What is toxicology?

- **Toxicology** is the study of drugs and poisons, and their interactions with or effects on the body.

- **Forensic Toxicology** is the application of toxicology to the law, including:
  - Workplace or Forensic Drug Testing
  - Postmortem Toxicology
  - Human Performance Testing
History of Toxicology

- Socrates was one of the earliest reported victims of poisoning, by hemlock, in 399 BC.

- By the 17\textsuperscript{th} century, it was not uncommon for rich European families to use poisoning as a means of settling disputes.
  - Arsenic became known as “inheritance powder.”
History of Toxicology

- **Mathieu Orfila** (1787-1853) is considered one of the fathers of toxicology as he helped to develop a method of chemical analysis to identify arsenic and other toxins in human tissue.

- Today, less than 0.5% of all homicides result from poisoning.
Toxicology

- **Toxin**: a substance that causes injury to the health of a living thing on contact or absorption, typically by interacting with enzymes and receptors.

- **Toxicologist**: detects and identifies the presence of drugs and poisons in body fluids, tissues, and organs
  - Legal Institutions: crime laboratories and medical examiner’s office
  - Hospital laboratories
What is a toxin?

Properties that affect the toxicity

- Dosage
- The chemical or physical form of the substance
- How it enters the body
- The body weight and physiological conditions of the victim including age and sex
- Time of the exposure
- Interaction of the toxin with other chemicals present in the body or the dose
Types of toxicity

- **Chronic exposure**: continuing exposure to toxins over a long period of time

- **Acute toxicity**: occurring almost immediately (hours or days) after an exposure

- **Synergism**: combined effect of substances that exceeds the sum of their individual effects

  - Alcohol and Valium
  - Cannabis and LSD
  - Codeine and Ibuprofen
Role of the Toxicologist

- Studies body fluid, tissue, and organs for drugs and/or poisons
- Must detect, identify, quantify, and assess toxicity
  - May have extremely minute quantities to test
- May conduct postmortem pathological examinations, and examination of personal effects and empty containers, etc.
Where can a Toxicologist work?

- **Postmortem**: Medical examiner or coroner
- **Criminal**: Motor Vehicle Accidents (MVA)
- **Workplace**: Drug testing
- **Sports**: Professional athlete (human and animal) drug testing
- **Environment**: Industrial toxins, biological and chemical warfare
Collecting Toxicological Evidence

- When possible, collect both blood and urine
  - Collect two voids (samples) of urine in separate specimen containers
  - Collect a sample of blood if a physician or registered nurse (RN) is available
ALCOHOL
Toxicology of Alcohol

- Alcoholic beverages contain **ethanol**, also called ethyl alcohol, which is obtained by the fermentation of sugars from grains, fruits, and vegetables.

- Alcohol is a **depressant**, a chemical that slows the heart rate and brain activity, and causes drowsiness.
Alcohol Metabolism

- Alcohol is absorbed through the walls of the stomach and small intestine, and distributed by blood throughout the body.

- In the liver, the enzyme alcohol dehydrogenase (ADH) breaks down ethanol into acetylaldehyde (causes hangovers), then eventually into carbon dioxide and water.

- The liver can normally metabolize 1-2 drinks (15-30 mL or up to 1 ounce) an hour. When a person drinks more than the liver can metabolize, the excess is distributed to the tissues of the body which can damage them.
Alcohol Absorption and Evaporation

- Alcohol gets absorbed from the stomach and intestines into the bloodstream.

- Alcohol is not chemically changed in the bloodstream.

- As the blood goes through the lungs, some of the alcohol moves across the membranes of the lung's air sacs into the air, because alcohol will evaporate from a solution.

- The concentration of the alcohol in the lungs is related to the concentration of the alcohol in the blood with a ratio of 1 to 2100.

- It can be detected by breath alcohol testing devices, such as a Breathalyzer.
Rate of Absorption

- What affects the rate of absorption?
  - Total time to consume the drink
  - Alcohol content in the beverage
  - Amount of alcohol consumed
  - Quantity and type of food present in the stomach

- Maximum blood-alcohol concentration
  - May take as long as 2-3 hours
  - Normal social drinking conditions: 30-90 minutes from time of final drink
How is the alcohol eliminated?

- Elimination rate can vary up to 30% between individuals
  - Average is 0.015% w/v (15 mg of alcohol per 100 mL of blood)

- **Oxidation**: 95-98% of alcohol consumed is oxidized to carbon dioxide and water in the liver
  - alcohol $\rightarrow$ acetaldehyde $\rightarrow$ acetic acid $\rightarrow$ CO$_2$ and H$_2$O

- **Reduction**: remaining portion excreted unchanged in breath, urine, and perspiration
  - Amount of alcohol exhaled in breath is in direct proportion to the concentration of alcohol in blood
Movement of alcohol in the body

1. Alcohol is ingested; moves down the esophagus to the stomach
   a. 20% moves through the stomach wall to the blood stream; the remaining alcohol passes through the walls of the small intestine

2. Alcohol is carried in the blood stream through the liver and then to the heart

3. Blood enters the right atrium, then goes to the right ventricle
   a. At this point there is alcohol and CO₂ in the blood; very little O₂

4. Blood goes to the lungs via the pulmonary artery to be replenished with O₂

5. Rapid exchange of gases by breathing
   a. Oxygen for CO₂ and alcohol
Henry’s Law

Definition: When a volatile chemical (alcohol) is dissolved in a liquid (blood) and is brought to equilibrium with air, there is a fixed ratio between the concentration of the volatile compound (alcohol) in the air and its concentration in the liquid (blood), and this ratio is constant for a given temperature.
Blood Alcohol Content (BAC)

\[
BAC_{\text{male}} = 0.071 \times (\text{vol. consumed, oz.}) \times (\% \text{ alcohol})
\]

Body weight

\[
BAC_{\text{female}} = 0.085 \times (\text{vol. consumed, oz.}) \times (\% \text{ alcohol})
\]

Body weight
Arterial versus Venous BAC

- Arterial blood-alcohol level is 41% higher than your venous blood 30 minutes after the last drink
  - Breath test reflects the alcohol concentration in the pulmonary artery
  - Blood is drawn from the vein during a blood test
  - Blood tests reflect the alcohol concentration in the brain and therefore better indicate the impairment of the individual
- At the end of the absorption phase, alcohol is evenly distributed and both tests should show minimal difference
Toxicology of Alcohol

- Approximately 40% of traffic deaths in the U.S. are alcohol-related (2008)

- Toxicologists have had to develop specific procedures for measuring the degree of alcohol intoxication

- Methods for diagnosis must be defendable within the framework of the legal system
Alcohol in the Blood

- Blood Alcohol Content (BAC) is usually written as a decimal
  - Example: 0.08
  - This means there are 8 g of alcohol per 10,000 mL of blood; your blood is 0.08% alcohol.

### Effects of Alcohol at Different BACs

<table>
<thead>
<tr>
<th>BAC Range</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03 – 0.12</td>
<td>euphoria</td>
</tr>
<tr>
<td>0.25 – 0.40</td>
<td>vomiting, loss of bladder control</td>
</tr>
<tr>
<td>0.35 – 0.50</td>
<td>circulatory and respiratory system impairment</td>
</tr>
<tr>
<td>0.40 and up</td>
<td>coma and death</td>
</tr>
</tbody>
</table>
Field Sobriety Tests

- If a police officer smells alcohol on a driver, he/she may perform field sobriety tests, including:
  - Horizontal gaze nystagmus (HGN) test
    - Nystagmus is involuntary jerking movements of the eyes; more pronounced when intoxicated
  - Walk and turn
    - Heel to toe in a straight line, following directions
  - One leg stand
    - Count aloud by 1000’s for 30 seconds or recite alphabet backwards
Types of Testing Devices

- Two breath testing technologies are most prevalent.

- Desktop analyzers generally use infrared spectrophotometer technology, electrochemical fuel cell technology, or a combination of the two.

- Hand-held field testing devices are generally based on electrochemical platinum fuel cell analysis and, depending upon jurisdiction, may be used by officers in the field as a form of "field sobriety test" or as evidential devices in point of arrest testing.
Alcohol Breath Test

- 90% of alcohol is processed by the liver. The remaining 10% is excreted through breath, perspiration, and urine.

- A breath test, such as a Breathalyzer measures the amount of alcohol in exhaled air.

- The amount of alcohol in breath is 1/2100 the amount in blood.
  - 2100 mL of air has the same amount of alcohol as 1 mL of blood.
Negative Effects of Alcohol

- All alcohols are toxic to the body.

- Consumption of alcohol can lead to liver damage, possibly cirrhosis. Chronic alcohol abuse can lead to Korsakoff’s Syndrome.

- Driving while intoxicated can have deadly results.

- Alcohol may change the effect of medications.

Never consume alcohol while taking drugs with a sedative effect.
BAC and the Law

- A BAC greater than 0.08 is considered to be “drunk driving”

- **Implied consent** says drivers who receive a driver's license are automatically consenting to be tested for blood alcohol content if a police officer has probable cause.
  - While a driver can refuse to take this test, implied consent laws often automatically revoke licenses on the spot.
Factors Affecting Blood Alcohol Tests

- Drinking on empty stomach (faster metabolism)
- Drinking with a fever (false positive)
- Using mouthwash or breath spray (false positives)
- No good way to spoof the systems.
Schmerber v. California (1966): while being treated for injuries during a car accident, Schmerber was charged with DUI and blood was taken.

- Supreme Court ruled that the Fifth Amendment only prohibits giving testimonial evidence that is self-incriminating, not physical evidence.
- Also Schmerber was not subjected to unreasonable search and seizure since it was an emergency situation. DUI is an emergency situation since the body naturally eliminates the alcohol over time.
DRUGS
In 2010, 22.6 million Americans 12 or older (8.9 % of the population) were current illicit drug users. This was an increase over previous years, mostly due to more marijuana use.

Drug overdoses and brain damage linked to long-term drug abuse killed an estimated 37,485 people in 2009, surpassing the toll of traffic accidents by 1,201.

Many of these fatalities were due to prescription drug abuse.

Drugs

- “Drug” can mean different things...
  - **Illicit or illegal drugs** that have no accepted medical use in the US
  - **Controlled substances**: legal drugs whose sale, possession, and use are restricted because of their effects and the potential for abuse.

- Drugs can fall into one of several different classes: narcotics, hallucinogens, depressants, stimulants, club drugs, and steroids
Classification of Illicit Drugs

- Classified by Origin
  - Naturally occurring substances
  - Derived from a naturally occurring substance (semi-synthetic)
  - Synthetic

- Classified by Major Effect on Humans
  - Stimulants
  - Depressants
  - Hallucinogens
  - Narcotics
Types of Drugs: Narcotics

- **Narcotics** reduce pain by suppressing the central nervous system’s ability to relay pain messages to the brain.
  - Pain relievers are called **analgesics**.

- **Narcotics** induce sleep and depress vital body functions such as blood pressure, pulse, and breathing.
Types of Drugs: Narcotics

- Varieties of narcotics:
  - Opiates: derived from the Asian Poppy
    - Herionene, morhpine, codeine
  - Synthetic opiates: man-made
    - Methadone: given to heroine addicts to try and break their addiction
    - Oxycodone (OxyContin or Percocet)
    - Hydrocodone (Vicodin)

- Overdose on narcotics can result in difficulty breathing, low blood pressure, loss of consciousness, and possibly coma and death.
Types of Drugs: Hallucinogens

- **Hallucinogens** alter the user’s perceptions, thinking, self-awareness, and emotions.

- Some hallucinogens can cause panic attacks, seizures, headaches, and sometimes *psychosis* that can last for weeks.

- Many hallucinogens, particularly PCP, increase the user’s heart rate, which could lead to *heart failure*. 
Types Of Drugs: Hallucinogens

- Varieties of Hallucinogens
  - **Marijuana** (from cannabis plant)
    - The most widely used illicit drug in the U.S.
    - Contains tetrahydrocannabinol (THC)
    - Has medical uses such as treating glaucoma and relieving nausea due to chemotherapy
  - **MDMA** (“Ecstacy”)
  - **Mescaline** (from Peyote cactus)
  - **LSD** (Lysergic Acid, or simply “Acid”)
  - **PCP** (phencyclidine or “Angel Dust”)
  - **Mushrooms** (contain psilocybin)
Types of Drugs: Depressants

- **Depressants** are used to relieve anxiety and produce sleep.
- Depressants reduce body functions such as heart rate.
- Overdose can cause coma and death.
- Mixing depressants with other drugs or alcohol can increase their effects and health risks.
Types Of Drugs: Depressants

- Varieties of Depressants:
  - Alcohol
  - Barbiturates: “downers” such as Phenobarbital and Methaqualone (also called Quaaludes, illegal)
  - Anti-psychotic and anti-anxiety drugs including benzodiazepines such as Diazepam (Valium)
  - Inhalants (“huffing”)
  - Sedatives, muscle relaxers, etc.
  - Marijuana and opiates (like morphine) are also considered depressants.
Types of Drugs: Stimulants

- **Stimulants** increase feelings of energy and alertness while suppressing fatigue and appetite.
- Also called "uppers."
- Depression often results as the drug wears off.
- Stimulants are highly addictive.
- Overdose can result in irregular heart beat, heart attack, stroke, seizures, coma, and death.
Types of Drugs: Stimulants

- Varieties of Stimulants
  - **Amphetamines**, also called “speed.”
  - **Cocaine**, including **crack** cocaine
    - Derived from the South American coca plant
    - Addictions to cocaine are very difficult to overcome
  - **Methamphetamines**, also called “meth.”
    - Typically methamphetamines are more potent and dangerous than amphetamines
Meth Addiction

2005© "Faces of Meth"

2.5 Years Later
Types of Drugs: “Club Drugs”

- Club drugs are called such because they are most often used at nightclubs, bars, and raves (all night dance parties).

- Varieties of Club Drugs
  - Methylenedioxymethamphetamine (aka MDMA or Ecstasy)
    - Chronic use can cause body system breakdown, severe brain damage, memory loss, and seizures.
  - Ketamine or “Special K” is an animal anesthetic used by veterinarians.
Types of Drugs: “Club Drugs”

- **Date Rape Drugs** are called that because they are often associated with drug-facilitated sexual assault, rape, and robbery.

- These drugs can produce increased libido and depress the central nervous system, resulting in loss of consciousness and memory.

- Varieties include GHB and Rohypnol (also called “Roofies”).
Types of Drugs: Anabolic Steroids

- **Anabolic Steroids** promote cell division and tissue growth
- Athletes may take steroids to increase muscle mass
- Anabolic steroids are chemically related to testosterone
- Side effects include liver malfunction, cancer, breast development in males, masculinizing effects in females, diminished sex drive in males, unpredictable moods (“roid rage”), personality changes, depression, hypertension, and high cholesterol
How are Illicit Drugs Controlled?

- Title 21 United States Code Controlled Substance Act Section 801

- Controlled substances are put into one of five schedules.
  - Schedule I = Heroin, LSD, Marijuana
  - Schedule II = Cocaine and Methamphetamine
  - Schedule III = Anabolic steroids and Aspirin or Tylenol with Codeine
  - Schedule IV = Darvon and Valium
  - Schedule V = OTC Cough Medicines with Codeine
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  - Schedule IV = Darvon and Valium
  - Schedule V = OTC Cough Medicines with Codeine
Be careful…

- All of these drugs, even the legal ones, can have harmful side effects. Overdose can be deadly.

- **Assignment**: Drug Brochures
Poisons!
Toxins and Poisons

- A *poison* is any substance that causes disturbance to an organism.

- More specifically, a *toxin* is poison produced naturally by an organism.
  - Examples: snake venom, poison ivy
Is it a poison?

- Arsenic
  - Found in the foods we eat and the water we drink
  - May have a positive affect on humans; arsenic deficiency stunts growth in chickens, rats, pigs, and goats
  - Used to treat a rare form of cancer
  - Used as a poison to kill people

- Oxygen, Water, Aspirin, Alcohol, Food
Measuring Toxicity

- **Lethal dose** \((\text{LD}_{50})\): the amount of substance that kills half of the test population within four hours; it is measured in milligrams \((\text{mg})\) of substance per kilogram \((\text{kg})\) of body weight

- Estimating lethal dose in humans is uncertain; measurements usually carried out in lab animals

<table>
<thead>
<tr>
<th>Species</th>
<th>(\text{LD}_{50}) ((\text{mg/kg}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>0.9</td>
</tr>
<tr>
<td>Dogs</td>
<td>9.2</td>
</tr>
<tr>
<td>Pigeons</td>
<td>75</td>
</tr>
<tr>
<td>Rats</td>
<td>53</td>
</tr>
</tbody>
</table>
### Toxicity Classes and Definitions

<table>
<thead>
<tr>
<th>LD$_{50}$ (rats, oral)</th>
<th>Correlation to 150 lb adult human</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 mg/kg</td>
<td>A taste to a drop</td>
<td>Extremely</td>
</tr>
<tr>
<td>1 – 50 mg/kg</td>
<td>A teaspoon</td>
<td>Highly</td>
</tr>
<tr>
<td>50 – 500 mg/kg</td>
<td>An ounce</td>
<td>Moderately</td>
</tr>
<tr>
<td>500 – 5,000 mg/kg</td>
<td>A pint</td>
<td>Slightly</td>
</tr>
<tr>
<td>5 – 15 g/kg</td>
<td>A quart</td>
<td>Practically nontoxic</td>
</tr>
<tr>
<td>&gt; 15 g/kg</td>
<td>More than a quart</td>
<td>Relatively harmless</td>
</tr>
</tbody>
</table>
## Some Lethal Doses

<table>
<thead>
<tr>
<th>Substances</th>
<th>LD$_{50}$ (rats, oral) mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>29,700</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>11,900</td>
</tr>
<tr>
<td>Ethanol</td>
<td>7,060</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>4,220</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>3,000</td>
</tr>
<tr>
<td>Arsenic metal</td>
<td>763</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substances</th>
<th>LD$_{50}$ (rats, oral) mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffeine</td>
<td>192</td>
</tr>
<tr>
<td>Arsenic trioxide</td>
<td>14.6</td>
</tr>
<tr>
<td>Arsenic pentoxide</td>
<td>8</td>
</tr>
<tr>
<td>Sodium cyanide</td>
<td>6.4</td>
</tr>
<tr>
<td>Ricin</td>
<td>0.020</td>
</tr>
<tr>
<td>Botulin toxin</td>
<td>0.000005</td>
</tr>
</tbody>
</table>
## Effect of Poisons on the Body

<table>
<thead>
<tr>
<th>Poison</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lye</td>
<td>Characteristic burns around mouth and lips</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Red or bright pink patches on the chest and thighs; bright red lividity</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Black vomit</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>Greenish-brown vomit</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>Yellow vomit</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Burnt almond smell</td>
</tr>
<tr>
<td>Arsenic, mercury</td>
<td>Pronounced diarrhea</td>
</tr>
<tr>
<td>Methyl (wood) alcohol and rubbing alcohol</td>
<td>Nausea and vomiting, unconsciousness, and blindness</td>
</tr>
</tbody>
</table>
Poisons enter and affect the body in different ways:

- **Ingestion** (poisons are eaten)
  - 90% of all poisonings involve children swallowing household products or medicine

- **Inhaled**
  - Example: carbon monoxide, sarin nerve gas

- **Injected**
  - Heroine

- **Absorbed** (through skin, eyes, or mucous membranes)
  - Poison sumac
Poisons: Pesticides

- Pesticides are by definition poisons as they are used to kill organisms that threaten plants such as food crops
  - Example: DDT (for mosquitoes)

- These chemicals lead to an excess of the neurotransmitter acetylcholine
  - Overdose can lead to muscle spasms, seizures, anxiety, rapid heartbeat, sweating, diarrhea, and at high concentrations coma and death
Poisons: Heavy Metals

- Metal compounds can enter the body by ingestion, inhalation, or absorption through the skin or mucous membranes.
- Metals are stored in soft body tissues and damage organs.
- Examples:
  - Lead
  - Mercury
  - Arsenic
  - Cyanide
  - Strychnine
Poisons: Heavy Metals

- **Arsenic Poisoning**
  - Within 30 minutes: abdominal pain, severe nausea, vomiting and diarrhea, muscle cramps, convulsions, kidney failure, delirium, and death.

- **Cyanide Poisoning**
  - Can be fatal in 6-8 minutes.
  - Signs of poisoning include weakness, confusion, coma, pink skin, and an almond-like odor.
Lead Poisoning

- Lead compounds are not highly poisonous
  - Taste sweet
  - Metallic lead is insoluble, but in acidic water and food, the lead can become slightly soluble

- Chronic exposure is a health problem for many Americans especially children
  - Brain damage
  - Affects memory or thought processes

- Lead-based products
  - 38 millions houses have lead-based paint (prominent until the late 70s)
  - Leaded gasoline (banned in 1995) still remains in soils
  - Lead pipes (banned in 1986) in older houses and towns
  - Solder joints in older houses
  - Leaded crystal and ceramics
Carbon Monoxide Poisoning

- Carbon Monoxide (CO) binds with hemoglobin in red blood cells and does not allow the cells to carry O₂. Death by asphyxiation follows.

- CO saturation of 50-60% is considered fatal in middle-aged people
  - In conjunction with a BAC of 0.20, CO saturation of 35-40% is fatal
  - Chain smokers normally have a CO saturation of 8-10%

- CO from automobile fumes is a common way to commit suicide
  - Enough CO accumulates in 5-10 minutes to cause death

- Death from fire or foul play
  - High CO levels in victims of a fire is proof that the person was alive when the fire began and died from the combustion products of the fire
Poisons: Bioterrorism Agents

- A **bioterrorism attack** is the deliberate release of viruses, bacteria, toxins or other harmful agents used to cause illness or death in people, animals, or plants. Examples include:
  - **Ricin**
  - **Anthrax**
  - **Mustard Gas**
    - used in World War I
    - A man-made gas
    - Forms large blisters on exposed skin and the lungs
Poisons: Bioterrorism Agents

- **Ricin** comes from castor beans.
  - Can be inhaled as a mist or powder, or ingested in food
  - Amount the size of a pin head can be deadly!
  - Within a few hours of exposure the victim may die
    - If inhaled effects include fever, cough, nausea, sweating, low blood pressure, fluid in the lungs, and death
    - If ingested effects include vomiting diarrhea, dehydration, low blood pressure, hallucinations, seizures, and death
Poisons: Bioterrorism Agents

- **Anthrax** poisoning is caused by the spores of the bacteria *Bacillus anthracis*
- Anthrax can enter the body through inhalation, ingestion, or skin absorption
- Symptoms depend on exposure type:
  - **Inhalation**: flu-like symptoms that become progressively worse and usually result in death.
  - **Ingestion**: vomiting, fever, abdominal pain, and severe diarrhea. 25 - 60% fatal.
  - **Skin**: itchy bumps that develop into sores with a black center. Death is rare with appropriate treatment.
Government Agencies that Regulate Toxins

- The Food and Drug Administration (FDA): deals with pharmaceuticals, food additives, and medical devices
- The Environmental Protection Agency (EPA): works on agricultural and industrial chemicals released into the environment
- The Consumer Product Safety Commission: concerned with toxins in consumer products
- The Department of Transportation (DOT): watches over the shipment of toxic chemicals
- The Occupational Safety and Health Administration (OSHA): concerned with exposure to chemicals in the workplace
Warning Labels

- **Material Safety Data Sheets (MSDS)**
  - Chemical Identity
  - Health Hazard Data
  - Manufacturer information
  - Precautions for Safe Handling and Use
  - Hazardous ingredients
  - Exposure controls/personal protection
  - Physical and chemical properties
  - Fire and Explosion Hazard Data

- **Transportation Placards**
  - Four digit number refers to the specific chemical carried inside
  - Class refers to the type of chemical inside the vehicle
    - Class 1 = Explosives
    - Class 2 = Compressed Gases
    - Class 3 = Flammable Liquids
    - Class 4 = Flammable Solids
    - Class 5 = Oxidizers
    - Class 6 = Poisons
    - Class 7 = Radioactive Materials
    - Class 8 = Corrosive Liquids
Drug Control Laws

- There are varying levels and penalties based on:
  - manufacture vs. distribution vs. possession
  - type, amount, concentration
Controlled Substance Act

- **The Controlled Substances Act** – the federal law that establishes five classifications ("schedules") of controlled dangerous substances on the basis of a drug’s potential abuse, potential for physical and psychological dependence, and medical value.

- The **U.S. Attorney General** has the authority to add, delete, or reschedule a drug as needed.
Controlled Substances Act

Schedule I

- High potential for abuse
- No currently accepted medical use in the U.S.
- Examples: heroin, marijuana (some states), methaqualone, LSD
Controlled Substances Act

Schedule II

- High potential for abuse
- Some accepted medical use with severe restrictions,
- Potential for severe physiological and psychological dependence
- Examples: morphine, cocaine, methadone, PCP, most amphetamine preparations, most barbiturate preparations, and medical marijuana (some states)
Controlled Substances Act

Schedule III

☐ Less potential for abuse
☐ currently accepted medical use
☐ potential for low to moderate physiological and high psychological dependence

☐ All barbiturates not included in Schedule II, such as codeine preparations and anabolic steroids
Controlled Substances Act

**Schedule IV**
- Low potential for abuse
- Current medical use
- Examples: tranquilizers such as Valium

**Schedule V**
- Low abuse
- Medical use
- Less potential for dependence than Schedule IV
- Examples: Robitussin cough syrup, non-narcotic medicinal ingredients and some opiate drug mixtures in low concentrations
Criminal Penalties

- Schedule I and II have the most severe penalties
- The Controlled Substance Act controls substances that are chemically similar or related to controlled substances such as “designer drugs”
- It also regulates the manufacture and distribution of chemical compounds used by clandestine labs to make drugs
Color Tests

• Used for SCREENING ONLY

• Marquis Reagent- Purple for Heroin, morphine, and most opiates, Orange-brown for amphetamine and methamphetamine, Black for MDMA
Marquis Reagent
Dillie-Koppanyi

- Turns violet-blue in the presence of barbiturates
Two step test for marijuana, results in a purple color
Scott Test

- Add cobalt thiocyanate turns blue in the presence of cocaine and then pink when HCl is added
Microcrystalline Tests

- This is a CONFIRMATION test, but not commonly used in the lab
  - too difficult, requires lots of training, drug must be extremely pure

- Based on the color and shape of crystals formed when different reagents are added
Microcrystalline Tests
Chromatography

- A physical method of separation
- Components partition between two phases
  - Stationary phase—doesn’t move
  - Mobile phase—does move
- Solutes are separated due to differences in how they interact with the two phases
The separation process

- Sample components are carried by a mobile phase through a bed of stationary phase

- Individual substances are slowed by the stationary phase based on various interactions such as:
  - surface adsorption
  - relative solubility
  - charge
Compound A has a greater affinity for the stationary phase than compound B and, therefore, will take longer to elute (that is, have a greater retention time).
Thin layer chromatography (TLC)

- Stationary phase is solid coated onto surface of glass
- Mobile phase is liquid or liquid solution
- Analyte is introduced as spot at bottom of TLC plate
- Mobile phase carries up plate by capillary action
- Detection by UV or color spray
Diagram of TLC Experiment

- Sample spot

- Very thin coating of silica gel or alumina

- Rising solvent; original spot has separated into several spots
TLC results
TLC results
Gas Chromatography

- Stationary phase is viscous liquid coated onto solid substrate
- Most stationary phases are capillary columns
- Mobile phase is an inert gas under pressure; usually nitrogen or helium
- Substances must be thermally stable
- Measures retention time
Diagram of gas chromatograph

Carrier gas

Flow controller

Injector port

Column oven

Detector

Recorder
Chromatogram of Organic Compounds from Fermented Cabbage
Chromatogram of Orange Juice Compounds
Gas Chromatography

- Analyte is usually solid or liquid
- Liquids directly injected with syringe
- Solids are dissolved in solvent and then injected
- Analyte is vaporized and mixed with mobile phase in injector
- Injector is heated to 25 degrees above maximum column temperature
- Usually micrograms of analyte are sufficient
Stationary phase

- Usually a thin walled capillary coated with viscous liquid. May be 3-60 meters long
- Heated to 300 degrees C maximum
- The higher the temperature, the faster that substances will elute
  - but fast elution rates mean poorer resolution
- Separation is based on mass action and polarity
Separation of analyte components

- **Mass action**: heavier molecules travel more slowly

- **Polarity**: stationary phase is polar relative to mobile phase. Stationary phase polarity is chosen to compliment polarity of analyte components.
  - Nonpolar analytes are better separated by nonpolar stationary phases
Detection of GC Peaks

- Detector must be able to detect change in vapor composition at microgram to nanogram level. Detectors enable both quantitative and qualitative analysis
- Qualitative: retention time characteristic of substance but not dispositive
- Quantitative: Area under peak is proportional to amount of substance present
Gas Chromatography - Mass Spectrometry

- Mass spectrometer is detector for GC
- GS separates components of mixture.
- Each component is sent to mass spectrometer
Mass Spectrometry

- Mass spectrometer bombards analyte component with beam of electrons
- Molecule breaks apart into stable, reproducible fragment ions by lose of electron
- Pattern of fragments can ID the molecule
Spectroscopy

- **SPECTRUM**: series of colors, including those beyond the visible, produced by dispersion of radiated energy.
- **SPECTROSCOPY** ($n$): The branch of science dealing with the theory and interpretation of spectra. It is the study of the interaction of electromagnetic radiation with the quantized energy states of matter.
Theory of Spectroscopy

- Spectroscopy is based upon the fact that there is a quantized energy transfer between radiation and matter.
- The energy of light affected by this transfer reveals information about the structure and environment of the matter in question.
Electromagnetic spectrum

- Gamma rays
- X-rays
- Ultraviolet
- Visible
- Infrared
- Microwave
- Radio
Interactions of matter and light

In forensic science, we are more concerned with what happens to a substance when it is exposed to light of much lower frequencies and energies.

There are two principle regions of light that are most important in characterizing evidence

Ultraviolet/visible (UV/vis)

Infrared (IR)
Ultraviolet light and matter

- All compounds have color
  - They absorb more or less light of a wavelength
  - We only perceive color in the visible range
  - 400-800 nm

- Light appears uniform but is really composed of many colors
  - White light can be broken down into its component colors with a prism
Roy G Biv
Pigments “make” the color

- Molecules absorb light of specific energy or wavelength
- Wavelength of light absorbed depend on electronic structure of molecule
- Pigments and dyes of ink are designed to absorb in visible range
UV/Vis Spectrophotometry

- Measures the absorption of UV or visible wavelengths of light and produces a graph called an absorption spectrum.

- Not specific enough for 100% confirmation - some compounds with similar chemical structures will give very similar absorption spectra.
UV/Vis Spectrophotometry
Infrared Spectroscopy

- All substances absorb some infrared radiation at particular wavelengths because of the arrangement of their chemical bonds.

- The infrared spectrum of an unknown compound can be compared to known spectra in order to identify the unknown compound.
Infrared spectrophotometry

- Atoms and bonds act like balls and springs
- Vibrate at certain frequencies
- When they encounter energy at the exact same frequency, they absorb at that frequency
  - The rest of the signal transmits through
- Each molecule can have numerous combinations of vibrations
- Gives a far more complex absorption spectrum → positive id for CONFIRMATION
Infrared Spectroscopy

When every wavelength has been absorbed from both samples they are plotted against each other for identification.
Infrared Spectroscopy

The infrared source is split into two beams with mirrors. These shine through both the reference and unknown sample.
The beams hit a **chopper** which alternately allows each beam to pass so that one beam is always blocked.
One beam passes through the chopper and hits a prism. This separates the light into its component wavelengths.
A slit allows only a small range of wavelengths to hit the detector. The slit and detector move together to individually sample each wavelength.
Infrared Spectroscopy

Post-processing can compare the differences in the signal to quantify alcohol content.
Infrared spectrophotometry

Note inverted peaks
- **Top**: 100% transmission
- **Bottom**: No transmission

Frequency
- $\text{cm}^{-1} = \text{Hz/cm}$
The fuel cell uses a chemical reaction to generate an electrical signal in response to the breakdown of alcohol in the fuel cell.

The fuel cell converts alcohol and water into acetic acid, $H^+$, and $e^-$ at the anode.

At the cathode, $H^+$ and $e^-$ combine with atmospheric oxygen to regenerate the water. This net reaction involves a flow of electrons from anode to cathode.

The electron flow is measured and the signal is displayed on the readout.

More alcohol releases more electrons.
Testing For Drugs

- Bodily fluids and tissues might be tested for the presence of drugs, especially:
  - **Blood** (drug remains for 24 hours)
  - **Urine** (drug remains for 72 hours)
  - **Hair** (drug is permanently embedded in hair’s protein structure)

- Location along hair shaft gives clues to time of drug use. If drug is found closer to the root, use was more recent.
Qualitative vs Quantitative Tests

- **Qualitative tests** can define what type of drug is present but lacks the ability to determine how much drug is present.

- Various criminal charges depend on knowing how much of a drug is present. This requires a **quantitative test**.

- In a **quantitative test**, the sample is weighed and then the test is used to estimate what mass of the sample is the drug. The mass of the drug is divided by the total mass to give the percentage of drug in the sample.
# Categories of Drug Analysis

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<td>Thin Layer Chromatography</td>
<td>Cannabis only: Macroscopic and Microscopic Examination</td>
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Drug Test Selection Criteria

- When a validated Category A technique is incorporated into an analytical scheme, at least one other technique (from either Category A, B or C) shall be used.

- When a Category A technique is not used, at least three different validated techniques shall be employed. Two of the three techniques shall be based on uncorrelated techniques from Category B.
All Category A and botanical identifications shall have data that are reviewable.

Where a Category A technique is not used, the requirement for reviewable data applies to category B techniques.

- Printed spectra, chromatograms, digital images, photographs or photocopies (color, where appropriate) of TLC plates
- Contemporaneous documented peer review for microcrystalline tests
- Reference to published data for pharmaceutical identifiers (physical characteristics of tablets, capsules or packaging indicating the identity, manufacturer, or quantity of substances present)
- For cannabis and botanical materials only: recording of detailed descriptions of morphological characteristics.
Analysis of Controlled Substances

- For a test method to be considered of value in establishing the forensic identification of a drug, the results shall be considered “positive.”

- “Negative” test results provide useful information for ruling out the presence of a particular drug or drug class, these results have no value toward establishing the forensic identification of a drug.
Analysis of Controlled Substances

- The laboratory shall employ quality assurance measures to ensure the results correspond to the exhibit.

- Example measures are:
  - The use of two separate samplings
  - Sample identification procedures such as bar-coding and witness checks
  - Good laboratory practices (e.g., positive and negative controls, one sample opened at a time, procedural blanks)
Watch drug dog video