Unit 8

* Metals, Paint, Soil, and Impressions
Many manufactured products and even most natural materials contain small quantities of elements, known as trace elements, present in concentrations of less than 1 percent.

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.
For chemists, **nuclear chemistry** provides a new tool for identifying and quantifying the elements.

A nuclear reactor is simply a source of neutrons that can be used for bombarding atoms, causing some neutrons to be captured to produce **radioactive isotopes** (atoms with the same number of protons but a different number of neutrons).
To identify the radioactive isotope, it is necessary to measure the energy of the gamma rays emitted as radioactivity.

Neutron activation analysis measures the gamma-ray frequencies of specimens that have been bombarded with neutrons.
* Neutron Activation

* This method provides a highly sensitive and nondestructive analysis for simultaneously identifying and quantifying 20 to 30 trace elements.

* Forensic analysis has employed neutron activation to find trace elements in metals, drugs, paint, soil, gunpowder residue, and hair.
* Neutron Activation

* Since this technique requires access to a nuclear reactor it has limited value to forensic analysis
* Paint is composed of a binder and pigments, and other additives that are dissolved or dispersed in a solvent.

* Paint spread onto a surface will dry into a hard film that can best be described as consisting of pigments and additives suspended in the binder.

* Automobile paint is the most common type of paint examined in crime labs.
Automobile manufacturers normally apply a variety of coatings to the body of an automobile.

These coatings may include electrocoat primer, primer surfacer, basecoat, and clearcoat.
* **Methods for Paint Comparison**

* Layers of automobile paint
  * **Electrocoat primer** - applied to the steel body of a car for corrosion resistance; colors range from black to grey
  
* **Primer surfacer** - applied to the primer to completely smooth it out and hide any seams or imperfections; highly pigmented (light grey for lighter colored cars and red oxide for darker cars)
Methods for Paint Comparison

Layers of automobile paint

* **Basecoat** - the actual color of the vehicle

* **Clearcoat** - unpigmented; improves gloss, durability, and appearance
Methods for Paint Comparison

* The **microscope** is the most important instrument for locating and comparing paint specimens.

* **Color** is the most distinctive forensic characteristic of paint.

* An examiner observes color layers and tries to match the number and sequence of colors. This process can connect paints to a common origin.
Methods for Paint Comparison

* The **wide diversity of automotive paint** contributes to the forensic significance of an automobile paint comparison.

* Questioned and known specimens are best compared side by side under a stereoscopic microscope for **color**, **surface texture**, and **color layer sequence**.

* Unfortunately, most paint specimens do not have layers that can be individualized to a single source, so a chemical analysis must be done.
* Methods for Paint Comparison

* Characterization of paint binders

* Pyrolysis gas chromatography
  * Many solids cannot be injected into a gas chromatograph, so items must be heated, or pyrolyzed, to high temperatures so they will decompose into gaseous products
**Methods for Paint Comparison**

* Characterization of paint binders

* **Pyrolysis gas chromatography**
  * Then they are put into a chromatograph, and a pyrogram is produced showing the chemical makeup of the binder

  * Even the smallest of paint chips can be pyrolyzed and sent through the gas chromatograph

* Pyrograms can distinguish one polymer from another
Methods for Paint Comparison

* Characterization of paint binders
  * Infrared spectrophotometry
    * Binders absorb infrared radiation to yield a spectrum that is characteristic to that specimen
The elements that are contained within paint pigments can be identified by emission spectroscopy or X-ray spectroscopy.

Emission spectrograph

- Can detect 15 - 20 elements in auto paint simultaneously
- Some are common to all paints, but others have significant forensic uniqueness
Methods for Paint Comparison

* Crime laboratories are often asked to identify the make and model of a car from a small amount of paint and will make use of color charts for automobile finishes or the PDQ database
  * Paint layers beneath the surface layer offer valuable points of comparison
  * Color charts for automobile finishes are available from manufacturers
  * **Paint Data Query (PDQ)**
    * A database that provides information on paints based on make, model, and year
    * Maintained by the Royal Canadian Mounted Police
* Paint chip off a wall in old Belmont Art Park in LA.

About 1 cm in thickness, there are somewhere between 150-200 paint layers in this sample. Note the fingerprint in the lower right corner to get a sense of scale. Is this Individual or Class evidence?
Pink Paint from pry bar found in suspect’s vehicle

Pink Paint from door jam at crime scene
Comparison of two paint chips side by side in a comparison stereoscope
Origin of Spectra

* An atom is composed of a nucleus containing protons and neutrons, with electrons found outside the nucleus in electron orbitals.

* The orbitals are associated with a definite amount of energy called an energy level.

* Each element has its own set of characteristic energy levels at varying distances from the nucleus.
* Because energy levels have **fixed values**, an atom will absorb only a definite value of energy, which may come from heat or light.

* This **absorbed energy** pushes the electrons into higher energy level orbitals and the atom is now considered in an excited state.
Normally, the electrons will not stay in this excited state for long, and they will quickly fall back to their original energy level, releasing energy in the form of light emission.
Emission spectroscopy collects and measures the various light energies given off by the atom.
The specific frequency of light absorbed or emitted can be determined by the relationship \( E=hf \), where \( E \) is the energy difference between two orbitals, \( f \) is frequency, and \( h \) is a universal constant called Planck’s constant.

Because each element has its own characteristic set of energy levels, each will emit a unique set of frequencies.
**Emission Spectrograph**

* An *emission spectrograph* vaporizes and heats samples to a high temperature so that the atoms present in the material achieve an “excited” state.

* Under these circumstances, the excited atoms will *emit light*. If the light is separated into its components, one observes a line spectrum. Each element present in the spectrum can be identified by its characteristic line frequencies.
* Emission Spectrograph

* **Emission spectra** can then be matched line for line in a comparison between samples
In inductively coupled plasma emission spectrometry (ICP), the sample, in the form of an aerosol, is introduced into a hot plasma, creating charged particles that emit light of characteristic wavelengths corresponding to the identity of the elements present.
* An area of forensic casework where ICP has been applied are the identification and characterization of mutilated bullets
Collection and Preservation

* Paint evidence is mostly involved in burglaries and hit-and-run incidents

* Paint chips should be picked up with forceps and placed in a paper bindle or a glass or plastic container
**Collection and Preservation**

* If paint is smeared on or embedded into something, package the entire item

* With hit-and-run cases, collect uncontaminated paint from an undamaged area as a reference for comparison

* ¼-inch square samples are sufficient, but you must go all the way to bare metal
Tools used to gain entry into buildings or safes often contain traces of paint, requiring the tool be collected, along with reference paint samples.
The value of soil as evidence rests with its prevalence at crime scenes and its transferability between the scene and the criminal.

Most soils can be differentiated by their gross appearance.
A side-by-side visual comparison of the **color** and **texture** of soil specimens is easy to perform and provides a sensitive property for distinguishing soils that originate from different locations.

In many forensic laboratories, **forensic geologists** will characterize and compare the mineral content of soils.
* Collection of Soil

* **Standard/reference soils** are to be collected at various intervals within a 100-yard radius of the crime scene, as well as the site of the crime, for comparison to the questioned soil.

* Soil found on the suspect, such as adhering to a shoe or garments, must not be removed.

* Instead, each object should be individually wrapped in paper, and transmitted to the laboratory.
* * Types of Impressions

* **Patent impression** - visible, two-dimensional (ex. bloody shoeprints)

* **Latent impression** - hidden, visualized by chemical or physical development

* **Plastic impression** - three-dimensional imprints (ex. left in snow, soil, etc.)
Class Characteristics

* Characteristics that are common among similar articles of footwear

* Examples
  * size
  * tread pattern
  * brand
* Individual Characteristics

* Unique characteristics observed only on an individual piece of footwear:
  * An unusual wear pattern
  * A pebble stuck in a part of the tread pattern
  * Damages (cuts, tears, abrasions, etc.)
* Typical Clues Determined from Shoe Impressions

* Size of the footwear
* Brand of the footwear
* Sex of the wearer
* Weight of the wearer (based on the depth of the impression)
* The type of footwear (high heels, work boots, etc.)
Impression Databases

* TreadMark
* SoleMate
* TreadMate
Factors Affecting Shoe Wear Patterns

* Walking habits (walking on toes or heels, feet straight or toes pointed in/out)
* Body weight
* Shape of the feet
* Activities often engaged in
* Surface walked on
* Unique debris, holes, cuts
Collection and Preservation

* Photograph that includes a ruler
* Lifting with electrostatic dusting or gel lifting
* Casting with plaster of Paris (CaSO₄) or dental stone (on snow or soil)