMPRESSION EVIDENCE:

Shoeprints & Tire Tracks: Impression evidence can be photographed, lifted with tape, or cast with plaster. Investigators will examine the evidence to identify the brand of shoe or tire based on the tread pattern and other physical features. Shoes and tires will also show wear patterns after being used for a period of time as well as other features (scratches, nicks, and cuts) that can be used to match evidence to specific items.
**Bite Marks**: Each of the 32 teeth in humans is unique due to age and wear. Impressions and photographs of bite marks left on a victim, suspect, or other object at a crime scene can be matched to dental records for the identification of a victim or suspect.

**Tool Marks**: Tiny nicks and chips form on the edges of a tool as it is used, which can be used to identify matches between evidence and suspects. Tools may also pick up traces of blood or other substances that can be tested or have fingerprints that can be lifted.

**FINGERPRINTS** - There are 3 types of patterns: arches, loops, and whorls. Unique ridge characteristics (minutiae) are also used for identification. **AFIS** stands for the Automated Fingerprint Identification System and is a database used by investigators to find matches to latent fingerprints found at a crime scene.

**FRACTURE MATCHES** - When an object is broken, torn, or cut, two unique edges (fracture lines) are formed. These can be compared to see if they fit together to show that they may have been part of the same object at one time. Investigators compare the pieces of tape, glass fragments, paint chips, pieces from a car, etc. to find possible matches.

**WOUNDS** - Wounds can often be matched to weapons or tool marks on the weapon. The weapon's size, shape, and length may also be determined. Wound analysis provides clues about a victim’s injuries, the suspect (left-handed, right-handed, height, etc.), and the positions of the victim and suspect.

**QUESTIONED DOCUMENTS** – Examiners analyze a ransom note or other document to find clues to link it to a crime scene or a suspect. The type of paper used, printing method or handwriting style, or type of ink will be analyzed. Unique features, such as watermarks or indentations on a paper, may provide useful clues.

**INSECTS** - Flies, beetles, and other insects can provide useful clues about a corpse. Forensic entomologists use factors such as weather conditions, the location and condition of the body, and their knowledge of the life cycles of insects to help them estimate the postmortem interval or PMI (the time between death and the discovery of the body).

**DNA** can be extracted from almost any tissue (hair, fingernails, bones, teeth, & body fluids) and used to create DNA profile to identify a suspect or victim. **CODIS** (Combined DNA Index System) is a database that is used to find matches to unknown DNA samples from a crime scene.

**SKELETAL REMAINS** - These can be analyzed by forensic anthropologists to identify remains or determine the cause of death or life history. Sex can be determined by examining the pelvis, humerus, and femur. Age and stature (height/build) can be determined by analyzing the teeth, bone growth, and the length of specific bones. Race can be determined by analyzing the skull for specific characteristics.

**BODY FLUIDS** - Blood, semen, saliva, sweat, and urine can be analyzed to provide information about the crime as well as its victim or the suspect. Chemicals and UV light can be used at a crime scene to find areas with body fluids, which are swabbed, bagged and collected in vials.

**HAIRS & FIBERS** - These may be transferred from a suspect to a victim and vice versa. Hairs can be examined to identify their origin, such as human or animal. Hairs with roots intact can be tested for DNA. Fibers are used to make clothing, carpeting, and furniture. They may be natural fibers (plants or animals) or synthetic (man-made).
Examination of Physical Evidence:

Why examine physical evidence?

1. Physical evidence is examined to allow the investigator to understand what has happened during the crime. In the past, eye witness testimony has played a much larger role in determining what happened at a crime scene. Eyewitness testimony is known as direct evidence. Physical evidence does not speak for itself, but rather points towards something else; therefore it is known as circumstantial evidence. Because physical evidence cannot speak for itself, it must be interpreted. For example, fingerprints on a glass at a crime scene do not necessarily mean that a particular person was at the crime scene, but they did touch the glass. The glass may have been in their hand when they were unconscious and transported to another crime scene. The forensic scientists give a possible explanation of what the evidence suggests. Their interpretation should be without bias or personal involvement.

2. The second reason for forensic examination is for the purpose of identification or comparison. To identify a particular substance as a controlled narcotic or a common chemical would be paramount in determining if a perpetrator is guilty of a crime. Examining evidence for comparative purposes would tell if a particular piece of evidence had the same origin as another; for example, comparing the chemistry of particular drugs to determine if they are from the same source or comparing different bullets to determine if they were fired from the same gun.

3. Thirdly, it allows the investigator to reconstruct the crime scene; however, the reconstruction of crime scenes is a miss nomenclature. You are in reality interpreting the information that you find by examining and processing the scene for evidence. This evidence will then permit you to make factual statements in regards to your findings. For instance, examining a footwear impression left at a scene you will be able to determine what direction the person was walking when that impression was made. Therefore you are interpreting the information you discovered to develop a factual reconstruction. In other words you are placing your interpretations in a logical order to reconstruct what has taken place in the crime scene. This will apply to all crime scenes that are left intact and are not disturb by the victims, paramedics or police officers. Without this "virgin" crime scene the interpretation could be altered and may not be as it was when the
suspect(s) were there. Never, never assume or guess at the reconstruction without all the facts from the interpretation.

**Fig 4-2.** Crime scene reconstruction relies on the combined efforts of medical examiners, criminalists, and law enforcement personnel to recover physical evidence and to sort out the events surrounding the occurrence of a crime.

**Crime scene reconstruction is a team effort that involves putting together many different pieces of a puzzle.** The right connections have to be made among all the parts involved so as to portray the relationship among the victim, the suspect, and the crime scene. If successful, reconstruction can play a vital role in aiding a jury to arrive at an appropriate verdict.
Check Your Understanding:
Answer the following questions and email your responses to Mr. Sewell at Marty.sewell@yadkin.k12.nc.us. Be sure to include in the subject line [Forensics; Chapter 4, Check Your Understanding; Your Name] in that order.

1. What is the difference between class and individual characteristics?
2. What is a fracture line? Give an example of a material that could be identified using fracture matches.
3. What are three examples of impression evidence?
4. What type of light is used to find body fluids at a crime scene?
5. What must be present in a hair sample in order to test for DNA?
6. What could a scientist learn from a wound?
7. What four things can a scientist learn about a victim from studying skeletal remains?
8. What could a scientist learn from a sample of dirt from a suspect’s car?
9. Besides handwriting, what else could an investigator use to match a ransom note to a suspect?
10. What does a forensic entomologist study?
11. What are the three main types of fingerprints?
12. What does each of these acronyms represent? AFIS  CODIS  IBIS  GSR  RI  PMI
13. What are the three reasons for the examination of physical evidence?
14. What is the difference between direct and circumstantial evidence?
15. Explain the cooperation between different agencies in crime scene reconstruction.
Reading Assignment #4:

Fibers and Probability Theory

An excerpt from
Trace Evidence
By Katherine Ramsland
CourtTV Crime Library

From 1979 to 1981, someone was killing Atlanta’s youth. More than twenty-five black males, some as young as nine, had been strangled, bludgeoned or asphyxiated. A few females were killed and some children were just missing, but all potential leads turned into dead ends. The only real clue – which was valuable only if a suspect surfaced – was the presence on several of the bodies and their clothing of some kind of fiber threads. A few also bore strands of what was determined to be hair from a dog.

These specimens were all sent to the Georgia State Crime Laboratory for analysis, and technicians there isolated two distinct types: a violet-colored acetate fiber and a coarse yellow-green nylon fiber with the type of tri-lobed (three branch) qualities associated with carpets (see image to the right). They searched unsuccessfully for the manufacturer.

The fiber discovery was reported in the newspaper and shortly thereafter, bodies were found stripped and thrown into the river. Some authorities surmised that the killer believed that the water would wash away trace evidence. They took it to mean that the killer (or killers) was paying attention to the media. (Others, however, did not think that all of these deaths were related.)

Wayne Williams (AP)

Since the unknown predator seemed to favor the Chattahoochee River, the police set up a stakeout. On May 22, 1981, this strategy appeared to pay off. In the early morning hours, the stakeout patrol heard a loud splash. Someone had just thrown something rather large into the river. On the James Jackson Parkway Bridge, they saw a white Chevrolet station wagon, and when they stopped it, they learned that the driver’s name was Wayne Williams. He was a 23 year-old black photographer and music promoter. They questioned him, but when he said he’d just dumped some garbage they let him go. (Later he would claim that he’d come there to see the stakeout, having heard about it from friends in the police force.)

Only two days later, the police found what they believed had been the source of the splash – the body of 27-year-old Nathaniel Cater. He was dredged up about a mile from the bridge, and despite his murderer’s carefulness, a single yellow-green carpet fiber was found in his hair. (The assumption was that it had stuck there despite the water rather than thinking that he might have acquired it in the water.) Cater also showed signs of asphyxiation, but it was difficult to determine just how this had happened. Nevertheless, the medical examiner thought that he had been dead for at least two days.

The police got a search warrant for Wayne Williams’ home and car, and the search turned up a valuable piece of evidence: The floors of Williams’ home were covered with yellow-green carpeting, and he also had a dog. Comparisons from the samples removed from the victims showed good consistency with Williams’ carpet. Although Williams claimed to have an alibi, the description he gave of his movements
the night they found him on the bridge was partly false and partly unsubstantiated. Three separate polygraph tests indicated deception on Williams’ part.

Then FBI experts analyzed samples from his rugs. With special equipment, and in consultation with DuPont, they managed to ascertain that the fibers came from a Boston-based textile company. The fiber was called Wellman 181B and it had been sold to numerous carpet companies. Each uses its own dye, so that made it possible to narrow down the likely source, which was the West Point Pepperell Corporation in Georgia. Their “Luxaire English Olive” color matched that found in Wayne William’s home. There were also similarities between the hair from Williams’ dog and the dog hair found on several victims.

However, many other homes had this carpeting installed, too. Thus, it had to be determined just how likely it was that Williams’ carpeting was unique enough to persuade a jury of his connection to the murders. The next step was calculating the odds.

A look into company records turned up information that they had only made that type of carpet during a one-year span of time, with over 16,000 yards of carpet distributed throughout the South. In comparison with the total amount of carpet distributed across the country, this was a very small sample. That made the statistical probability of the carpet being in any one person’s home to be slight, if it could be assumed that Luxaire English Olive had been fairly evenly distributed. Altogether they figured that around eighty-two homes in Georgia were carpeted with Luxaire English Olive. That meant the odds were stacked against finding many homes in Atlanta: 1 in 7792.

To make their case, the prosecution relied on only two of the twenty-eight suspected murders---the one from the river, Nathaniel Cater, and another recovered in the same general area a month before, Jimmy Ray Payne (although it had not been concluded that he had been murdered). A single rayon fiber had been found on his shorts, which was consistent with the carpeting in Williams’ station wagon. In this second case, statistical probability was also employed. With Chevrolet’s help, the investigators determined that there was a 1 in 3,828 chance that Payne had acquired the fiber via random contact with a car that had this carpeting installed.

When the odds in both cases were multiplied, the law of probability that both men could have picked up these fibers in places other than Williams’ home and car came out to 1 in almost 30,000,000. That seemed pretty staggering.

The prosecution also introduced into evidence the fibers found on the bodies of ten of the other victims (allowed in Georgia courts), which also matched those in Williams’ car or home. These, they claimed, showed a pattern, and taken altogether, it increased the odds in the fiber evidence into numbers that no one could even comprehend. In total, there were 28 fiber types linked to Williams. In addition, several witnesses had come forward to place Williams with some of the victims, and others claimed to have seen suspicious scratches on Williams’ arms.

After only twelve hours, the jury returned a guilty verdict, with two life sentences. The police announced that twenty-two of the unsolved murder cases were now closed, despite the fact that there was no real proof for those victims.

Subsequently the Williams conviction has become controversial. To understand this, let’s look at how fiber analysis is done.

**Fiber Analysis**

Cross transfers of fiber often occur in cases in which there is person-to-person contact, and investigators hope that fiber traceable back to the offender can be found at the crime scene, as well as vice versa. Success in solving the crime often hinges on the ability to narrow the sources for the type of fiber found, as the prosecution did with their probability theory on the fibers in the Williams case.
The problem with fiber evidence is that fibers are not unique. Unlike fingerprints or DNA, they cannot pinpoint an offender in any definitive manner. There must be other factors involved, such as evidence that the fibers can corroborate or something unique to the fibers that set them apart. For example, when fibers appeared to link two Ohio murders in the 1980s, it was just the start of building a case, but without the fibers, there would have been no link in the first place.

In 1982, Kristen Lea Harrison was abducted from a ball field in Ohio and her body was found six days later some thirty miles away. She had been raped and strangled. Orange fibers in her hair looked suspiciously like those that had been found on a twelve-year-old female murder victim from eight months earlier in the same county. Since they were made of polyester and were oddly shaped (trilobal), forensic scientists surmised that it was carpet fiber. In addition, a box found near Kristin’s body and plastic wrap around her feet indicated that the killer had once ordered a special kind of van seat, but then leads dried up.

Some time later, a 28 year-old woman was abducted and held prisoner in a man’s home. He tortured her and appeared to be intent on killing her. When he left, she escaped and reported him. Police noticed that he had a van similar to the one into which Kristin had been forced. It proved to have orange carpeting that matched the fibers in her hair. The color was unique, which allowed scientists to trace it to a manufacturer who supplied information about its limited run. Apparently only 74 yards of it had been shipped to that area of Ohio. That helped to narrow down possibilities. Other evidence established a more solid link and Robert Anthony Buell was eventually convicted.

Fibers are gathered at a crime scene with tweezers, tape, or a vacuum. They generally come from clothing, drapery, wigs, carpeting, furniture, and blankets. For analysis, they are first determined to be natural, manufactured, or a mix of both.

Natural fibers come from plants (cotton) or animals (wool). Manufactured fibers are synthetics like rayon, acetate, and polyester, which are made from long chains of molecules called polymers. To determine the shape and color of fibers from any of these fabrics, a microscopic examination is made.

Generally, the analyst gets only a limited number of fibers to work with – sometimes only one. Whatever has been gathered from the crime scene is then compared against fibers from a suspect source, such as a car or home, and the fibers are laid side by side for visual inspection through a microscope.

A compound microscope uses light reflected from the surface of a fiber and magnified through a series of lenses, while the comparison microscope (two compound microscopes joined by an optical bridge) is used for more precise identification. A different device, the phase-contrast microscope, reveals some of the structure of a fiber, while the various electron microscopes either pass beams through samples to provide a highly magnified image, or reflect electrons off the sample’s surface. A scanning electron microscope converts the emitted electrons into a photographic image for display. This affords high resolution and depth of focus.

Another useful instrument is the spectrometer, which separates light into component wavelengths. In 1859, two German scientists discovered that the spectrum of every organic element has a uniqueness to its constituent parts. By passing light through something to produce a spectrum, the analyst can read the resulting lines, called “absorption lines.” That is, the specific wavelengths that are selectively absorbed into the substance are characteristic of its component molecules. Then a spectrophotometer measures the light intensities, which yields a way to identify different types of substances.

A combination of these instruments for the most effective forensic analysis is the microspectrophotometer. The microscope locates minute traces or shows how light interacts with the material under analysis. Linking this to a computerized spectrophotometer increases the accuracy. The scientist
can get both a magnified visual and an infrared pattern at the same time, which increases the number of identifying characteristics of any given material.

The first step in fiber analysis is to compare color and diameter. If there is agreement, then the analysis can go into another phase. Dyes can also be further analyzed with chromatography, which uses solvents to separate the dye’s chemical constituents. Under a microscope, the analyst looks for lengthwise striations or pits on a fiber's surface, or unusual shapes – as with the one short and two long arms of the trilobal fibers in the Williams case.

In short, the fiber analyst compares shape, dye content, size, chemical composition, and microscopic appearances, yet all of this is still about “class evidence.” Even if fibers from two separate places can be matched via comparison, that does not mean they derive from the same source, and there is no fiber database that provides a probability of origin.

Since the Wayne Williams case pretty much came down to fiber evidence, it’s obviously open to serious challenge. Chet Dettlinger is a former assistant to the Atlanta Chief of Police. He and a group of other high-ranking ex-law-enforcement officers independently investigated the case. Dettlinger, now a Georgia attorney, was asked by Williams’ defense lawyer, Al Binder, to act as a consultant, and he co-authored, The List, the only book to be published on the case. Among other problems, he saw glaring errors with the way the fiber evidence was presented.

“The ‘matching’ fibers were taken only from victims,” he says.” Only one individual red cotton fiber was found at the Williams home, which can be found in abundance at K-Mart or Walmart, which is similar to fibers in victim Michael McIntosh’s underwear. That came from the vacuum sweepings of a car, which the Williamses may or may not have owned at the time that McIntosh was murdered. Not one fiber from any victim was found anywhere near the carpet in the Williams’ house.

“Insofar as the Wellman fiber is concerned, they were attempting to demonstrate how rare the fiber in the carpet in ‘Wayne Williams’ room’ was. This ignores the fact that all of the Williamses, and any regular visitor to the home, existed in the same environment.”

Dettlinger goes on to pinpoint the central errors in the prosecution’s probability analysis as:

1. They ignored the fact that the same carpet was in all but one or two rooms in the house, including the parents’ bedroom and the living room.
2. They overlooked the fact that Wayne Williams had changed rooms since the last murder on their list. The room they identified as his was actually used by a relative.
3. They ignored the fact that even in residential applications many of the exact same fibers were dyed the same color and used in rugs which are not the same model number as those used in the Williams’ house.
4. They chose to narrow their analysis to a statistical area that doesn’t exist – the southeast. They also failed to allow for the possibility that the killer or killers lived elsewhere and traveled regularly to the area.
5. They included only fibers said to have been used in carpets for residential applications, ignoring the fact that the same fiber could be found in many apartments and businesses.
6. They ignored the fact that millions of pounds of the exact same fiber had been sold undyed to other manufacturers for use in applications such as car mats.

About the finer probability ration involving the car, Dettlinger points out that “the prosecution used metro Atlanta figures to show how rare this vehicle would be. This means the Williamses’ vehicle was not included because it was registered in Muscogee County, which is far from Atlanta.”

In addition, since four people had been in the Williams home regularly, that made four suspects, not one. “The prosecution summed up by saying that even though the fibers were common, it is the combination
of fibers which could not be found in any other environment except the Wayne Williams environment. This gives us four or more suspects, not one, and more importantly: What about a Laundromat where the environments of hundreds, perhaps thousands of fibers are mixed and even clogged together in filters? Clifford Jones was killed in the back room of a Laundromat.

“Clifford Jones was the final blow to the state’s fiber case. He was one of only seven who had the even remotely-unique Wellman fiber. However, both the FBI and the investigating officer agree with me that Jones was killed by someone other than Williams and the Jones case was not introduced at the trial even though the defense begged for its submission.”

Clearly the fiber probability ratio was not as impressive as it seemed.

This case was the first to have relied on this type of analysis for pivotal evidence, and several appeals justices noted that it was too weak: There were no eyewitnesses, weapon, motive, confession, or clear placement of Williams with any of the victims prior to their deaths. Exactly what did this evidence corroborate? It was not even that clear that the two victims had been murdered, and both were adult males, completely unlike any of the young boys used in the ten “pattern” cases. It seems obvious from the many problems in this case that fiber alone should not be a deciding factor.

The same can be said for shafts of hair that have only basic distinguishing characteristics. Nevertheless, trace evidence does have its place, as seen in the following investigation.

**Discussion:**
- List the apparent strengths of the prosecution’s case.
- List the obvious weaknesses.
Lab #6: Analysis of Secured Physical Evidence

Background:
Forensic Science is scientific information that is used to address legal issues. Every crime leaves a visible sign called physical evidence that can lead the careful investigator back to the perpetrator – the individual who committed the act. The form of physical evidence can be a tire track, and impression in the soil or even snow, a scratch or other marking, or particles and fibers that need to be viewed through a microscope.

Particles-Soils and Powders
Particl
es are tiny pieces of physical evidence. Soil is a mixture of different sized and shaped particles – minerals and sand, clay, and organic matter.

Powders are fine, dry masses of particles. Grinding or crushing materials usually creates powders. Cosmetics and many foods such as flour, and confectioner sugar, are powders.

Particle Collection and Analysis Methods
Forensic investigators use the tape lift method to collect particle evidence (see figure 4-3 below).

Procedure:
1. Try to “tape lift” some physical evidence from various objects in the room (clothing, floor…etc.).
2. Make careful observations and notes about the samples.
3. Try to make some inferences about the evidence (where came from, who the fibers belong to…etc).

Fig 4-3. Demonstration of a tape lifted fingerprint from an Alabama license plate. 1) Once the evidence is located, tear off about a 2 inch strip of tape. 2) Fold the edges over so that you can hold the tape without contaminating it with your own prints. 3) Apply the tape over the area containing the evidence being careful to not let air bubbles form. 4) Lift the tape off and apply to a clear plastic sheet or to a glass slide. You are then ready to view under the microscope.
Lab Activity #7: Methods for Analyzing Soil as Evidence

Before you proceed with the lab: download and view the PowerPoint on Soil from the class website.

General Description
1. Write a description of the soil sample. Note the color, texture, and general appearance. Record all observations on the data sheet.
2. Then, use a magnifying glass, and note the presence of any vegetation or any unusual materials. Record your observations on the data sheet.

Ultraviolet Light
1. Observe the soil sample with an ultraviolet light. It is best to have the soil in a dark area when doing this.

pH
1. Mix 2 grams of the soil sample in 50 mL of distilled water.
2. Stir the mixture for 1 minute then use a pH probe to read the pH of the solution.

Soil Density Profile
1. Before making the soil profile, dry the soil, then put through a 30-45 mesh sieve.
2. Make a density gradient tube by carefully putting 1-2 mL of each of the following liquids in a small test tube: rubbing alcohol, corn oil, water, glycerin, and corn syrup. Allow to settle. (Determine the density of each solutions before placing in the profile column.)
3. Drop a small amount of well-mixed soil into the tube and allowed to sit for 12 to 24 hours. Then sketch the sample profile and estimate the percentage of the total sample at each density.

Reaction with Acid
1. In a well-plate place a small sample of soil (about the size of an aspirin). Add 10 drops of HCl to the sample. Carefully look for the presence of any gas bubbles and record your observations in the data sheet.
2. If gas bubbles are produced it indicates presence of a carbonate or the presence of the metals, zinc, iron, or magnesium. In soil the most likely would be carbonate but at a crime scene you might find the metal fragments mixed in with the soil.

Settling Rate
1. Use a spectrophotometer to determine the settling rate of the soil particles. Make sure the Spec20 has been warmed up and calibrated.
2. Obtain 0.5 g of a well-mixed soil sample. Fill a clean cuvette about two-thirds full of water. Add the soil to the water and shake vigorously for about 1 minute.
3. Immediately insert the tube into the sample compartment, close the cover, and record the percent transmittance from the scale.
4. Continue to take readings every 30 seconds for the first few minutes, then at one-minute intervals until the transmittance reaches a stable value or until 10 minutes of recording has been completed.
5. Use a piece of graph paper to plot time versus percent transmittance. This graph can then be compared to graphs from other soil samples.
Lab Activity #8: Forensic Analysis Using Physical Properties

Skills/Concepts
- Experimental Design
- Deductive Reasoning
- Qualitative Analysis of Physical Properties
- Identifying Unknown Compounds

Introduction, Part 1:
Forensics: The scientific analysis of physical evidence (as from a crime scene)
Forensics relies heavily on chemical analysis. Forensic scientists use knowledge of the physical properties of compounds to identify unknown substances, such as those found on a crime scene.

You have been asked to help solve a crime. A local art museum has reported a theft. The art piece was found with traces of white powder on it. Three of the arrested suspects also have traces of white powder on their clothing. The forensics department wants you to identify the powders from the stolen item and from the suspects’ clothing. To do this, you will observe physical and chemical properties of the 4 samples.

Introduction, Part 2:
A pure substance is a material with a fixed, definite composition throughout the sample. Chemists often try to catalogue the physical and chemical properties associated with various pure substances. Once known, these properties can help identify unlabeled matter and to predict the properties of mixtures or solutions created from pure substances.

We often subject samples to conditions that change the properties of a sample. Physical changes alter the matter’s form and appearance, but not its chemical composition. Grinding wheat, melting butter, and boiling water are examples of physical change. Chemical changes alter the chemical composition. Baking bread, getting a suntan, and reacting oxygen and hydrogen to form water are examples of chemical changes. Chemical changes often include physical changes. Physical change can be informative of chemical change.
**Pre Lab**

Decision trees can be used to find the solution to a question while asking the minimum intermediate questions. In this lab, you will determine the characteristics of known compounds and then create a decision for identifying unknown compounds. Below is a sample set of data and a flow chart made from it. Note that even though four characteristics are known for each animal, three of the animals can be identified by observing only two features.

<table>
<thead>
<tr>
<th>Has Long Tail?</th>
<th>Herbivore?</th>
<th>Bipedal?</th>
<th>Furry?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Puma</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Elephant</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mouse</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Panda</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Think of 5 objects and 4 relevant properties. Fill out the data table below and then draw a decision tree for testing the identity of any of the 5 objects.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<tr>
<td>2.</td>
<td></td>
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<td></td>
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<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Procedure
First, determine physical and chemical properties of four common household substances using the three tests below.

<table>
<thead>
<tr>
<th>Household Name</th>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornstarch</td>
<td>(C₆H₁₀O₅)ₙ</td>
</tr>
<tr>
<td>Epsom Salt</td>
<td>MgSO₄</td>
</tr>
<tr>
<td>Baking Powder</td>
<td>Mixture of</td>
</tr>
<tr>
<td></td>
<td>• KOCO(CHOH)₂COOH (cream of tartar)</td>
</tr>
<tr>
<td></td>
<td>• NaHCO₃ (baking soda)</td>
</tr>
<tr>
<td></td>
<td>• (C₆H₁₀O₅)ₙ (cornstarch)</td>
</tr>
<tr>
<td>Table Salt</td>
<td>NaCl</td>
</tr>
</tbody>
</table>

**Water Solubility Test**
To a test tube, add
- a pea-sized amount of powder
- ~5 mL of water
Invert the tube repeatedly to mix. Determine if the solid has sufficiently dissolved or not.

**Iodine Test**
To a test tube, add
- a pea-sized amount of powder
- a few drops of tincture of iodine
- ~1 mL of water
Invert the tube repeatedly to mix. Note the color of the solution or mixture.

**Phenolphthalein**
To a test tube, add
- a pea-sized amount of powder
- a few drops of phenolphthalein
- ~1 mL of water
Invert the tube repeatedly to mix. Note the color of the solution or mixture.

**Acetic Acid (Vinegar)**
To a test tube, add
- a pea-sized amount of powder
- a few mL of vinegar
Invert the tube repeatedly to mix. Note whether or not the solution or mixture fizzes.
**Procedure**

Record your test results below:

<table>
<thead>
<tr>
<th></th>
<th>Appearance</th>
<th>Water Solubility</th>
<th>Iodine</th>
<th>Phenolphthalein</th>
<th>Acetic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornstarch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epsom Salt</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Baking Powder</td>
<td></td>
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</tr>
<tr>
<td>Table Salt</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

With your lab partner, determine a flowchart to test to the samples from the forensics lab.
Using the available tests and the decision tree that you have made, identify the samples provided by the forensics department. Fill in the following chart with data you collect. You do not need to perform each test on each sample. The decision chart should help you reduce the number of tests you need to perform.

Table 2: Physical Property Tests

<table>
<thead>
<tr>
<th></th>
<th>Appearance</th>
<th>Water Solubility</th>
<th>Iodine</th>
<th>Phenolphthalein</th>
<th>Acetic Acid</th>
<th>Identity of Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art Piece</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspect 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspect 2</td>
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<td></td>
</tr>
<tr>
<td>Suspect 3</td>
<td></td>
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</tr>
</tbody>
</table>

**Final Analysis:** Write up a lab report that addresses the following components:
1. What powder was on the stolen art piece?
2. Which suspect had the same powder on his clothing?
3. Is this person the thief? Why or why not?
4. A summary of how the crime was committed.
Lab Activity #9: Methods for Analyzing Fibers/Fabrics as Evidence

Supplies needed (per team):
- enough of each known fabric (use white or off-white samples of cotton, wool, acetate, silk, and polyester)
- unknown fabric
- stereomicroscope
- candle, matches
- forceps
- 6 small test tubes/rack per team
- Acetone
- 6 microscope slide/cover slip
- microscope

IT IS VERY IMPORTANT TO KEEP THE FLAMES AND THE ACETONE AWAY FROM EACH OTHER!

Student Procedures
In this lab, you will be exploring the characteristics of various fabrics and their fibers. You will then attempt to identify an unknown fabric based on your initial observations. You will work with five different fabric samples, numbered as follows: 1. wool; 2. silk; 3. acetate; 4. polyester; and 5. cotton. Be sure to create a data table and record all of your results!

Exercise A. Initial Observation
1. Look carefully at each sample without any magnification. Describe what you see, in detail. This could include descriptions of the weave pattern, roughness, size of fibers, thickness of material, sheen, etc.
2. Observe the sample using a stereomicroscope and describe what you see.
3. Feel and smell the samples, and describe.

Exercise B. Burn Test
CAUTION: Use all due caution. All flammable materials (including the acetone supplied with this lab) should be kept far away from the work area or in another room. Do not perform burn tests without your teacher’s supervision.
1. Light a small candle and place it on a table in a safe place.
2. Use forceps to pull one thread of wool from the sample.
3. Holding the thread with the forceps, slowly move the end of the thread toward the flame from the side.
Note the reaction of the fibers in the thread as they approach the flame (e.g., curls away from the flame or melt).
4. Move the end of the thread into the flame and pull it back out. Notice the manner in which the fibers ignite and burn (e.g., quickly or slowly).
5. Do the fibers continue burning when removed from the flame? If the burning fibers give off a noticeable odor, try to describe it. Allow the thread to burn itself out.
6. After the flame has been dead for several seconds, examine any ash or residue left.
Note the color and form of the residue. Press a finger tip on the cooled residue to see if it is hard or brittle.
7. Record your observations.
8. Repeat the flame test for each of the samples.
**Exercise C. Solvent Test**

1. Obtain 5 small test tubes and a test-tube rack.
2. Use a glass-marking pencil to number the tubes with the numbers 1 through 5.
3. Carefully add about 3 ml of acetone to each tube.
4. Use forceps to pull a thread of wool from the fabric.
5. Use scissors to cut three pieces of the thread each about 5 mm long. Discard the rest of the thread. Use forceps to drop a piece of thread into tube #1.
6. Repeat Steps 4 and 5 for the other fibers. Place the pieces of silk in tube #2, acetate in tube #3, polyester in tube #4, and the cotton in tube #5.
7. Observe the test tubes for 10-15 minutes. Note if any of the threads is dissolved or affected by the solvents. Record your observations.

**Exercise D. Microscopic Examination**

1. Use forceps to pull a thread of wool from the fabric.
2. Unravel the thread.
3. Obtain a clean microscope slide and place a small drop of water on it.
4. Use forceps to tease a few fibers gently from the unraveled thread. Place the fibers on the drop of water. Discard the rest of the thread.
5. Obtain a clean cover slip and carefully lower it over the drop of water.
6. Examine the slide under the low and high power objectives of a microscope. Examine the fibers closely, noting any distinct features. Pay close attention to the presence of striations (longitudinal or cross markings), folds, or twists. Note whether the fibers are transparent or opaque. Record your observations.
7. Repeat steps 1 through 6 for each of the other four types of fibers.
8. Repeat the above procedures to identify your unknown sample.

**Analysis:**

A person has been suspected of selling fraudulent clothing. They claim that their product is pure cotton. It is your job to determine if they are telling the truth or not.

- Make a table to record your laboratory results.
- Write up a summary of your findings to present to your supervisor. Be sure that your writing is spell checked and organized. Use internal headings. Explain all lab tests and procedures.
Chapter 5: Organic Analysis

In its basic definition, organic analysis is the examination of organic compounds; any substance containing the element Carbon, and may also contain Hydrogen, and lesser amounts of Oxygen, Nitrogen, Chlorine, Phosphorus, or other elements. Organic also describes a substance that is produced by a living organism. Most often, a forensic chemist would be the person who would employ the methodology and instrumentation to analyze chemicals of abuse (drugs), explosives and other compounds for their identity and specificity. Gas Chromatography (GC), Thin-Layer Chromatography, Infra Red (IR) spectroscopy, Mass Spectroscopy (MS) and microscopy are some of the techniques that a forensic chemist might use. Therefore, to begin our discussion of organic analysis, we must first begin with a basic primer on chemistry.

Key Terms:
- Chromatography
- Compound
- EM spectrum
- Electrophoresis
- Element
- Enzyme
- Fluoresce
- Infrared
- Inorganic
- Ion
- Laser
- Organic
- Phase
- Photon
- Physical State
- Pyrolysis
- Spectrophotometry
- Ultraviolet
- X-ray

Elements and Compounds

Matter is anything that has the qualities of mass and volume. All matter can be broken down into fundamental building blocks called elements, which are reduced to a single identifiable substance. As of today, there are 109 identified elements, 89 of which occur naturally on Earth. The remaining elements that do not occur naturally have been created in the laboratory. Each of these elements are listed by name and symbol on a periodic table, which is extremely useful to chemists since it arranges the element systematically with similar properties in the same vertical row or group (see table 5.1).

Matter can also be described as a substance composed of atoms (building blocks of elements) and molecules (groups of two or more different types of atoms with a specific ratio).
Table 5.1 – The periodic table of the elements. Each colored grouping represents elements with similar properties.
For convenience, chemists have chosen letter symbols to represent the elements. Many of these symbols come from the first letter of the element’s English name; C for carbon, N for nitrogen. Some of the symbols are derived from the Latin name of the element; Ag (silver) from *Argentum*, Cu (copper) from *Cuprum*. The symbol may be composed of one, two or in a few cases, three letters; the first letter is always capitalized with the remaining letters lower case.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Atomic Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A one- or two-letter abbreviation derived from the element’s English or Latin name.</td>
<td>Equal to the number of protons in the nucleus, as well as the number of electrons in the electron cloud.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element’s common name.</td>
<td>Weighted average of the masses of all the element’s isotopes. Rounding the atomic mass to the nearest whole number yields the mass number of the most common isotope.</td>
</tr>
</tbody>
</table>

Other pertinent information on the periodic table includes the Atomic number, which not only tells the number of protons in the nucleus of the atom, but the number of electrons in the electron cloud (area outside the nucleus) when the atom is in elemental form. Atoms don’t always remain in elemental form, but will often gain or lose electrons from the electron cloud, which in turn give the atom a charge of either positive or negative. An atom that has gained or lost electrons acquiring a charge is referred to as an ion.

For example, Chlorine (element 17) tends to gain one electron. When the protons are then compared to the electrons, Chlorine has 17 protons (+ charge) and 18 electrons (- charge); thus the ionic state of Chlorine is said to be -1 and is written as Cl⁻.

Atoms of like kind are grouped into “periods” or vertical columns. Refer back to the periodic table on page 90. Period 1A all tend to lose one electron; therefore they all have a +1 charge as an ion. Group 2A are +2. Group 3A are +3. Group 4A are +4. There are some exceptions to this that you should note; Carbon (C) doesn’t form an ion, but rather shares valence electrons with other elements forming covalent bonds which are much stronger than the ionic attractions of a positive particle (+) to a negative (-). Boron (element 5) also tends to form covalent bonds. It is after the 4A group that things begin to change. Group 5A tends to gain 3 electrons, forming ions with a charge of -3. Groups 6A gain two electrons forming -2 ions and group 7A gain one, forming -1 ions. The last group (8A) does not form ions, nor do they form
covalent bonds with other atoms. These atoms are chemically stable due to their outer valence level of electron being full. These are known as the noble gases.

The transition elements are those elements having a partially filled valence subshell in any common oxidation state. The term "transition elements" most commonly refers to the d-block transition elements. The 2B elements zinc, cadmium and mercury do not strictly meet the defining properties, but are usually included with the transition elements because of their similar properties. The f-block transition elements are sometimes known as "inner transition elements". The first row of them is called the lanthanides or rare earths. The second row consists of the actinides. All of the actinides are radioactive and those above Z=92 are manmade in nuclear reactors or accelerators.

The general properties of the transition elements include:
1. They are usually high melting point metals.
2. They have several oxidation states.
3. They usually form colored compounds.
4. They are often paramagnetic (display magnetic qualities without containing iron).

The transition elements include the important metals iron, copper and silver. Iron and titanium are the most abundant transition elements. Many catalysts for industrial reactions involve transition elements.

There are many different kinds of atoms from the 109 elements. Ninety-two of these elements occur naturally on the planet Earth. Six of these elements (carbon, hydrogen, nitrogen, oxygen, phosphorus & sulfur) comprise about 98% of the body weight of most living organisms. Two or more atoms joined together by chemical bonds form molecules of chemical compounds such as water (H₂O), glucose (C₅H₁₂O₆) and sucrose (C₁₂H₂₂O₁₁). The four major elements of living (organic) systems are carbon (C), hydrogen (H), oxygen (O) and nitrogen (N).

The major compounds of living systems are hydrocarbons, carbohydrates, lipids, proteins and nucleic acids. Molecules of these compounds are composed mostly of atoms from the four major elements, plus some additional elements, such as phosphorus (P), sulfur (S), iron (Fe), magnesium (Mg), sodium (Na), chlorine (Cl), potassium (K), iodine (I) and calcium (Ca). Following is a discussion of the major types of organic compounds.

Hydrocarbons are the simplest of the organic compounds. As the name suggests, hydrocarbons are made from hydrogen and carbon. The basic building block is one carbon with two hydrogens attached, except at the ends where three hydrogens are attached to the carbon. Remember carbon has vacancies for four electrons in its outer shell. So it wants to bond to four atoms. Here we see hydrocarbons with one to four carbons: methane (natural gas), ethane, propane, and butane (lighter fluid).

Fig 5.1 shows the atomic arrangement of various hydrocarbons.
When the chain is between 5 and 9 carbons, the hydrocarbon is gasoline. At about a dozen carbons, it is diesel. Around 20 carbons is motor oil. A chain of hundreds to thousands of carbon and hydrogens make plastic. Figure 5.2 shows a particular plastic known as polyethylene.

By adding various functional groups (groups of molecules) a simple hydrocarbon can be altered into a different type of chemical compound. For example, methane, the simplest hydrocarbon has the formula CH$_4$. By removing one of the hydrogen and replacing it with an –OH (alcohol) group, methane is transformed into methanol, an alcohol. Study the Figure 5.3 and determine the base hydrocarbon and its formula for each of the following alcohols.

- Ethanol base compound = __________,
  chemical formula __________
- Propanol base compound = __________,
  chemical formula __________
- Isopropyl alcohol base compound __________,
  Chemical formula __________.

Fig. 5.3 Various alcohols.
Alcohols are not the only compounds that use the three elements of oxygen, hydrogen, and carbon. Organic acids is another class of organic compounds that uses these three elements. Let’s consider a few common small organic acids. Don’t forget that an extra oxygen replaces two hydrogens. Remember, an oxygen has two vacancies and two electrons to share. Formic acid is the smallest organic acid. Acetic acid is very common. Butyric acid is produced when butter goes rancid. These are all acids because the hydrogen bonded to the oxygen can come off easily. More exactly, just the nucleus (1 proton) of the hydrogen comes off. Hydrogen’s electron stays behind. Organic acids combined with alcohols are building blocks for all kinds of flavorings and fragrances. In the example shown in figure 5.4 below, propanol is boiled with acetic acid. As the bump into each other, the -OH from the acetic acid combines with the hydrogen from the alcohol to make water, H₂O.

Figure 5.4. When propanol is boiled with acetic acid, propyl acetate and water are formed. Propyl acetate is otherwise known as "pear" flavoring.

Another class of organic compounds is carbohydrates. Carbohydrates are the main energy source for the human body. Chemically, carbohydrates are organic molecules in which carbon, hydrogen, and oxygen bond together in the ratio: Cₓ(H₂O)ᵧ, where x and y are whole numbers that differ depending on the specific carbohydrate to which we are referring. Animals (including humans) break down carbohydrates during the process of metabolism to release energy. For example, the chemical metabolism of the sugar glucose is shown below:

\[ C₆H₁₂O₆ + 6 O₂ \rightarrow 6 CO₂ + 6 H₂O + \text{energy} \]

Animals obtain carbohydrates by eating foods that contain them, for example potatoes, rice, breads, and so on. These carbohydrates are manufactured by plants during the process of photosynthesis. Plants harvest energy from sunlight to run the reaction just described in reverse:

\[ 6 CO₂ + 6 H₂O + \text{energy (from sunlight)} \rightarrow C₆H₁₂O₆ + 6 O₂ \]
A potato, for example, is primarily a chemical storage system containing glucose molecules manufactured during photosynthesis. In a potato, however, those glucose molecules are bound together in a long chain. As it turns out, there are two types of carbohydrates, the simple sugars and those carbohydrates that are made of long chains of sugars - the complex carbohydrates.

**Simple sugars**

All carbohydrates are made up of units of sugar (also called saccharide units). Carbohydrates that contain only one sugar unit (monosaccharides) or two sugar units (disaccharides) are referred to as simple sugars. Simple sugars are sweet in taste and are broken down quickly in the body to release energy. Two of the most common monosaccharides are glucose and fructose. Glucose is the primary form of sugar stored in the human body for energy. Fructose is the main sugar found in most fruits. Both glucose and fructose have the same chemical formula ($\text{C}_6\text{H}_{12}\text{O}_6$); however, they have different structures, as shown (note: the carbon atoms that sit in the "corners" of the rings are not labeled):

<table>
<thead>
<tr>
<th>Glucose</th>
<th>Fructose</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Glucose structure" /></td>
<td><img src="image" alt="Fructose structure" /></td>
</tr>
</tbody>
</table>

Disaccharides have two sugar units bonded together. For example, common table sugar is sucrose, a disaccharide that consists of a glucose unit bonded to a fructose unit:

<table>
<thead>
<tr>
<th>Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Sucrose structure" /></td>
</tr>
</tbody>
</table>

**Complex Carbohydrates**

Complex carbohydrates are polymers of the simple sugars. In other words, the complex carbohydrates are long chains of simple sugar units bonded together (for this reason the complex carbohydrates are often referred to as polysaccharides). The potato we discussed earlier actually contains the complex carbohydrate starch. Starch is a polymer of the monosaccharide glucose:
Starch is the principal polysaccharide used by plants to store glucose for later use as energy. Plants often store starch in seeds or other specialized organs; for example, common sources of starch include rice, beans, wheat, corn, potatoes, and so on. When humans eat starch, an enzyme that occurs in saliva and in the intestines called amylase breaks the bonds between the repeating glucose units; thus allowing the sugar to be absorbed into the bloodstream. Once absorbed into the bloodstream, the human body distributes glucose to the areas where it is needed for energy or stores it as its own special polymer - glycogen. **Glycogen**, another polymer of glucose, is the polysaccharide used by animals to store energy. Excess glucose is bonded together to form glycogen molecules, which the animal stores in the liver and muscle tissue as an "instant" source of energy. Both starch and glycogen are polymers of glucose; however, starch is a long, straight chain of glucose units, whereas glycogen is a branched chain of glucose units, as seen in figures 5.5 and 5.6:
Another important polysaccharide is cellulose. **Cellulose** is yet a third polymer of the monosaccharide glucose. Cellulose differs from starch and glycogen because the glucose units form a two-dimensional structure, with hydrogen bonds holding together nearby polymers, thus giving the molecule added stability. Cellulose, also known as plant fiber, cannot be digested by humans, therefore cellulose passes through the digestive tract without being absorbed into the body. Some animals, such as cows and termites, contain bacteria in their digestive tract that help them to digest cellulose. Cellulose is a relatively stiff material, and in plants it is used as a structural molecule to add support to the leaves, stem, and other plant parts. Despite the fact that it cannot be used as an energy source in most animals, cellulose fiber is essential in the diet because it helps exercise the digestive track and keep it clean and healthy.
A third category of organic compound is lipids. **Lipids** are largely hydrocarbon like, and therefore do not dissolve in water but in nonpolar solvents like diethyl ether and benzene. The lipid family is very large and diverse. It includes cholesterol, hormones, and the edible fats and oils we eat.

**Triacylglycerols**
The edible fats and oils we eat are *triacylglycerols* (commonly called *triglycerides*). They are esters between glycerol (an alcohol with three OH groups) and any three of several long-chain carboxylic acids (see image below).

![Diagram of a triacylglycerol molecule]

**Fatty Acids**
*Fatty acids* are the carboxylic acids used to make molecules of triacylglycerols. They generally have just one carboxyl group on a chain of even numbers of carbon atoms. They are unbranched in the most abundant ones. Some fatty acids have alkene groups. Long hydrocarbon chains are what make them nonpolar and like hydrocarbons. Lipids from vegetable sources are liquid at room temperature while lipids from animal fats are solid at room temperature. This is because vegetable oils have more alkene double bonds per molecule than animal fats, and are *polyunsaturated* materials. Table 5.2 on the next page shows several different fatty acids along with varied information concerning each.
Table 5.2: Common Fatty Acids

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th># of carbon atoms</th>
<th>Structure</th>
<th>Melting point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic acid</td>
<td>14</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>54</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>16</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>63</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>18</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>70</td>
</tr>
<tr>
<td>Oleic acid</td>
<td>18</td>
<td>CH₃(CH₂)₇CH=CH(CH₂)₇COOH</td>
<td>4</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>18</td>
<td>CH₃(CH₂)₄CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>-5</td>
</tr>
<tr>
<td>Linolenic acid</td>
<td>18</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>-11</td>
</tr>
</tbody>
</table>

Proteins

The proteins are a huge family that make up about half the human body's dry weight. They are found everywhere in all living organisms. They can function as a building material, in teeth and bones and muscles, and they can serve as enzymes, hormones, and neurotransmitters. It's functions is the most diverse of any family. The word protein comes from the Greek proteios, or "of first rank."

Proteins consist of macromolecules called polypeptides, made from monomers called amino acids. Most proteins also include traces of other organic molecules or metal ions, which give it its characteristic biological function.

Amino Acid Structure

Fig. 5.8. The amino acid is called such due to the amine group (-NH₂) on one end of the molecule and an acid (-COO⁻) group on the other end. The “R” group is some variant hydrocarbon, which determines the peptide identity.
Polypeptides
When amino acids are joined together, they make polypeptides. The carboxyl group of one amino acid becomes joined to the amino group of another by a peptide bond (amide bond). For example, this is the linking of glycine and alanine:

\[
\begin{align*}
\text{glycine (Gyl)} & \quad + \quad \text{alanine (Ala)} \quad => \quad \text{glycylalanine (Gly-Ala)} \quad + \quad \text{water}
\end{align*}
\]

Glycylalanine is a dipeptide because it has two amino acids linked by a peptide bond (CO - NH). A different dipeptide could be made using the same two amino acids, but putting them in a different orientation. This would make alanylglycine (Ala-Gly). The three letter abbreviations can be used to represent the structural formulas of the amino acids.

Also, because the molecules produced are still dipolar ions, more amino acids can be put together. Proteins have hundreds, thousands, or sometimes even millions of these amino acids.

Proteins
Some proteins consist of only single polypeptides. But most involve two or more aggregated polypeptides, sometimes with other small organic molecules or metal ions.

Hemoglobin, the substance in your blood that carries the oxygen, has four polypeptides (two similar pairs), and one molecule of heme, which colors the blood red. Heme holds an Fe^{2+} ion. If one piece of it is altered in any way, the substance will cease to function, or will function improperly.

Shape is also important. Proteins are coiled and twisted, giving it a unique shape. The shape is critical in the ability of the protein. The shape depends on the sequence of the amino acids, which can be hydrophilic or hydrophobic. Those that are hydrophilic want contact with water and will be twisted to maximize contact. Those that are hydrophobic are twisted in such a way to minimize contact. Changing one amino acid in the polypeptide sequence can destroy this shape and make the protein function improperly if not at all.

The shape can also change when protons are donated to accepting sites or released from donating sites. Thus, any change in the pH can change the shape drastically. Because of this, living systems must have tight control over the pH of its fluids by means of buffers.

As seen in the image to the right, proteins can be found in a variety of forms; meats, nuts, beans and eggs are all organic materials that are high in protein.
Enzymes

A very important function of proteins is that they can serve as **catalysts**. Enzymes are organic catalysts made of proteins. They speed up reactions inside an organism. The molecule which an enzyme catalyzes is called a substrate. Enzymes can only act on the substrate that they were designed for. This is again because of protein shape. If the substrate molecule's shape matches the enzyme's active site, it undergoes the reaction specified. This is called the **lock-and-key theory of enzyme action**.

Enzymes can either break or put together substrates. And they can enhance the rate of reactions to over half-a-million molecules per second. Because of the lock-and-key theory, enzymes must retain their shape to keep their function. If the temperature is too high, the enzyme will change its shape, becoming almost like a random mass of coils, in a process called **denaturation**, and thus losing its function. Some dangerous poisons work by deactivating enzymes by changing their shapes.

Nucleic Acids

All the proteins of an organism are made under the chemical direction of **nucleic acids**. There are two types, RNA (ribonucleic acid) and DNA (deoxyribonucleic acid).

DNA forms the chemical basis through which genetic information is carried. All physical and biological characteristics are inherited through it. DNA molecules direct their own duplications and guide the assembly of amino acid units into a unique polypeptide sequence.

Both DNA and RNA have a similar structure. They consist of a chain of deoxyribose or ribose sugars linked by phosphate groups with side chain **bases**, as seen in Figure 5.9 to the left.

One structural difference between DNA and RNA is that the sugar in DNA, deoxyribose, is lacking an oxygen atom where ribose has an OH group.

Fig 5.9. The structural formula of DNA. Only one side of the double stranded molecule is shown.
The side chain bases are all heterocyclic amines. Their molecular shapes give the nucleic acids their function. They are represented by single letters--A for adenine, T for thymine, U for uracil, G for guanine, and C for cytosine. A, T, G, and C occur in DNA. A, U, G, and C occur in RNA. They make up the "letters" of the genetic alphabet. Pictured below, these nitrogen containing bases are further classified as purines (double rings) or pyrimidines (sing rings). In the bonding arrangement of DNA, a purine will bond with a pyrimidine; A-T and C-G.

Genes, the individual units of heredity, are unique in the length of the backbone and the sequence in which the bases occur. All of an organism’s hereditary information resides on these aspects of DNA.

The DNA Double Helix

In DNA, there are two backbones (or strands) of nucleic acids and they are intertwined like a spiral staircase called the DNA double helix. A 3D rendered computer model of the DNA double helix is shown on the right (the purple lines are to help visualize the backbone). Hydrogen bonds (···) between the N-H groups and the O=C units in the side chain bases hold it together.

N-H···O=C

However, hydrogen bonding only occurs between certain pairs of bases. A always pairs with T and C always pairs with G in DNA. A will pair with U, but U occurs in RNA only, which is important in the work of RNA. If an A is found on one strand, a T will be found on the other. The same goes for C and G.
DNA-Directed Synthesis of Polypeptides

Each polypeptide in a cell is made under the direction of its own gene. To make the polypeptide, a few basic steps are followed:

\[
\text{transcription} \quad \rightarrow \quad \text{translation} \\
\text{DNA} = \rightarrow \text{mRNA} = \rightarrow \text{tRNA} = \rightarrow \text{polypeptide}
\]

In transcription, a type of RNA called *messenger RNA* (mRNA) is used to read the code of a gene in DNA. The gene in the DNA strand opens up, allowing RNA nucleotides to bond in a certain sequence complementary to the bases on the DNA (though U is used instead of T in RNA). Once completed, the mRNA goes out of the cell nucleus to a ribosome (manufacturing center for polypeptides) and the DNA reforms its original shape. At the ribosome, *transfer RNA* (tRNA) reads the mRNA in a process called translation. The tRNA has an open faced part (anticodon) for reading the mRNA consisting of three letters (codon) a time. Each tRNA is attached to a specific amino acid, and as it reads the mRNA, the amino acids are put together in a certain sequence. For example, the anticodon CCA on tRNA matches up with the codon GGU on mRNA. Since CCA is always with glycine, the glycine will become part of the growing chain. If the next codon is GCU, it matches up with anticodon CGA, which is alanine. So, the alanine will be attached to the glycine. Through this process, long chains of polypeptides are formed.
Lab Activity #10: Identification of Biomolecules

Introduction:
Our physical bodies are essentially a collection of common and exotic chemicals. Many of these chemicals are simple inorganic combinations such as sodium chloride, hydrochloric acid, molecular oxygen, and carbon dioxide. Most chemicals comprising our bodies are larger more complex organic molecules. The biochemical reactions that are occurring constantly within our cells synthesize new, larger molecules or decompose larger molecules into smaller pieces. **Anabolism** is a term used for all the synthesis reactions occurring at any time; **Catabolism** is a term that refers to all the decomposition reactions occurring at any time. **Metabolism** is a term that refers to ALL the reactions that might be occurring in the body. While our bodies can metabolize a wide variety of organic molecules, the vast majority belong to three major groups: **carbohydrates, lipids and proteins.**

**Carbohydrates** are composed of carbon, hydrogen and oxygen atoms in a ration of \((\text{CH}_2\text{O})_n\) where \(n\) can be any number depending on the complexity of the carbohydrate. **Simple sugars** such as glucose and fructose are called **monosaccharides.** More complex carbohydrates such as starches are **polymers** of these monosaccharide units and are called **polysaccharides.** Simple carbohydrates are broken down or catabolized in a process called **glycolysis** which provides the cells with most of its energy.

**Lipids,** including fats and steroids are composed of carbon, hydrogen and oxygen atoms. They are important components of cell membranes and are used as hormones and for energy storage. Excess food is usually stored as fat in adipose tissue cells.

**Proteins** are constructed from long chains of amino acids and contain carbon, hydrogen, oxygen, nitrogen and sulfur atoms. Proteins provide the major structural components of our cells and therefore our bodies. Other proteins serve as **enzymes** which are the major catalysts that facilitate complex biochemical reactions in our cells We can perform simple tests to identify some of these molecules by adding indicators to a solution to be tested. A change in color or other physical characteristic indicates the presence or absence of a particular kind of organic molecule.

A. **Simple carbohydrates (sugars).**
Benedicts solution causes some sugars to turn green, yellow, orange or red when heated to boiling. The color of a positive reaction depends on how much sugar is present (green indicates low levels; red high sugar levels).

B. **Complex carbohydrates (polysaccharides or starches).**
Lugol’s iodine causes a solution containing starch to turn dark blue to black. The more starch there is the darker the color.

C. **Lipids (fats and oils).**
Large amounts of concentrated lipids leave a translucent stain on absorbent paper after drying.

D. **Proteins (and Polypeptides)**
Biuret solution causes a protein solution to turn pink or violet.

The first step in learning to detect these chemicals is to perform **control** tests with substances known to contain or not to contain specific chemicals. You will perform each of the above tests on a “positive” and a “negative” solution (the “negative” is usually water). After completing the tests you will see both the positive and negative results for each of the different kinds of molecule above. Then you can compare your experimental tests to the control results to see if each of the different kinds organic molecules are present in each test solution.
Control Test Procedures:

1. Sugars:
   a. take two clean test tubes and label one su+ and the other su-.
   b. add about 1 cm of glucose solution (10% Karo) to su+
   c. add about 1 cm of DI water to su-
   d. add 5 drops of Benedict’s solution to each test tube
   e. place both test tubes in a boiling water bath at your table for about 2 minutes
   f. record the reaction as either “+” or “-“ in the table on your data sheet

2. Starches
   a. add a drop of boiled starch solution (1% starch) to one of the wells in the spot plate and a drop of DI water to another well
   b. add 1-3 drops of Lugol’s iodine to each of the wells
   c. record the reaction as either “+” or “-“ in the table on your data sheet

3. Lipids
   a. with a dropper add a drop of oil (vegetable oil) to one half of a paper towel
   b. with another clean dropper add a drop of DI water to the other half of a paper towel
   c. place the paper towel in the incubator on a warming tray for 5 minutes
   d. record the reaction as either “+” or “-“ in the table on your data sheet

4. Proteins
   a. add a drop of protein solution to a clean spot plate
   b. then add a drop of Biuret solution to the same well
   c. add a drop of DI water to another well on the spot plate
   d. then add a drop of Biuret solution to the same well
   e. record each of the two reactions as either “+” or “-“ in the table on your data sheet

Experimental Tests
In the second part of this exercise you will be testing each of the solutions that you are given by adding indicators to test for the above molecules. But before you actually perform the tests make predictions by noting which organic molecules you would expect to find in each of the solutions with a “+” sign in the “expected results” section of your data table. Place a “-“ if you do not expect to find that kind of molecule.

Perform the tests on each of the solutions provided the same way you tested each control solution and record your results in the “experimental results” section of your table on your data sheet.

*Use the spot plate for the starch tests; use a paper towel for the oil test; use test tubes for the benedicts and protein tests.*

You will need to clean and rinse the test tubes in DI water and reuse them during this lab. At the end of the lab you can discard the test tubes in the glass disposal boxes.

Cleanup and Disposal
- Discard all solutions into the sink with the water running
- **Do NOT** empty water from beaker on hot plate
- Make sure the hot plate is turned off and unplugged before you leave; leave the beaker on the hot plate
- Dispose of empty test tubes in the glass disposal box
- Dispose of plastics and paper towels in trash
- Clean spot plates with soap and water and return it to your lab table
- Wipe down counters with disinfectant
Identification of Biomolecules
Lab Data Sheet

Control Tests: For each control test below record your results as a “+” or “-” in the column to the right.

<table>
<thead>
<tr>
<th>Control Tests</th>
<th>Results +/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Test</td>
<td></td>
</tr>
<tr>
<td>Sugar Solution</td>
<td></td>
</tr>
<tr>
<td>DI water</td>
<td></td>
</tr>
<tr>
<td>Starch Test</td>
<td></td>
</tr>
<tr>
<td>Starch Solution</td>
<td></td>
</tr>
<tr>
<td>DI water</td>
<td></td>
</tr>
<tr>
<td>Lipid Test</td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td>DI water</td>
<td></td>
</tr>
<tr>
<td>Protein Test</td>
<td></td>
</tr>
<tr>
<td>Protein Solution</td>
<td></td>
</tr>
<tr>
<td>DI water</td>
<td></td>
</tr>
</tbody>
</table>

1. Did all the control tests give the expected results, if not explain?

2. Why are these called “control” tests?

3. What would be the consequences for the rest of this experiment if any of the control tests did not produce the expected results? Describe a specific example.
**Experimental Tests:** Write out your ‘hypothesis’ being tested (your expected results) for each solution below and then record your experimental results as a “+” or “-” in the columns to the right.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Expected Results [+/-]</th>
<th>Experimental Results [+/-]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sugar</td>
<td>starch</td>
</tr>
<tr>
<td>Apple Juice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diet Soda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oatmeal sol.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottled Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honey sol.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown #2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown #3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Make a table that lists any **discrepancies** between what you expected to find (your hypotheses) and what you actually found (your experimental tests) in each of the solutions. Then try to explain each of these specific discrepancies, ie: Why, **specifically**, do you think you did not get your expected results in each case? (use additional sheets as needed):
The biological and chemical changes undergone by a body after death are known as decomposition. Decomposition is the continual process of gradual decay and disorganization of organic tissues and structures after death. Some tissues, such as bones, teeth, and hair, are more resistant to the action of microorganisms and other environmental factors and may last for centuries. Fossilized bones from animals and hominids, extinct millions of years ago, are studied today by paleontologists and anthropologists, thanks to such resilience.

Forensic medicine and forensic anthropology investigate the sequence and types of changes that affect decomposing bodies under different conditions and environments. A number of variables may affect both the rate and sequence of decomposition. Therefore, the estimation of time elapsed since death, known in forensics as the postmortem interval, takes into consideration the particular conditions associated with the decomposing body, such as temperature, level of humidity, and medium, such as exposure to preservatives, water, or soil.

For centuries, pigs were the animal model used to study both anatomy and the decomposition process due to their internal structural similarities to the human body. However, in 1980, the University of Tennessee at Knoxville began a research project on human decomposition with cadavers donated by the families of deceased persons or by the individuals who willed their bodies to science. In an area known as the Anthropological Research Facility, human bodies were laid to decompose in several different controlled conditions. These controlled experiments have significantly contributed to the better understanding of human decomposition and to new levels of accuracy of forensic reconstruction techniques, such as the circumstances of death, time and cause of death, and determination of age, race, and gender. The data collected from several types of experiments and the measurements of each skeleton are recorded in a computer data bank named ForDisc (Forensic Discrimination).

A general description of postmortem changes due to decomposition basically includes two stages of autolysis, and four stages of putrefaction, besides some conservative phenomena such as saponification or adipocere, natural mummification, calcification, etc. However, these latter events only occur in specific conditions. Autolysis consists of the fast and intense spontaneous self-destruction of tissues by the body enzymes present in the cells, without any bacterial interference. Once cells stop receiving nutrients and oxygen via blood circulation, they start anaerobic (without oxygen) "breathing", breaking ATP (adenosine tri-phosphate) into ADP (adenosine di-phosphate) to obtain energy. Anaerobic respiration lasts for a few hours, until all ATP reserves are exhausted. The anaerobic respiration induces the accumulation of lactic acid in cell tissues that
disrupts cell function. Enzymes then collapse the cell nucleus and cell breakdown (necrosis) occurs.

Tissues rich in blood vessels (more dependent on oxygen and energy) are the first ones to suffer autolysis, whereas those poorly irrigated or deprived from blood vessels, like the ocular corneas, are not immediately affected by decomposition. Putrefaction (or breakdown by microorganisms) follows autolysis. With the exception of fetuses and newly born babies, the main source of these microorganisms in corpses is the right part of the large intestines. Microorganisms then invade the abdominal cavity, the chest, head, and limbs. The first visible signs of such activity are the greenish abdominal stains, accompanied by the initial odors of rotting flesh. The stains gradually expand to other parts of the body (thorax, head, and limbs) and change from light to dark green, then beginning to blacken. In people who have drowned, the greenish coloration starts on the face, progresses toward the thoracic area, and then to other parts, due to the position that drowned bodies assume in water, which facilitates putrefaction of the upper respiratory pathways first. In newly born infants, putrefaction agents (bacteria, fungi, etc.) invade the body through all cavities, especially through the respiratory pathways. The greenish stains appear in newly born babies first on the face, neck, and chest due to bacterial activity in the upper and lower respiratory pathways, and because their intestines are sterile. This phase of decomposition is known as the chromatic period.

Bacterial action destroys the structure of cells and soft tissues, releasing in the process body fluids in internal cavities such as chest, abdomen, and oral tract. Anaerobic microorganisms produce methane, hydrogen sulphide, and other gases responsible for the increasing stench that surrounds rotting organic matter. As gases accumulate inside the body, it starts to swell, forcing more fluids from organs to internal cavities and blood to the periphery of the body. This phase of decomposition is called the gaseous period.

Subcutaneous (under the skin) blisters containing a mixture of plasma, hemoglobin, and gases appear and a marbled-like pattern spreads through the skin. The outer layers of the skin (epidermis) begin to detach from inner layers of the skin (dermis) as the gaseous period progresses. The subsequent phase involves the process of liquid putrefaction, in which the soft tissues are gradually dissolved. The body loses its shape as tissue mass decreases and the separation of skin layers is completed. During this liquefaction period, gases are released and a putrefied creamy substance covers the skeleton. The next phase is known as skeletonization, with the environmental elements (e.g., larvae, worms, and sometimes insects) separating the skeleton from ligaments, which causes the detachment of the skull, the mandible, and long bones, with bones eventually collapsing apart. Bones become increasingly fragile and lighter over the years, and acidic soils eventually dissolve them.

Adipocere (a waxy substance formed after death by fatty tissues) formation is not a universal phenomenon during decomposition. It is more common in remains of
children, women, and overweight people, requiring both adipose (fatty) tissues and contact with humidity in the soil, or immersion in water, or the prevention of body water evaporation. Collective burial graves, where bodies are piled together, are also favorable to adipocere formation. Adipocere is very rare in remains of slim individuals because it results from the spontaneous chemical transformation of fatty tissues into a grayish-white waxy matter. Coroners have a special interest in adipocere because of its preservation properties of other tissues underneath. Adipocere-conserved body parts allow the performance of several forensic tests some months (and even years) after death. Examples are, the study of facial or neck lesions, toxicological tests, or the study of perforations caused by bullets.

Unborn fetuses that die between the sixth and the ninth months of pregnancy undergo a different process, known as maceration, due to prolonged exposure to the amniotic fluid. Fetal maceration external signs resemble in some ways those found in corpses immersed in water. However, the precise sequence of internal changes in fetal maceration is unique and offers three different well-defined phases or maceration degrees that allows the forensic determination of postmortem interval.

Questions to answer based on your reading (Email the answers to marty.sewell@yadkin.k12.nc.us. Be sure to include in the subject line: [Forensics-Chapter 5-Reading Assignment (your name)]

1) Describe the difference between autolysis and putrefaction.
2) It is said that a human body can decompose into skeletal remains in only a couple of weeks if the conditions are right. What would those conditions be and how do those conditions contribute to such rapid decay?
**Physical Properties of Matter:**
In looking at all the materials that our world is composed of, it would become an impossible task to estimate the number of different types of matter that exist. A much more logical approach would be to study the physical form that matter takes. These physical states of matter include solids, liquids and gases. **Solids** have a definite shape and volume while **liquids** can change shape based upon the container but retain the same volume regardless of the shape. **Gases** have neither a definite shape nor definite volume. Physical state may change depending upon environmental conditions.

Substances may change from one state to another. For example, as water is heated, it is converted from a liquid to a vapor at 100°C. Water will also change from a liquid to a solid at 0°C. Under certain conditions, a solid may be converted directly to a gaseous state without ever becoming a liquid. This process is called **sublimation**. Solid Carbon Dioxide (dry ice) will sublimate at room temperatures. In all of these examples, no new chemical compounds are formed, only the state of the matter is changed.

In forensics, it is crucial to be able to observe the state of matter that any substance or substances are in and if those states change over time. Whenever there is a visible boundary between substances, different phases are said to exist. For example, when oil is combined with water, the oil will float on the water and each can be distinguished from each other. This is said to be a two-phase system; the oil and water represent two distinct liquid phases. When sugar is combined with water, initially the sugar will not dissolve. This would also constitute a two-phase system; the solid sugar and the liquid water. On stirring the solution, the sugar dissolves and can no longer be distinguished from the water, therefore it becomes a one-phase system at that point.

**Selecting Analytical Techniques**
When trying to identify unknown chemical compounds, selecting the proper tools and techniques are crucial to the determination of the unknown. Several techniques will be discussed over the next few pages. You should familiarize yourself with each technique, how it is used, why it is used and under what conditions it is employed.

**Chromatography**
Most of us have got our papers wet at some time or another, but have you ever noticed what happens to the ink as the water spreads? It doesn't always smudge and blur, as you might expect. Sometimes it splits up into weird colored streaks that creep across the page. When that happens, you're seeing chromatography in action. In this case it's totally accidental, but we can also use it by design to split up mixtures and other substances into their components. Chromatography is actually one of the most useful analytical techniques chemists have at their disposal, helpful in everything from identifying biological materials to finding clues at crime scenes.

**Chromatography** is a pretty accurate description of what happens to ink on wet paper, because it literally means "color writing" (from the Greek words *chroma* and *graphe*). Really, though, it's a bit of a misnomer because it often doesn't involve color, paper, ink, or writing. Chromatography is actually a way of separating out a mixture of chemicals, which are in gas or liquid form, by letting them creep slowly past another substance, which is typically a liquid or solid. So, with the ink and paper trick for example, we have a liquid (the ink) dissolved in water...
or another solvent creeping over the surface of a solid (the paper).

The essential thing about chromatography is that we have some mixture in one state of matter (something like a gas or liquid) moving over the surface of something else in another state of matter (a liquid or solid) that stays where it is. The moving substance is called the mobile phase and the substance that stays put is the stationary phase. As the mobile phase moves, it separates out into its components on the stationary phase. We can then identify them one by one.

**How does chromatography work?**

Think of chromatography as a race and you'll find it's much simpler than it sounds. Waiting on the starting line, you've got a mixture of chemicals in some unidentified liquid or gas, just like a load of runners all mixed up and bunched together. When a race starts, runners soon spread out because they have different abilities. In exactly the same way, chemicals in something like a moving liquid mixture spread out because they travel at different speeds over a stationary solid. The key thing to remember is that chromatography is a surface effect.

As the liquid starts to move past the solid, some of its molecules (energetic things that are constantly moving about) are sucked toward the surface of the solid and stick there temporarily before being pulled back again into the liquid they came from. This exchange of molecules between the surface of the solid and the liquid is a kind of adhesive or gluing effect called adsorption (don't confuse it with absorption, where molecules of one substance are permanently trapped inside the body of another). Now remember that our liquid is actually a mixture of quite a few different liquids. Each one undergoes adsorption in a slightly different way and spends more or less time in either the solid or the liquid phase. One of the liquids might spend much longer in the solid phase than in the liquid, so it would travel more slowly over the solid; another one might spend less time in the solid and more in the liquid, so it would go a bit faster. Another way of looking at it is to think of the liquid as a mixture of glue-like liquids, some of which stick more to the solid (and travel more slowly) than others. This is what causes the different liquids within our original liquid mixture to spread out on the solid.

For chromatography to work effectively, we obviously need the components of the mobile phase to separate out as much as possible as they move past the stationary phase. That's why the stationary phase is often something with a large surface area, such as a sheet of filter paper, a solid made of finely divided particles, a liquid deposited on the surface of a solid, or some other highly adsorbent material.

**What are the different types of chromatography?**

There are many different ways of using chromatography. These are some of the best known:

**Paper chromatography:**

This is the "spot of ink on paper" experiment you often do in school (also the effect we described at the start when you get your papers wet). Typically you put a spot of ink near one edge of some filter paper and then hang the paper vertically with its lower edge (nearest the spot) dipped in a solvent such as alcohol or water. Capillary action makes the solvent travel up the paper, where it meets and dissolves the ink. The dissolved ink (the mobile phase) slowly travels up the paper (the stationary phase) and separates out into different components. Sometimes these are colored; sometimes you have to color them by adding other substances (called developers or developing fluids) that help you with identification.

**Column chromatography:**

Instead of paper, the stationary phase is a vertical glass jar (the column) packed with a highly adsorbent solid, such as crystals of silica or silica gel, or a solid coated with a liquid. The mobile phase is pumped at high pressure through the column and splits into its components, which are then removed and analyzed. In liquid-column chromatography, the mixture being studied is placed at one end of the column and an extra added substance called an eluant is poured in to help it travel through. Thin-film chromatography is a
variation of this technique in which the "column" is actually a film of glass, plastic, or metal coated with a very thin layer of adsorbent material

**Gas chromatography:**
So far we've considered chromatography of liquids travelling past solids, but one of the most widely used techniques is a type of column chromatography using gases as the mobile phase. Gas chromatography is a largely automated type of chemical analysis you can do with a sophisticated piece of laboratory equipment called, not surprisingly, a gas chromatograph machine.

**Photo:** Gas chromatography is largely automated, but it still takes a trained operator to work one of these machines.

First, a tiny sample of the mixture of substances being studied is placed in a syringe and injected into the machine. The components of the mixture are heated and instantly vaporize. Next, there is added a carrier (sometimes called the eluant), which is simply a neutral gas such as hydrogen or helium, designed to help the gases in the sample move through the column. In this case, the column is a thin glass or metal tube usually filled with a liquid that has a high boiling point (or sometimes a gel or an adsorbent solid). As the mixture travels through the column, it's adsorbed and separates out into its components. Each component emerges in turn from the end of the column and moves past an electronic detector (sometimes a mass spectrometer), which identifies it and prints a peak on a chart (see Fig 5.10 to the right). The final chart has a series of peaks that correspond to all the substances in the mixture. Gas chromatography is sometimes called vapor-phase chromatography (VPC) or gas-liquid partition chromatography (GLPC).

**Fig 5.10:** Each peak in the chart represents a different chemical compound. The peaks can be analyzed and identified.
**What is chromatography used for?**

Chromatography was developed in Russia in 1906 by an Italian-born botanist named Mikhail Tswett (sometimes spelled Tsvet; 1872–1919), who used it for studying plant pigments such as chlorophyll. During the 20th century, chemists found chromatography was a superb technique for studying and separating all kinds of complex mixtures. It's now widely used in forensic science (for identifying samples taken from crime scenes), in pollution monitoring (for identifying small concentrations of unknown pollutants in air and water samples), and for studying complex mixtures in such things as food, perfume, petrochemical, and pharmaceutical production. One of chromatography's big advantages is that it works with tiny samples and low concentrations (particularly helpful when it comes to such things as forensic science and drug or pollution testing).

**Electrophoresis**

The term ‘electrophoresis’ simply means the movement of analytes by an electric force. Electrophoresis is an analytical separation technique with some similarities to chromatography but with some major differences. Most current slab gel electrophoretic techniques use a gel matrix perfused by an aqueous phase of buffer salts. This aqueous phase is not a mobile phase except in the specialized case of capillary electrophoresis.

This gel-like matrix (usually agarose or polyacrylamide) stabilizes the process against solution turbulence. The primary purpose of the gel matrix is as a sieve that allows separations based on molecular size. Electrophoresis and chromatography share many characteristics. They are separation techniques used to separate complex mixtures, can be used qualitatively and quantitatively, use standards, can be used to collect bands/peaks of interest, and are relatively fast and effective methods.
On the other hand there are a number of significant differences that should be understood. These are listed in the table below.

<table>
<thead>
<tr>
<th>Electrophoresis</th>
<th>Chromatography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has a stationary gel but no mobile phase.</td>
<td>Has a stationary phase and a mobile phase.</td>
</tr>
<tr>
<td>Separation is achieved by molecular sieving (based on size and charge).</td>
<td>Separation is achieved by the relative affinity of analyte for the stationary and mobile phases (based on a number of different variables).</td>
</tr>
<tr>
<td>Movement of the sample is achieved under an electric current.</td>
<td>Movement of the sample is achieved by movement of the mobile phase.</td>
</tr>
<tr>
<td>Is a planar technique.</td>
<td>May be planar but usually column.</td>
</tr>
<tr>
<td>Sample volume usually about 25 µL but may be increased to mL volumes for preparative procedures.</td>
<td>Sample volume is usually in the µL range.</td>
</tr>
<tr>
<td>Visualization usually by staining of analyte bands.</td>
<td>Visualization via a detector that converts the signal to a chromatogram.</td>
</tr>
<tr>
<td>Generally used for proteins and nucleic acids.</td>
<td>Used for a wide range of analyte types.</td>
</tr>
<tr>
<td>Equipment is relatively simple.</td>
<td>Equipment may be simple (paper, TLC, simple columns) but is often complex and costly (HPLC, GC).</td>
</tr>
</tbody>
</table>

**Table 5.4.** Differences between the electrophoretic process and that of chromatography.

Electrophoresis separates species of interest by moving the sample mixture through a gel of material. The sample components are moved using an electric current and hence the sample components must be charged molecules or molecules that can readily have a charge added to them. As the molecules move through the gel they must negotiate a torturous route of small interstices (pores) through the gel. The smaller molecules move faster and hence migrate faster and the larger molecules move more slowly and hence migrate more slowly.

The electrophoresis apparatus is set up in such a way that the buffer bathing the top and bottom of the gel has a different pH (and sometimes ionic strength) to the buffer in the gel. This has the effect of concentrating like components into tight bands as they migrate down the gel in an analogous way to the banding of components in column chromatography to produce peaks.

There are many varieties of electrophoresis including gradient gel electrophoresis, disc electrophoresis, SDS electrophoresis, two-dimensional electrophoresis and isoelectric focusing.

Sodium dodecyl sulfate (SDS also called sodium lauryl sulfate) is a powerful detergent that is often used to solubilize samples prior to electrophoresis. There have been many agents used to produce the gels but the two in common use today are agarose and polyacrylamide.

Agarose is used for nucleic acid separations and polyacrylamide is used for proteins and DNA sequencing. Electrophoresis is generally used only for the separation of nucleic acids and proteins and can be used for such samples as tissue and cell extracts, serum proteins, membrane proteins and DNA restriction fragments. Intact DNA is a very large molecule and needs to be analyzed in relatively small fragments.
Figure 5.11 displays how an electrophoresis setup works. In forensics, DNA samples are constantly being analyzed. Restriction enzymes cut the DNA into small segments that can pass through the gel material more easily. Once an electric current has been applied to the gel for a certain length of time, a stain is often applied to the gel. The DNA fragments will then be more visible. Each sample loaded will produce a characteristic set of bands based upon the DNA that was tested. The banding pattern can then be compared to a known (possibly a suspect of a crime) and then identified.

**Fig. 5.11.** Gel electrophoresis using restriction enzymes.
Class Activity 5-1: Reading the Banding Pattern of Electrophoresis Gels
Consider the following scenario: Four suspects’ DNA is obtained and run through an electrophoresis apparatus. The following banding pattern was obtained:

The “Ladder” is a set of known DNA fragments that travel known distances in an electric field. “CS” is the DNA recovered from the Crime Scene.
The gel is read from top (where the samples were loaded) to the bottom (the farthest distance traveled by the DNA). Direct comparison can be made to the crime scene DNA. Answer the following questions based on the banding pattern on the previous page. **You will submit these answers in an email to Mr. Sewell along with some material in the next section.**

1. How many samples of DNA can you assume were placed in each separate well?

2. What would be a logical explanation as to why there is more than one band of DNA for each of the samples?

3. What caused the DNA to become fragmented?

4. Which sample has the smallest DNA fragment?

5. From the gel drawing, which DNA samples appear to have been “cut” into the same number and size of fragments?

6. Based on your analysis of the gel drawing, what is your conclusion about the DNA samples in the drawing? Do any of the samples seem to be from the same source? If so, which ones? Describe the evidence that supports your conclusion.
Quantitative Analysis of DNA Fragment Sizes

If you were on trial, would you want to rely on a technician’s eyeball estimate of a match, or would you want some more accurate measurement? In order to make the most accurate comparison between the crime scene DNA and the suspect DNA, other than just a visual match, a quantitative measurement of the fragment sizes needs to be completed. This is described below:

1. Using a ruler, measure the distance (in mm) that each of your DNA fragments or bands traveled from the well. Measure the distance from the bottom of the well to the center of each DNA band and record your numbers in the table below. The data in the table will be used to construct a standard curve and to estimate the sizes of the crime scene and suspect restriction fragments.

2. To make an accurate estimate of the fragment sizes for either the crime scene of suspect DNA samples, a standard curve is created using the distance (x-axis) and fragment size (y-axis) data from the known HindIII I lambda digest (the Ladder DNA marker). Using excel, graph the distances traveled by the Ladder DNA (x-axis) against the following known base pair values:

<table>
<thead>
<tr>
<th>Distance</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mm</td>
<td>23,130 bp</td>
</tr>
<tr>
<td>7.5 mm</td>
<td>9416 bp</td>
</tr>
<tr>
<td>10 mm</td>
<td>6577 bp</td>
</tr>
<tr>
<td>13 mm</td>
<td>4361 bp</td>
</tr>
<tr>
<td>19 mm</td>
<td>2322 bp</td>
</tr>
<tr>
<td>40 mm</td>
<td>2027 bp</td>
</tr>
</tbody>
</table>

3. On the graph, draw a line of best fit through the points. Extend the line all the way to the right-hand edge of the graph.

4. To estimate the size of an unknown crime scene or suspect fragment, find the distance that fragment traveled. Locate that distance on the x-axis of your standard graph. From that position on the x-axis, read up to the standard line, and then follow the graph line to over to the y-axis. You might want to draw a light pencil mark from the x-axis up to the standard curve and over to the y-axis showing what you’ve done. Where the graph line meets the y-axis, this is the approximate size of your unknown DNA fragment. Do this for all crime scene and suspect fragments.
5. Compare the fragment sizes of the suspects and the crime scene. Is there a suspect that matches the crime scene? How sure are you that this is a match? Calculate a % error for each band for your choice of the suspect that matches the crimes scene suing the following formula:

\[
\frac{\text{Suspect bp size} - \text{CS bp size}}{\text{CS bp size}}
\]

**Final Analysis:** Write a summary report of your findings and include:

- a) the graph of data on the previous page,
- b) your created graph with the line of best fit,
- c) calculated % error for the suspect of your choice,
- d) a summary explaining how all this information led you to believe that the particular suspect you chose is the same person as the crime scene.

Submit your summary report by email to: marty.sewell@yadkin.k12.nc.us. Don’t forget to put in the subject line: [Forensics-Chapter 5-Reading Gels Activity (your name)].
Reading Assignment #6: DNA and Forensics

How does forensic identification work?

Any type of organism can be identified by examination of DNA sequences unique to that species. Identifying individuals within a species is less precise at this time, although when DNA sequencing technologies progress farther, direct comparison of very large DNA segments, and possibly even whole genomes, will become feasible and practical and will allow precise individual identification.

To identify individuals, forensic scientists scan 13 DNA regions, or loci, that vary from person to person and use the data to create a DNA profile of that individual (sometimes called a DNA fingerprint). There is an extremely small chance that another person has the same DNA profile for a particular set of 13 regions.

Some Examples of DNA Uses for Forensic Identification

- Identify potential suspects whose DNA may match evidence left at crime scenes
- Exonerate persons wrongly accused of crimes
- Identify crime and catastrophe victims
- Establish paternity and other family relationships
- Identify endangered and protected species as an aid to wildlife officials (could be used for prosecuting poachers)
- Detect bacteria and other organisms that may pollute air, water, soil, and food
- Match organ donors with recipients in transplant programs
- Determine pedigree for seed or livestock breeds
- Authenticate consumables such as caviar and wine

Is DNA effective in identifying persons?

[answer provided by Daniel Drell of the U.S. DOE Human Genome Program]

DNA identification can be quite effective if used intelligently. Portions of the DNA sequence that vary the most among humans must be used; also, portions must be large enough to overcome the fact that human mating is not absolutely random.

Consider the scenario of a crime scene investigation . . .

Assume that type O blood is found at the crime scene. Type O occurs in about 45% of Americans. If investigators type only for ABO, finding that the "suspect" in a crime is type O really doesn't reveal very much.

If, in addition to being type O, the suspect is a blond, and blond hair is found at the crime scene, you now have two bits of evidence to suggest who really did it. However, there are a lot of Type O blonds out there.
If you find that the crime scene has footprints from a pair of Nike Air Jordans (with a distinctive tread design) and the suspect, in addition to being type O and blond, is also wearing Air Jordans with the same tread design, you are much closer to linking the suspect with the crime scene.

In this way, by accumulating bits of linking evidence in a chain, where each bit by itself isn't very strong but the set of all of them together is very strong, you can argue that your suspect really is the right person.

With DNA, the same kind of thinking is used; you can look for matches (based on sequence or on numbers of small repeating units of DNA sequence) at many different locations on the person's genome; one or two (even three) aren't enough to be confident that the suspect is the right one, but thirteen sites are used. A match at all thirteen is rare enough that you (or a prosecutor or a jury) can be very confident ("beyond a reasonable doubt") that the right person is accused.

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**How is DNA typing done?**

Only one-tenth of a single percent of DNA (about 3 million bases) differs from one person to the next. Scientists can use these variable regions to generate a DNA profile of an individual, using samples from blood, bone, hair, and other body tissues and products.

In criminal cases, this generally involves obtaining samples from crime-scene evidence and a suspect, extracting the DNA, and analyzing it for the presence of a set of specific DNA regions (markers).

Scientists find the markers in a DNA sample by designing small pieces of DNA (probes) that will each seek out and bind to a complementary DNA sequence in the sample. A series of probes bound to a DNA sample creates a distinctive pattern for an individual. Forensic scientists compare these DNA profiles to determine whether the suspect's sample matches the evidence sample. A marker by itself usually is not unique to an individual; if, however, two DNA samples are alike at four or five regions, odds are great that the samples are from the same person.

If the sample profiles don't match, the person did not contribute the DNA at the crime scene.

If the patterns match, the suspect may have contributed the evidence sample. While there is a chance that someone else has the same DNA profile for a particular probe set, the odds are exceedingly slim. The question is, How small do the odds have to be when conviction of the guilty or acquittal of the innocent lies in the balance? Many judges consider this a matter for a jury to take into consideration along with other evidence in the case. Experts point out that using DNA forensic technology is far superior to eyewitness accounts, where the odds for correct identification are about 50:50.

The more probes used in DNA analysis, the greater the odds for a unique pattern and against a coincidental match, but each additional probe adds greatly to the time and expense of testing. Four to six probes are recommended. Testing with several more probes will become routine, observed John Hicks (Alabama State Department of Forensic Services). He predicted that DNA
chip technology (in which thousands of short DNA sequences are embedded in a tiny chip) will enable much more rapid, inexpensive analyses using many more probes and raising the odds against coincidental matches.

What are some of the DNA technologies used in forensic investigations?

**Restriction Fragment Length Polymorphism (RFLP)**

RFLP is a technique for analyzing the variable lengths of DNA fragments that result from digesting a DNA sample with a special kind of enzyme. This enzyme, a restriction endonuclease, cuts DNA at a specific sequence pattern known as a restriction endonuclease recognition site. The presence or absence of certain recognition sites in a DNA sample generates variable lengths of DNA fragments, which are separated using gel electrophoresis. They are then hybridized with DNA probes that bind to a complementary DNA sequence in the sample.

RFLP was one of the first applications of DNA analysis to forensic investigation. With the development of newer, more efficient DNA-analysis techniques, RFLP is not used as much as it once was because it requires relatively large amounts of DNA. In addition, samples degraded by environmental factors, such as dirt or mold, do not work well with RFLP.

**PCR Analysis**

Polymerase chain reaction (PCR) is used to make millions of exact copies of DNA from a biological sample. DNA amplification with PCR allows DNA analysis on biological samples as small as a few skin cells. With RFLP, DNA samples would have to be about the size of a quarter. The ability of PCR to amplify such tiny quantities of DNA enables even highly degraded samples to be analyzed. Great care, however, must be taken to prevent contamination with other biological materials during the identifying, collecting, and preserving of a sample.

**STR Analysis**

Short tandem repeat (STR) technology is used to evaluate specific regions (loci) within nuclear DNA. Variability in STR regions can be used to distinguish one DNA profile from another. The Federal Bureau of Investigation (FBI) uses a standard set of 13 specific STR regions for CODIS. CODIS is a software program that operates local, state, and national databases of DNA profiles from convicted offenders, unsolved crime scene evidence, and missing persons. The odds that two individuals will have the same 13-loci DNA profile is about one in a billion.

**Mitochondrial DNA Analysis**

Mitochondrial DNA analysis (mtDNA) can be used to examine the DNA from samples that cannot be analyzed by RFLP or STR. Nuclear DNA must be extracted from samples for use in RFLP, PCR, and STR; however, mtDNA analysis uses DNA extracted from another cellular organelle called a mitochondrion. While older biological samples that lack nucleated cellular material, such as hair, bones, and teeth, cannot be analyzed with STR and RFLP, they can be analyzed with mtDNA. In the investigation of cases that have gone unsolved for many years, mtDNA is extremely valuable.

All mothers have the same mitochondrial DNA as their offspring. This is because the mitochondria of each new embryo comes from the mother’s egg cell. The father’s sperm
contributes only nuclear DNA. Comparing the mtDNA profile of unidentified remains with the profile of a potential maternal relative can be an important technique in missing-person investigations.

Y-Chromosome Analysis
The Y chromosome is passed directly from father to son, so analysis of genetic markers on the Y chromosome is especially useful for tracing relationships among males or for analyzing biological evidence involving multiple male contributors.

Some Interesting Uses of DNA Forensic Identification

- **Identifying September 11th Victims**
  Identifying the victims of the September 11, 2001, World Trade Center attack presented a unique forensic challenge because the number and identity of the victims were unknown and many victims were represented only by bone and tissue fragments. At the time of the attack, no systems were in place for rapidly identifying victims in disasters with more than 500 fatalities. The National Institutes of Justice assembled a panel of experts from the National Institutes of Health and other institutions to develop processes to identify victims using DNA collected at the site. Panel members produced forms and kits needed to enable the medical examiner's office to collect reference DNA from victims' previously stored medical specimens. These specimens were collected and entered into a database. The medical examiner's office also received about 20,000 pieces of human remains from the World Trade Center site, and a database of the victims' DNA profiles was created. New information technology infrastructure was developed for data transfer between the state police and medical examiner's office and to interconnect the databases and analytical tools used by panel members. In 2005 the search was declared at an end because many of the unidentified remains were too small or too damaged to be identified by the DNA extraction methods available at that time. Remains of only 1585, of the 2792 people known to have died had been identified. In 2007, the medical examiner's office reopened the search after the Bode Technology Group developed a new methodology of DNA extraction that required much less sample material than previously necessary. The victim DNA database and the new methods have allowed more victims to be identified, and further identifications will be possible as forensic DNA technology improves.

- **The DNA Shoah Project**
  The DNA Shoah Project is a genetic database of people who lost family during the Holocaust. The database will serve to reunite families separated during wartime and aid in identifying victims who remain buried anonymously throughout Europe.

- **Disappeared Children in Argentina**
  Numerous people (known as "the Disappeared") were kidnapped and murdered in Argentina in the 1970s. Many were pregnant. Their children were taken at birth and, along with other kidnapped children, were raised by their kidnappers. The grandparents of these children have been looking for them for many years.

- **Son of Louis XVI and Marie Antionette**
  PARIS, Apr 19, 2000 (Reuters) -- Scientists cracked one of the great mysteries of European history by using DNA tests to prove that the son of executed French King Louis XVI and Marie-Antoinette died in prison as a child. Royalists have argued for 205 years over whether Louis-Charles de France perished in 1795 in a grim Paris prison or managed
to escape the clutches of the French Revolution. In December 1999, the presumed heart of the child king was removed from its resting place to enable scientists to compare its DNA makeup with samples from living and dead members of the royal family -- including a lock of his mother Marie-Antoinette's hair.

- **Peruvian Ice Maiden**
  The Ice Maiden was a 12-to-14-year old girl sacrificed by Inca priests 500 years ago to satisfy the mountain gods of the Inca people. She was discovered in 1995 by climbers on Mt. Ampato in the Peruvian Andes. She is perhaps the best preserved mummy found in the Andes because she was in a frozen state. Analysis of the Ice Maiden's DNA offers a wonderful opportunity for understanding her genetic origin. If we could extract mitochondrial DNA from the Ice Maiden's tissue and successfully amplify and sequence it, then we could begin to trace her maternal line of descent and possibly locate past and current relatives.

- **African Lemba Tribesmen**
  In southern Africa, a people known as the Lemba heed the call of the shofar. They have believed for generations that they are Jews, direct descendants of the biblical patriarchs Abraham, Isaac, and Jacob. However unlikely the Lemba's claims may seem, modern science is finding ways to test them. The ever-growing understanding of human genetics is revealing connections between peoples that have never been seen before.

- **Super Bowl XXXIV Footballs and 2000 Summer Olympic Souvenirs**
  The NFL used DNA technology to tag all the Super Bowl XXXIV balls, ensuring their authenticity for years to come and helping to combat the growing epidemic of sports memorabilia fraud. The footballs were marked with an invisible, yet permanent, strand of synthetic DNA. The DNA strand is unique and is verifiable any time in the future using a specially calibrated laser.

A section of human genetic code taken from several unnamed Australian athletes was added to ink used to mark all official goods — everything from caps to socks — from the 2000 Summer Olympic Games. The technology is used as a way to mark artwork or one-of-a-kind sports souvenirs.

- **Migration Patterns**
  Evolutionarily stable mitochondrial DNA and Y chromosomes have allowed bioanthropologists to begin to trace human migration patterns around the world and identify family lineage.

- **Angiosperm Witness for the Prosecution**
  The first case in which a murderer was convicted on plant DNA evidence was described in the PBS TV series, "Scientific American Frontiers." A young woman was murdered in Phoenix, Arizona, and a pager found at the scene of the crime led the police to a prime suspect. He admitted picking up the victim but claimed she had robbed him of his wallet and pager. The forensic squad examined the suspect's pickup truck and collected pods later identified as the fruits of the palo verde tree (*Cercidium spp.*). One detective went back to the murder scene and found several Palo Verde trees, one of which showed damage that could have been caused by a vehicle. The detective's superior officer innocently suggested the possibility of linking the fruits and the tree by using DNA comparison, not realizing that this had never been done before. Several researchers were contacted before a geneticist at the University of Arizona in Tucson agreed to take on the case. Of course, it was crucial to establish evidence that would stand up in court on whether individual plants (especially Palo Verde trees) have unique patterns of DNA. A preliminary study on samples from different trees at the murder scene and elsewhere
quickly established that each Palo Verde tree is unique in its DNA pattern. It was then a simple matter to link the pods from the suspect's truck to the damaged tree at the murder scene and obtain a conviction.

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### DNA Forensics Databases

**National DNA Databank: CODIS**

The COmbined DNA Index System, CODIS, blends computer and DNA technologies into a tool for fighting violent crime. The current version of CODIS uses two indexes to generate investigative leads in crimes where biological evidence is recovered from the crime scene. The Convicted Offender Index contains DNA profiles of individuals convicted of felony sex offenses (and other violent crimes). The Forensic Index contains DNA profiles developed from crime scene evidence. All DNA profiles stored in CODIS are generated using STR (short tandem repeat) analysis.

CODIS utilizes computer software to automatically search its two indexes for matching DNA profiles. Law enforcement agencies at federal, state, and local levels take DNA from biological evidence (e.g., blood and saliva) gathered in crimes that have no suspect and compare it to the DNA in the profiles stored in the CODIS systems. If a match is made between a sample and a stored profile, CODIS can identify the perpetrator.

This technology is authorized by the DNA Identification Act of 1994. All 50 states have laws requiring that DNA profiles of certain offenders be sent to CODIS. As of August 2007, the database contained over 5 million DNA profiles in its Convicted Offender Index and about 188,000 DNA profiles collected from crime scenes but not connected to a particular offender. (source [http://www.fbi.gov/hq/lab/codis/clickmap.htm](http://www.fbi.gov/hq/lab/codis/clickmap.htm)).

As more offender DNA samples are collected and law enforcement officers become better trained and equipped to collect DNA samples at crime scenes, the backlog of samples awaiting testing throughout the criminal justice system is increasing dramatically. In March 2003 President Bush proposed $1 billion in funding over 5 years to reduce the DNA testing backlog, build crime lab capacity, stimulate research and development, support training, protect the innocent, and identify missing persons. For more information, see the U.S. Department of Justice's Advancing Justice Through DNA Technology.

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### Ethical, Legal, and Social Concerns about DNA Databanking

The primary concern is privacy. DNA profiles are different from fingerprints, which are useful only for identification. DNA can provide insights into many intimate aspects of people and their families including susceptibility to particular diseases, legitimacy of birth, and perhaps predispositions to certain behaviors and sexual orientation. This information increases the potential for genetic discrimination by government, insurers, employers, schools, banks, and others.
Collected samples are stored, and many state laws do not require the destruction of a DNA record or sample after a conviction has been overturned. So there is a chance that a person's entire genome may be available—regardless of whether they were convicted or not. Although the DNA used is considered "junk DNA", single tandem repeated DNA bases (STRs), which are not known to code for proteins, in the future this information may be found to reveal personal information such as susceptibilities to disease and certain behaviors.

Practicality is a concern for DNA sampling and storage. An enormous backlog of over half a million DNA samples waits to be entered into the CODIS system. The statute of limitations has expired in many cases in which the evidence would have been useful for conviction.

Who is chosen for sampling also is a concern. In the United Kingdom, for example, all suspects can be forced to provide a DNA sample. Likewise, all arrestees--regardless of the degree of the charge and the possibility that they may not be convicted--can be compelled to comply. This empowers police officers, rather than judges and juries, to provide the state with intimate evidence that could lead to "investigative arrests."

In the United States each state legislature independently decides whether DNA can be sampled from arrestees or convicts. In 2006, the New Mexico state legislature passed Katie's Bill, a law that requires the police to take DNA samples from suspects in most felony arrests. Previous New Mexico laws required DNA to be sampled only from convicted felons. The bill is named for Katie Sepich, whose 2003 murder went unsolved until her killer's DNA entered the database in 2005 when he was convicted of another felony. Her killer had been arrested, but not convicted, for burglary prior to 2005.

Opponents of the law assert that it infringes on the privacy and rights of the innocent. While Katie's Law does allow cleared suspects to petition to have their DNA samples purged from the state database, the purging happens only after the arrest. Civil liberties advocates say that Katie's Bill still raises the question of Fourth Amendment violations against unreasonable search and seizure and stress that the law could be abused to justify arrests made on less than probable cause just to obtain DNA evidence.

As of September 2007, all 50 states have laws that require convicted sex offenders to submit DNA, 44 states have laws that require convicted felons to submit DNA, 9 states require DNA samples from those convicted of certain misdemeanors, and 11 states—including Alaska, Arizona, California, Kansas, Louisiana, Minnesota, New Mexico, North Dakota, Tennessee, Texas, and Virginia—have laws authorizing arrestee DNA sampling.

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**Potential Advantages and Disadvantages of Banking Arrestee DNA**

**Advantages**

1) Major crimes often involve people who also have committed other offenses. Having DNA banked potentially could make it easier to identify suspects, just as fingerprint databases do.
2) Innocent people currently are incarcerated for crimes they did not commit; if DNA samples had been taken at the time of arrest, these individuals could have been proven innocent and thereby avoided incarceration.

3) Banking arrestees' DNA instead of banking only that of convicted criminals could result in financial savings in investigation, prosecution, and incarceration.

Disadvantages

- Arrestees often are found innocent of crimes. The retention of innocent people's DNA raises significant ethical and social issues.
- If people's DNA is in police databases, they might be identified as matches or partial matches to DNA found at crime scenes. This occurs even with innocent people, for instance, if an individual had been at a crime scene earlier or had a similar DNA profile to the actual criminal.
- Sensitive genetic information, such as family relationships and disease susceptibility, can be obtained from DNA samples. Police, forensic science services, and researchers using the database have access to people's DNA without their consent. This can be seen as an intrusion of personal privacy and a violation of civil liberties.
- Studies of the United Kingdom's criminal database, which retains the DNA samples of all suspects, show that ethnic minorities are over represented in the population of arrestees and are, therefore, overrepresented in the criminal DNA database. This raises the concern of an institutionalized ethnic bias in the criminal justice system.
- Even the most secure database has a chance of being compromised.

RA #6: Questions based upon your reading
(email responses to Mr. Sewell; marty.sewell@vadkin.k12.nc.us. Don’t forget to format the subject line correctly. [Class – Assignment – name])

1. What potential ethical problems might arise if everyone in the US was databased by their DNA?
2. Discuss your opinion to the statement, “Banking DNA of arrestees is an invasion of privacy and a violation of personal privacy.” (Answer must be at least 150 words or more.)
3. Should your DNA be patented so that it could not be used without compensation? Why or why not?
Spectrophotometry

The physical characteristics of many compounds aside from their mass, crystalline structure and other features may include an ability to absorb light of specific wavelengths. Measurements of how light, from the ultraviolet to the infrared, is absorbed by samples can be accomplished using instruments known as spectrophotometers. These instruments are used for important measurements everyday in laboratories throughout the world.

Wavelengths of Light

The visible spectrum of light, which is the part of the electromagnetic spectrum that the human eye can perceive as light of specific colors, ranges from the violet to the red. Many schoolchildren learn the visible spectrum using the memory aid “ROY G. BIV”. This translates to red, orange, yellow, green, blue, indigo and violet. The wavelengths of the light that are perceived as these specific colors runs from roughly 620 to 700 nanometers (nm) for red, down to roughly 380 to 450 nm for violet. Beyond red is what is known as infrared (wavelength greater than 750 nm) and below violet is the ultraviolet (wavelengths shorter than approximately 350 nm).

Absorption of Specific Wavelengths of Light

Almost every material in existence absorbs light of one wavelength or another. Apple juice is golden in color because it absorbs light of specific wavelengths and lets other wavelengths of light pass through without affecting them. Many specimens in the laboratory have the same behavior; they will absorb light of one wavelength and not absorb light of a different wavelength. The absorption of specific wavelengths of light can be measured using a spectrophotometer. These instruments can be used to detect proteins, enzymatic reactions, nucleic acids and a host of other materials.

How Does a Spectrophotometer Work?

Probably the most commonly used laboratory spectrophotometer is what is known as a UV-Visible spectrophotometer (see Figure 5-12 on next page). In this device, light sources, such as mercury or xenon lamps for generating the ultraviolet portion of the spectrum, along with tungsten lamps or even light emitting diodes (LEDs) for the visible portion of the spectrum, shine their light on a monochromator, a device that will allow only light of a certain wavelength to pass through at any one time. This light is passed through a sample chamber and the specific sample, and the amount of light that still passes through is measured electronically by a photodetector. Electronic controllers allow the entire UV and visible spectra to be processed and an absorption spectrum is generated.
Any colored solution will have an absorption spectrum. Many assays used in biochemical laboratories use compounds that, when acted upon by specific other molecules, change colors. Thus by using a spectrophotometer to measure the change in the amount of a specific color produced, an estimate of the extent of the reaction can be made. These so-called “colorimetric assays” are used for a great number of different purposes ranging from estimating the activity of an enzyme to detecting the amounts of a specific antibody that is present, or even how much sugar is in a solution. But the absorption of light in the ultraviolet spectrum is an important tool in the biochemistry lab also, even though the human eye cannot see it. Why, because all nucleic acids and nearly all proteins absorb light in the ultraviolet spectrum.

**UV Light, Proteins and Nucleic Acids**

Just because a solution of a biological macromolecule does not have any visible coloration does not mean that it does not absorb light. The ultraviolet portion of the electromagnetic spectrum is used everyday to measure solutions of purified proteins or nucleic acids.

Proteins are polymers of chemically joined amino acids and three of the regularly found amino acids, phenylalanine, tryptophan, and tyrosine are different from all other amino acids, because they contain side chains with what are known as aromatic rings. These ring structures are able to absorb light in the ultraviolet (UV) spectrum, most strongly around 280 nm.

Nucleic acids are polymers built up from what are known as nucleotides, the sugar-phosphate-nitrogenous base building blocks of both DNA and RNA. All of the “bases” of DNA and RNA also absorb UV light, only, as opposed to aromatic amino acids, they absorb in the wavelengths around 260 nm.

This feature of proteins and nucleic acids is used everyday to measure solutions of proteins and of nucleic acids. And by comparing the relative amounts of absorption at both 260 nm and 280 nm, an estimate of the purity of the solution can be made.
Mass Spectrometry

A mass spectrometer is an instrument that measures the masses of individual molecules that have been converted into ions, i.e., molecules that have been electrically charged. Since molecules are so small, it is not convenient to measure their masses in kilograms, or grams, or pounds. In fact, the mass of a single hydrogen atom is approximately $1.66 \times 10^{-24}$ grams. We therefore need a more convenient unit for the mass of individual molecules. This unit of mass is often referred to by chemists and biochemists as the dalton (Da for short), and is defined as follows: $1 \text{Da} = (1/12)$ of the mass of a single atom of the isotope of carbon-12($^{12}\text{C}$). This follows the accepted convention of defining the $^{12}\text{C}$ isotope as having exactly 12 mass units.

As will become clear in what follows, a mass spectrometer does not actually measure the molecular mass directly, but rather the mass-to-charge ratio of the ions formed from the molecules. For reasons similar to those discussed in the context of mass, it is inconvenient to measure the charge on an individual ion in units appropriate to the macroscopic everyday world. A useful unit for this purpose is the fundamental unit of charge, the magnitude of the charge on an electron. It follows that the charge on an ion is denoted by the integer number $z$ of the fundamental unit of charge, and the mass-to-charge ratio $m/z$ therefore represents daltons per fundamental unit of charge. In many cases, the ions encountered in mass spectrometry have just one charge (z=1) so the m/z value is numerically equal to the molecular (ionic) mass in Da. Mass spectrometrists often speak loosely of the "mass of an ion" when they really mean the m/z ratio, but this convenient way of speaking is useful only for the case of singly-charged ions.

An actual mass spectrometer ranges in size from about the size of a home microwave oven to large research instruments that dominate entire rooms. The different functional units of a mass spectrometer are represented conceptually in the image below (Figure 5.13).

Form Fig 5.13. The basic components of a mass spectrometer.

Formation of gas phase samples ions is an essential prerequisite to the mass sorting and detection processes that occur in a mass spectrometer. Early mass spectrometers required a sample to be a gas, but due to modern developments described below, the applicability of mass spectrometry has been extended to include samples in liquid solutions or embedded in a solid matrix. The sample, which may be a solid, liquid, or vapor, enters the vacuum chamber through an inlet. Depending on the type of inlet and ionization
techniques used, the sample may already exist as ions in solution, or it may be ionized in conjunction with its volatilization or by other methods in the ion source.

The gas phase ions are sorted in the mass analyzer according to their mass-to-charge (m/z) ratios and then collected by a detector. In the detector the ion flux is converted to a proportional electrical current. The data system records the magnitude of these electrical signals as a function of m/z and converts this information into a mass spectrum. Below you can see the mass spectrum for cocaine. No other compound has this particular chemical signature.

![Mass Spectrum of Cocaine](Fig 5.14. Mass Spectrum of cocaine.)
Chapter 5 Review Questions:
Use the notes in the chapter or any other source you want to answer the following questions.

1) Anything that has mass and occupies space is defined as ____________________________.
2) The basic building blocks of all substances are the ____________________________.
3) The number of elements known today is ____________________________.
4) The arrangement of elements by similar chemical properties is accomplished in the ________________ table.
5) An ________________________ is the smallest particle of an element that can exist.
6) Substances composed of two or more elements are called ____________________________.
7) A ________________ is the smallest unit of a compound formed by the union of two or more atoms.
8) The physical state that retains a definite shape and volume is a ____________________________.
9) A gas has no definite __________________________ or ____________________________.
10) During the process of ____________________________ solids will evaporate directly to the gaseous state.
11) Carbon containing substances are classified as ____________________________.
12) ____________________________ substances encompass all non-carbon containing materials.
13) The study of absorption of light by substances is called ____________________________.
14) The separation of a mixture’s components can be accomplished utilizing the technique of ____________________________.
15) In performing paper chromatography ____________________________ action makes the solvent travel up the paper.
16) In gas chromatography, what is another name for the carrier gas? ____________________________.
17) The term ____________________________ simply means the movement of analytes by an electric force.
18) The primary purpose of the gel matrix is as a ____________________________ that allows separations based on ____________________________ size.
19) Gel electrophoresis is generally used for ____________________________ and ____________________________.
20) ___________________________ cut the DNA into small segments that can pass through the gel material more easily.

21) The study of how light, from the ultraviolet to the infrared, is absorbed by samples is called ____________________________.

22) The visible spectrum of light is called ____________________________, which stands for which colors?
   
   a. 
   b. 
   c. 
   d. 
   e. 
   f. 
   g. 

23) Beyond red is what is known as ____________________________ (wavelength greater than 750 nm) and below violet is the ____________________________ (wavelengths shorter than approximately 350 nm).

24) Probably the most commonly used laboratory spectrophotometer is what is known as a ____________________________.

25) A ____________________________ is an instrument that measures the masses of individual molecules that have been converted into ions.

26) The unit of mass that a chemist would use to describe the mass of single molecules is the ____________________________.
Chapter 6: Inorganic Analysis

In chapter 5, we discussed organic analysis; the study of material that usually contain the element carbon. However, carbon (chemical symbol C) only comprises less than 0.1% of the earth’s crustal material. Since Carbon is found in such small quantities, it is reasonable to assume that you might find inorganic substances (those that do not contain carbon) at crime scenes. Some common inorganic components that are prevalent in today’s society include Iron (Fe), Aluminum (Al), Nickel (Ni), Copper (Cu), and Steel (a combination of iron and carbon). Inorganics are found as pigments in paints and dyes, in explosives, and are prevalent in poisons such as mercury, lead and arsenic. For the criminalist, the presence of these trace elements is particularly useful, because they provide “invisible” markers that may establish the source of a material or at least provide additional points for comparison. In each case, the forensic scientist must perform tests that will ultimately determine the specific chemical identity of the suspect material to the exclusion of all others.

Six techniques available to forensic scientists for determining the elemental composition of materials are:

– Emission spectroscopy
– Inductively coupled plasma
– Atomic absorption spectrophotometry
– Neutron activation analysis
– X-ray diffraction
– X-ray analyzer

Each of these will be discussed in the following pages.
Reading Assignment #7

Kennedy Assassination

On November 22, 1963, John F. Kennedy, the thirty-fifth president of the United States, was shot and killed while riding in the back seat of a limousine in a motorcade passing through Dealey Plaza in Dallas, Texas. The shooting occurred at 12:30 p.m. Central Standard Time, just after the president's limousine made a 120-degree left-hand turn off of Houston Street onto Elm Street in front of the Texas Schoolbook Depository. Also injured was Texas governor John B. Connally, who was riding in the limousine's front seat directly in front of the president.

The shooting took place over a period of six to nine seconds. Only after the driver of the limousine, Secret Service agent Bill Greer, turned and saw what proved to be the fatal wound to the president's head did he speed up to exit the plaza and head to Parkland Memorial Hospital, where the president was pronounced dead in Trauma Room #1 at 1:00 p.m. Just an hour later, after a fifteen-minute argument involving Secret Service agents who were cursing and brandishing their weapons, the agents removed the president's body, in violation of state law because no forensic examination had been conducted. They took the body to Love Field, where it was placed on Air Force One, the president's plane, and flown to Washington, D.C. There, an autopsy was conducted at the Bethesda Naval Hospital.

Eighty minutes after the assassination, Lee Harvey Oswald, an employee at the Texas Schoolbook Depository, was arrested for shooting a police officer. That evening he was charged with the murder of the president, but he was never tried for the crime because just two days later, while in police custody, Oswald was shot and killed by Jack Ruby. On November 29, a week after the assassination, President Lyndon B. Johnson formed a commission headed by Earl Warren, chief justice of the U.S. Supreme Court, to investigate the assassination. In September 1964, the Warren Commission issued its report, concluding that Lee Harvey Oswald, acting alone, was the assassin. The commission further concluded that Oswald fired three shots from a window on the sixth floor of the book depository, where three shell casings and the rifle were found; that one shot likely missed the motorcade; that the first shot to hit Kennedy likely hit him in the upper back and exited near the front of his neck, then caused Governor Connally's injuries; and that the second shot to hit the president struck him in the head. All three shots, the commission concluded, came from the same location, above and behind the president.

In the decades following the assassination, the forensic evidence was examined and reexamined by numerous experts, many of whom disputed the Warren Commission findings. They raised troubling questions, many of them focusing on the "grassy knoll," a small sloping hill in front of and slightly to the right (west and north) of the president. Numerous witnesses claim to have heard at least one shot come from the grassy knoll, and photographs taken by people in Dealey Plaza that day give some credence to the claim that another gunman was positioned behind a picket fence on the knoll. These claims appear to have been substantiated by the report of the 1976–79 House Select Committee on Assassinations (HSCA), which relied on acoustical evidence to conclude that indeed a shot came from the grassy knoll, that Oswald

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did not act alone, and that he was likely part of a larger conspiracy, although the reach and extent of that conspiracy remain the subject of passionate debate.

A major focus for forensic examiners was the number, sequence, timing, and direction of the fatal shots. Connally sustained his injuries virtually simultaneously with Kennedy having been struck in the neck, raising the question of whether one or two bullets, and hence one or two shooters, caused the injuries to the two men. Standing at the center of the Warren Commission's conclusion that Oswald was the lone gunman is the so-called single bullet theory, a theory generally credited to commission member Arlen Specter, later a U.S. Senator. According to the commission, a single 6.5 mm Western Cartridge Company bullet, Warren Commission Exhibit 399, caused all of the nonfatal wounds both to Kennedy and, an instant later, to Connally. The single bullet theory was crucial to the commission's conclusion because it precluded the existence of another shooter. Oswald was using a bolt-action rifle, so it would have been impossible for him to fire two shots virtually simultaneously. Two bullets would have meant two gunmen.

The bullet in question was found in Parkland Hospital Trauma Room #2 on a stretcher on which Governor Connally had lain, although even this detail has been disputed. The path the bullet followed was complex, leading critics of the Warren Commission to refer to it not as the single bullet, but as the magic bullet. The commission concluded that it traveled downward at a net angle of 25 degrees and entered the president's back 2 inches (50 mm) to the right of his spine and 5.75 inches (146 mm) below his collar line, leaving a small (4x7 mm) reddish-brown to black abrasion on his collar that suggested that the bullet was traveling slightly upward when it entered his body. It then slightly fractured the sixth cervical vertebra; passed through his neck, shedding fragments; passed through his throat; and exited his body at the bottom edge of the Adam's apple. The bullet then continued on its course, entering Connally's back just below and behind his right armpit. It destroyed a portion of his right fifth rib, exited his body below his right nipple, then entered the outside of his right wrist, possibly striking his cufflink, which was never recovered. It broke his right radius wrist bone, leaving behind metal fragments, then exited the inner side of the wrist, entered the front side of his left thigh, and buried itself 2 inches (50 mm) in his thigh muscle, leaving behind a tiny (1.5–2 mm) fragment in his thigh bone. This bullet, which had passed through several layers of clothing and flesh and struck two bones, was found in nearly pristine condition, having lost only about 1.5 percent of its weight, after having apparently backed itself out of Connally's thigh.

In ballistics tests conducted with the same type of bullet, the only bullet that survived in a condition similar to the bullet in evidence was one fired into a tube of cotton. These tests, combined with the zigzagging course that the bullet would have had to follow, have led some forensics experts to dispute the single bullet theory, though many others note that a bullet can behave in strange ways when it hits its target and rapidly decelerates. Further, some forensic pathologists assert that the official medical record, both at Parkland and at Bethesda, is a record of inconsistencies, in large part because it was based on testimony not from forensic pathologists with experience examining gunshot wounds, but by emergency room physicians at Parkland and general pathologists at Bethesda. They note, for example, that at least three times the emergency room doctors referred to the wound in Kennedy's neck as an entrance wound rather than an exit wound. Numerous other details have been scrutinized, such as the path the bullet followed from Kennedy's back to his throat. Following this path, the bullet would have had to hit the president's spine, severely deforming the bullet. They note too that it was traveling upward when it exited the president's throat, but then downward when it entered Connally's
Further, they note inconsistencies in testimony about where the bullet entered the
president's back.

Forensic pathologists have also focused on the second, fatal bullet to the president's head.
Their primary purpose was to determine the direction of the bullet and the angle at which it
entered the president's head. Normally, a forensic pathologist relies on the beveling of bone,
similar to the appearance of glass when a BB has passed through it, to confirm the direction of
a bullet when it passes through bone. During the president's autopsy, pathologists had to
reconstruct skull fragments, at least one of which is missing, to show that the beveling of the
bone establishes that the bullet entered from above and behind, consistent with the conclusion
at which the Warren Commission ultimately arrived.

One difficulty that forensics experts faced was reconciling this conclusion with the movement of
the president's head and body captured on the so-called Zapruder film, a 26.6-second, 486-
frame, 8 mm film shot by amateur cameraman Abraham Zapruder from Elm Street as the shots
were fired. A frame-by-frame analysis of the Zapruder film suggests that when the president
was struck by the first bullet, he was sitting in a position inconsistent with the bullet's supposed
angle of entry (he would have had to have been leaning forward, but the film shows him sitting
bolt upright). More significantly, the film suggests that when the second bullet hit him, the
president was forced backward in a way more consistent with a shot from in front, not above
and behind. Specifically, they note that when the bullet struck, the president's head moved
slightly, about 1–2 inches (25–50 mm) forward and down. Then, as the wound in his head
opened, his right shoulder twisted forward and up. Kennedy's torso then lurched quickly
backward and to his left. He then bounced off the rear seat cushion and slumped lifelessly. If
the autopsy findings and the Zapruder film are indeed inconsistent, this inconsistency raises for
some the possibility that the source of the bullet was not Oswald's rifle on the sixth floor of the
book depository, but elsewhere. For others, such an inconsistency represents unanswerable
questions that may have arisen because of acceleration and deceleration of the limousine.

A sizable majority of Americans accept the crux of the Warren Commission's findings and
regard inconsistencies as inevitable human error. Debate about these and other details suggest
the monumental difficulty of establishing a clear, accurate, consistent forensic record of a crime
that took place in front of hundreds of witnesses.

RA #7: Reading Comprehension:

Create a table that compares and contrasts the theories of Kennedy’s assassination and
discusses the evidences supports each.

Email your table to Mr. Sewell
Emission Spectroscopy

An emission spectrum is the type of light a particular substance emits. Every element gives off a unique fingerprint of light. Analyzing the frequencies of this light helps identify the chemical that generated it. This process is called emission spectroscopy and is a very useful scientific tool. A prism that splits light into its different colors is a basic form of a spectrometer, the instrument of spectroscopy. Every element has a particular line spectrum, which can lead to the identity of an unknown substance.

The emitting substance in an emission spectrum can be a pure element, such as iron. It also could be a chemical compound such as water. Atoms and molecules tend to transition between higher and lower energy states. In an atom this might mean that an electron jumps from a higher orbit to a level closer to the nucleus of the atom. This would lower its energy state. In a molecule there can be changes in rotational or vibrational energy. In general, the higher the energy state, the more capable an atom or molecule is of emitting light.

![Emission Spectra](image)

**Fig 6.1.** Emission Spectra for various elements.

Each line in the spectral analysis above represents a separate wavelength of light emitted from gasses that were “excited” by heating. This becomes useful in forensics to determine if two chemicals are the same or if they are different. Direct line-for-line comparison can be made to identify or eliminate a suspected substance.
Consider the scenario below. Paint was analyzed from a victim in a hit-and-run murder case. Paint from the suspect’s car was also compared to the paint from the victim. The results are pictured below:

![Spectral analysis of two paint samples in a murder investigation using the Fourier Transform IR Spectrometer (FT-IR).](image)

This device subjects a sample to infrared light, which in turn produces various wavelengths of light that are recorded and graphed.

**What do you think? Is the paint from the car (prybar) the same paint found on the victim at the crime scene?**
Inductively Coupled Plasma (ICP)

Inductively Coupled Plasma (ICP) is an analytical technique used for the detection of trace metals in environmental samples. The primary goal of ICP is to get elements to emit characteristic wavelength specific light which can then be measured. The technology for the ICP method was first employed in the early 1960's with the intention of improving upon crystal growing techniques.

ICP hardware is designed to generate plasma, which is a gas in which atoms are present in an ionized state. The basic set up of an ICP consists of three concentric tubes, most often made of silica. These tubes, termed outer loop, intermediate loop, and inner loop, collectively make up the torch of the ICP. The torch is situated within a water-cooled coil of a radio frequency (r.f.) generator. As flowing gases are introduced into the torch, the r.f field is activated and the gas in the coil region is made electrically conductive. This sequence of events forms the plasma.

The ICP-MS (mass spectrometry) employs an inductively coupled argon plasma as an ionization source and a mass spectrometer to separate and measure analyte ions formed in the ICP source. Normally, the sample is taken into solution and pumped into a nebulizer, which generates a sample aerosol. The sample aerosol passes into the ICP, where it is desolvated, atomized and ionized. The resulting sample ions are then transferred from the plasma at atmospheric pressure, to the mass spectrometer that is situated inside a vacuum chamber, via a differentially pumped interface. The ions pass through two orifices in the interface, known as sampling and skimmer cones, and are focused into a quadrupole mass analyzer. The analyzer separates the ions based on their mass/charge ratio prior to measurement by an electron multiplier detection system. Each elemental isotope appears at a different mass with a peak intensity directly proportional to the initial concentration of that isotope in the sample; thus elemental concentrations in the sample can be measured.

Fig 6-3. Schematic of an ICP-MS.
Where ICP has made an impact in forensics has been in identification and characterization of mutilated bullets and glass fragments. Often, mutilated bullets may not be suitable for traditional microscopic examination against examples fired from a test firearm. In cases where the bullet cannot be directly compared, ICP analyzes the chemical makeup of the bullet and can then be compared to a bullet found at the suspect’s home or within their possession.

Below is a typical ICP analysis graph. In this analysis, surface waters were analyzed for trace metals. Four different sites were tested (A, B, C, DL).

**Atomic Absorption Spectrophotometry**

Atomic absorption methods measure the amount of energy (in the form of photons of light, and thus a change in the wavelength) absorbed by the sample. Specifically, a detector measures the wavelengths of light transmitted by the sample (the "after" wavelengths), and compares them to the wavelengths, which originally passed through the sample (the "before" wavelengths). A signal processor then integrates the changes in wavelength, which appear in the readout as peaks of energy absorption at discrete wavelengths.

Any atom has its own distinct pattern of wavelengths at which it will absorb energy, due to the unique configuration of electrons in its outer shell. This allows for the qualitative analysis of a pure sample.

In atomic Absorption (AA), the specimen is heated to a temperature that is hot enough to vaporize its atoms while leaving a substantial number of atoms in an unexcited state. Normally, the specimen is inserted into an air-acetylene flame to achieve this temperature. The vaporized atoms are then exposed to radiation emitted from a light source. In practice, the technique achieve great specificity by using as its radiation source a discharge tube made of the very same element being analyzed in the specimen. When the discharge lamp is turned on, it emits only those frequencies of light that are present in the emission spectrum of the element. Likewise, the sample will absorb these frequencies only when it contains this very same element.
Hollow cathode lamps (HCL) are the most common radiation source in AAS. Inside the sealed lamp, filled with argon or neon gas at low pressure, is a cylindrical metal cathode containing the element of interest and an anode. A high voltage is applied across the anode and cathode, resulting in an ionization of the fill gas. The gas ions are accelerated towards the cathode and, upon impact on the cathode, sputter cathode material that is excited in the glow discharge to emit the radiation of the sputtered material, i.e., the element of interest.

In the figures below, you can see an example of a HCL (fig 6-5) that would be utilized in AAS. A schematic diagram of a typical flame AA is pictured in fig 6-6.

![Fig 6-5: A typical hollow cathode lamp utilized as a radiation source for atomic absorption spectrophotometry.](image)

![Atomic Spectroscopy with Flames](image)

**Atomic Spectroscopy with Flames**

**Atomic Absorption Spectroscopy**

- Po = light intensity w/ blank
- P = light intensity w/ sample
- $A = \log(Po/P) = kBC$
- $b =$ flame path; $C =$ sample concn
- $k$ depends on absorptivity and flow

![Fig 6-6: Parts of a simple flame atomic abruption spectrophotometer.](image)
Activity 6-1: Using a Spectroscope for Simple Emissions Spectrometry

As you read earlier in this chapter, emission spectrometry is the study of light passing through a diffraction slit which causes wavelengths of light to separate into visible bands. What is needed is a detector of some type to view the bands. With a handheld spectroscope, your eye becomes the detector.

Directions: Part 1
1. Use the hand held spectrosopes to view various light sources.
2. As best you can, diagram the spectral lines from various sources and compare the differences.
3. Hypothesize how a device such as this can be used in forensics.

Directions: Part 2
CAUTION: FLAME TEST ANALYSIS. You must wear eye protection for this test.
1. Perform a flame test analysis on the known samples.
2. Using the wire loops, place a small amount of the sample at the end of the loop. Then place into the flame.
3. Observe the coloration of the flame with the spectroscope. Diagram the spectra of each of the known samples.
4. Obtain a sample of the unknown and analyze it to determine its identity. Record the information below in the table.

Data Table:

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Spectral Analysis</th>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

The unknown was determined to be:

Go to the following website for spectral analysis of various substances: