Chapter Overview

Toxicology is the study of poisons, the identification of drugs a person may have used, and the effects of poisons and drugs on the body. People may be exposed to toxic substances (1) intentionally, as in medicinal or recreational purposes; (2) accidentally, as in unintentional overdoses; or (3) deliberately, as in suicide or exposure through criminal actions. Forensic toxicology helps determine the cause-and-effect relationships between exposure to a drug or other substance and the toxic or lethal effects of that exposure to humans.

The Big Ideas

Toxic substances include illegal drugs, controlled substances, poisons produced by living organisms, and heavy metals and pesticides. Controlled substances are divided into five classes: hallucinogens, narcotics, stimulants, anabolic steroids, and depressants. Drugs classified as controlled substances can affect the user's perceptions, thinking, self-awareness, and emotions; affect the functioning of the central nervous system; stimulate feelings of well-being; relieve anxiety; and promote cell growth. Organic toxins interfere with an organism's metabolism. Alcohol affects behavior, damages the liver, and depresses the function of the central nervous system. Bacterial toxins paralyze muscles and damage the nervous system. Bioterrorism agents, such as ricin and anthrax, are extremely lethal poisons that can be easily introduced into the environment.

CHAPTER 1 2 3 4 5 6 7 8 **9** 10 11 12 13 14 15 16 17

CHAPTER 9

Drug Identification and Toxicology

AN ACCIDENTAL OVERDOSE

Within weeks of her death on February 9, 2007, it was determined that model and tabloid celebrity Anna Nicole Smith had died from an accidental overdose of prescription drugs, rather than as the result of foul play or illegal drug use. But how did the medical examiner know which drugs Smith had taken? And how was it determined that the overdose was accidental rather than intentional? Specific forensic analyses by toxicologists helped determine the drugs Smith used and how they caused her death.

©AP Photo/Manuel Balce Ceneta

Anna Nicole Smith died from an accidental overdose.

The Broward County Medical Examiner in Florida reported that nine drugs and a few drug metabolites were found in Smith's blood. The drugs included antianxiety and antidepression prescriptions, such as Valium, pain and allergy medications, such as Benadryl, the antibiotic Ciprofloxacin, as well as human growth hormones. All drugs were found at therapeutic levels. Tests also found the presence of chloral hydrate, a sedative and sleeping medication. Specialists determined that when this sedative combined with the other drugs in her system, it led to Smith's accidental death. The combined drug effect acted on her respiratory and circulatory systems, causing them to stop working. The medical examiner ruled out that this was a suicide, as some suggested, because of the large amount of chloral hydrate remaining in the bottle and the normal levels of the other medications in her system.

Drug interactions can cause death in even small doses. Anna Nicole Smith's 20-year-old son Daniel also appears to have died from a lethal combination of drugs. In Daniel's case, it was a lethal combination of antidepressants Lexapro and Zoloft, and the drug methadone. This drug cocktail appears to have affected his central nervous system and heart, leading to his sudden death. Forensic investigations of both tragic deaths found no evidence to indicate foul play. Both overdoses were accidental.

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SCENARIO

The death of Anna Nicole Smith was described by the medical examiner as an accidental overdose of prescription drugs she was taking. Ask students if they think a physician would prescribe drugs that, taken in combination, might be deadly. Smith's death occurred a short time after the drug overdose death of her son, Daniel. Smith's mother believes that the two deaths were not accidental. Have students discuss how they feel about the mother's claim.

KEY SCIENCE CONCEPTS

Biology: effects on the human body

Chemistry: components of drugs

Teaching Resources

- Instructor's Resource CD-ROM includes:
  - PowerPoint Presentation
  - Lesson Plan and extended Objective Sheets
  - Teacher Notes and Activities
  - Activity Forms
  - Rubric
- ExamView CD-ROM
- E-book on CD-ROM

Web site: school.cengage.com/forensicscience

Engage

Ask students to discuss this situation: They have a bad cold. Not only do they have a runny nose, they have a cough and a bad headache. They are planning to take three different medications for all three symptoms. What is a possible problem with their plan? Then ask: What toxic substances do you come in contact with in your everyday life? What is the purpose of these substances? How does the benefit of their use compare with the danger of exposure to their effects?

Evaluate

Encourage students to discuss these questions:

- Are any legal drugs dangerous?
- Are any toxins legal?

Another option is to ask students to create posters or pamphlets on various drugs and/or toxins. Posters should include symptoms, treatment, method of evidence collection, relationship to crime, etc.

Explore

Draw students' attention to the quotation from Paracelsus, a Swiss physician who traveled to Europe and China. He rejected the idea that healing was "magic" and pioneered the use of chemicals and metals in medicine. Ask students for examples of common substances that can be poisonous depending on the size of the dose, the length of the exposure, or the means of exposure.

Evaluate

Prescription and over-the-counter drug labels have printed warnings about possible side effects. Lead the class in a discussion about whether students think these warnings are helpful. Why or why not?

INTRODUCTION

Toxicology is the study of **poisons** and the identification of **drugs** and other substances a person may have used for medicinal, recreational, or criminal purposes. Toxicology also examines the harmful effects of poisons and drugs on the body. Most people are exposed to drugs or other **toxins** by (1) ingesting them so they enter the gastrointestinal system, (2) inhaling them into the lungs, (3) injecting them into the bloodstream, or (4) absorbing them through the skin.

The **toxicity**, the degree to which a substance is poisonous or can cause injury, of a drug or other substance depends on many factors: the dose (how much of it is taken in or absorbed), the duration (the frequency and length of the exposure), the nature of the exposure (whether it was ingested, inhaled, or absorbed through the skin), and other individual factors, such as whether the drug or toxin interacts with other substances in the body such as alcohol or prescription drugs. Also, many substances are only indirectly toxic because the substance that the drug is converted or metabolized to in the body is harmful. For example, wood alcohol or methanol is chemically converted to toxic metabolites, formaldehyde and formic acid, in the human liver.

Forensic toxicology helps determine the cause-and-effect relationships between exposure to a drug or other substance and the toxic or lethal effects from that exposure. Exposure to drugs and other toxins may be determined by performing chemical tests to analyze body fluids, stomach contents, skin, hair, or in the case of lethal exposures, internal organs, such as the liver, and from the vitreous humor fluid of the eye.

In addition to drugs that may be toxic, toxic agents may also include heavy metals, solvents and vapors, radiation and radioactive materials, dioxins/furans, pesticides, and plant and animal toxins.

Toxic substances also are classified by how people are exposed to them:

- *Intentionally.* As in drugs taken to treat an illness or relieve pain
- *Accidentally.* Ingested or exposed, as in unintentional overdoses or harmful combinations
- *Deliberately.* As in suicide or exposures intended to harm or kill others

Saliva-based drug tests are as accurate as urine-based tests. The saliva test can generally detect illegal drugs immediately on use for up to about 72 hours.

Obj. 9.5

A BRIEF HISTORY OF DRUG IDENTIFICATION AND TOXICOLOGY

> "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy." Paracelsus (1493–1541)

The Greek philosopher Socrates was one of the earliest reported victims of poisoning (hemlock, 399 B.C.). By the 17th century, poisoning had become a profession. Toxic doses of poisons were administered among the rich, and occasionally royal, families of Europe as a means of settling disputes. Arsenic and cyanide are extremely toxic in small amounts. The use of arsenic as a poison was widespread and became known as "inheritance powder." It was not until the 1800s that methods of chemical analysis were developed to identify arsenic and other toxins in human tissue. The first

Science

Biology

How does inhaling drugs or toxins into the lungs affect the body? Because the lungs have large beds of capillaries, which are tiny blood vessels, inhaled chemicals are capable of crossing the membranes to enter the blood fairly rapidly. The blood then travels through the circulatory system to the heart, which pumps it out through the arteries to cells in the body tissues.

Science

Biology

The liver detoxifies the body's wastes. This function causes it to be directly affected by drugs and toxins.

forensic toxicologists to popularize these new methods were physicians Mathieu Orfila (1787–1853) and Robert Christison (1797–1882).

If two people use the exact same amount of a drug and are tested, the person with darker hair will retain more drug in his or her hair than the lighter-haired person.

MURDER BY POISON

Although poisoning is popular in murder mysteries and detective stories, in reality, it is not a common form of murder. Less than one-half of 1 percent of all homicides result from poisoning. Throughout history, some notable individuals have died from poisoning: Nazi leaders Heinrich Himmler and Hermann Goering ingested cyanide capsules in 1945; Jonestown cult members consumed cyanide-laced punch in 1978, killing approximately 900 people; Bulgarian dissident Georgi Markov was killed by ricin in 1978; and most recently, Russian ex-spy Alexander Litvinenko was exposed to radiation in 2006. Today, the commonly used poisons include arsenic, cyanide, and strychnine, as well as an assortment of industrial chemicals that were created for other uses, such as fertilizers.

Testing for a vast array of possible toxins can be a challenge to the toxicologist. Toxicologists must distinguish between acute poisoning and chronic poisoning. *Acute poisoning* is caused by a high dose over a short period of time, such as cyanide ingestion or inhalation, which immediately produces symptoms. *Chronic poisoning* is caused by lower doses over long periods of time, which produces symptoms gradually. Mercury and lead poisoning are examples of chronic poisoning in which symptoms develop as the metal concentrations slowly rise and accumulate to toxic levels in the victims' bodies over a long period of exposure.

ACCIDENTAL DRUG OVERDOSES

Accidental deaths from drug overdoses are more common than deaths from poisoning. The deaths of comedians John Belushi and Chris Farley, actor River Phoenix, and musicians Steve Clark, Janis Joplin, Jim Morrison, and Jimi Hendrix were all linked to lethal drug combinations or overdoses.

DRUGS AND CRIME

Illegal drugs, such as heroin and lysergic acid diethylamide (LSD), are drugs with no currently accepted medical use in the United States. **Controlled substances** are defined as legal drugs whose sale, possession, and use are restricted because of the effect of the drugs and the potential for abuse. These drugs are medications, such as certain **narcotics**, depressants, and stimulants, that physicians prescribe for various conditions.

Arrests for drug abuse violations have increased steadily since the early 1990s. Drug abuse violations topped the list of the seven leading arrest offenses in

Digging Deeper

with Forensic Science e-Collection

Do research on modern detection methods and the techniques of forensic toxicology or drug-testing work, such as the different chromatography and spectrometry methods. Go to the Gale Forensic Sciences eCollection on school.cengage.com/forensicscience and research the various methods. Determine which methods are more appropriate for the major types of controlled substances. Relate your findings to the chemical properties of the major controlled substances. Cite any limitations or concerns in using any of these methods for drug testing.

Evaluate

Organize students into small groups. Instruct each group to gather and graph data on the number of drug abuse violations in the United States (or a select state) for one year, from 2000 to the present. Have each group share its results with the class. Then, compare the graphs, and discuss any trends students detect and how they might be explained.

Science

Chemistry

How does the dosage of a drug matter? Drugs have what is called the Maximum Therapeutic Concentration (or Maximum Toxic Concentration), which is the largest amount of the drug in the system that is helpful without having dangerous side effects. Taking a drug with a dosage that is too high, or too much of a drug, enters the Maximum Toxic Concentration level.

Digging Deeper

After students research drug-testing in Digging Deeper, instruct them to organize their material in a chart listing the major types of controlled substances, the chemical properties of each substance, the detection method most appropriate for each, and the limitations or concerns in using any of these methods for drug testing. For additional information, go to the Gale Forensic Sciences eCollection at school.cengage.com/forensicscience.

Differentiated Learning

Teaching At-Risk Students

Cooperative learning allows students of varying abilities to share responsibility for learning. Assign students to work together as a group to research recent accidental—and fatal—drug overdoses of musicians, actors, and/or athletes. Students should then organize and present their findings to the class.

Differentiated Learning

Teaching English-Language Learners

Ask students to tell you what the words "accidental" and "overdose" mean. They might first use words in their native language before learning the English word. Have them look in the chapter for some of the words they might need. The use of visual aids can help illustrate concepts.

Teaching Tip

People who accidentally overdose on OTC drugs or prescriptions do not realize that a drug in the system has a specific half-life, the amount of time it takes for half the drug to be eliminated from the system.

Evaluate

Allow students to debate these questions:

- Should student athletes be tested routinely for drugs?
- Should all students be tested routinely for drugs?
- You can find more information on the drug debate on the Instructor's Resource CD.

Explore

Have students research anabolic steroids. How are they used? What effects do they have on the body? Why is taking anabolic steroids dangerous? Then have students create posters illustrating their findings.

Science

Biology

Why are these substances controlled? Controlled substances such as hallucinogens and narcotics have a powerful effect on the human body. They increase or decrease blood flow to the brain and major organs. They affect liver functions and, depending on how they are taken into the body, can affect the lungs, throat, and other areas of contact.

the United States in 2005. Drug offenders make up more than half of the federal prison system population and about 20 percent of the state prison population.

Obj. 9.1, 9.2, and 9.3

CONTROLLED SUBSTANCES

There are five classes of controlled substances: (1) hallucinogens, (2) narcotics, (3) stimulants, (4) anabolic steroids, and (5) depressants.

Hallucinogens

Hallucinogens are often derived from plants and affect the user's perceptions, thinking, self-awareness, and emotions. Hallucinogens derived from plants include mescaline from a cactus (peyote), marijuana, and extracts from certain mushrooms. Hallucinogens, such as LSD, MDMA (the amphetamine ecstasy), and PCP (angel dust), are chemically manufactured. The effect and intensity of response to the drug varies from person to person.

LSD was originally found in 1938 in a fungus that grows on rye and other grains and is one of the most potent mood-changing chemicals. It is odorless, colorless, and tasteless and is sold in tablets or on absorbent paper divided into small decorative squares. PCP was first developed as an anesthetic, but it is no longer used because it induces hallucinations. In the illicit drug market, PCP is available in a number of forms. It may be a pure, white, crystal-like powder, a tablet, or a capsule. It can be sniffed, swallowed, smoked, or injected. Mescaline is smoked or swallowed in the form of capsules or tablets. Marijuana leaves (cannabis) may be smoked or refined, concentrated, and sold as hashish. Hashish is made from resin found on ripe flowers, which are rolled into balls and smoked. Figure 9-1 shows hallucinogenic drugs and the characteristic symptoms of an overdose.

Figure 9-1. *Table of hallucinogenic drugs and the characteristic symptoms of an overdose.*

Drug	Characteristics of Drug Overdose
MDMA (ecstasy)	Increased heart rate and blood pressure, muscle cramps, panic attacks, seizures, loss of consciousness, stroke, kidney failure, death
Mescaline	Hallucinations, euphoria, dizziness, vomiting, increased heart rate, dilated pupils, diarrhea, headaches, anxiety, irrationality of thoughts
LSD	Dilated pupils, loss of appetite, sleeplessness, increase in body temperature, increased heart rate and blood pressure, sweating, dry mouth, tremors, confusion, distortion of reality, and hallucinations
PCP	Increased heart rate and blood pressure, convulsions, sweating, dizziness, numbness, and possibly death from heart failure. Drowsiness, which can lead to accidents. Users sometimes exhibit psychosis (completely losing touch with reality) that can last for weeks.

Differentiated Learning

Teaching Gifted Students

Assign a group of students to explore gene doping, a procedure that adds genes to increase muscle development, and then prepare a short report to present to the class. Students could also explore how this practice is different from drug doping. They might also look at how this practice has crept into the sport of horse racing.

Differentiated Learning

Teaching Gifted Students

In May 2007, Bjarne Riis of Denmark, the 1996 Tour de France winner, admitted that he used the blood-booster drug erythropoietin (EPO) during his Tour victory. The leader of the Tour de France was disqualified before the completion of the race because of alleged drug abuse. At least six other Tour champions have been found guilty of using banned drugs. Let students work in groups to find out who these athletes were, what effects the drugs had on their bodies, how they were able to escape detection, and what procedures could be put in place to prevent this from happening in future races. Ask them to share their findings with the rest of the class.

Narcotics

Narcotics act to reduce pain by suppressing the central nervous system's ability to relay pain messages to the brain. Narcotics include opium and its derivatives—heroin and codeine. These painkillers are very habit forming. Hydrocodone (Vicodin, Lortab), methadone (Dolophine), morphine (MS Contin), oxycodone (Percocet, OxyContin), and codeine-containing pain relievers, such as Tylenol 3 (acetaminophen and codeine), are man-made narcotic painkillers that are often abused. See Figure 9-2 for a summary of narcotic drugs and the characteristic symptoms of an overdose.

Figure 9-2. *Table of narcotic drugs and the characteristic symptoms of an overdose.*

Drug	Characteristics of Drug Overdose
Opium	Difficulty breathing, low blood pressure, weakness, dizziness, confusion, loss of consciousness, coma, cold clammy skin, small pupils
Heroin Codeine Morphine	Difficulty breathing, low blood pressure, coma, spasms of the stomach or intestines, constipation, nausea, vomiting, sleepiness, blue fingernails and lips, death
Methadone	Difficulty breathing, drowsiness, coma, low blood pressure, muscle twitches, blue fingernails and lips
Oxycodone	Slow, difficult breathing, seizures, dizziness, weakness, loss of consciousness, coma, confusion, tiredness, cold clammy skin, and small pupils

Stimulants

Stimulants increase feelings of energy and alertness while suppressing appetite. Depression often results as the effect of the drug wears off. They are also used and sometimes abused to boost endurance and productivity. Examples of stimulants include amphetamines, methamphetamines, and cocaine (including crack), and are highly addictive. The key difference between methamphetamines and amphetamines is that methamphetamines are more potent than amphetamines. Figure 9-3 shows characteristic symptoms of an overdose with stimulant drugs.

Figure 9-3. *Table of stimulant drugs and characteristic symptoms of an overdose.*

Drug	Characteristics of Drug Overdose
Amphetamines (Speed)	High blood pressure, rapid heart rate, agitation, irregular heartbeats, stroke, seizures, coma, death
Cocaine/crack cocaine	Dangerous rise in body temperature, sweating, tremors, seizures, irregular heartbeats, stroke, confusion, heart attack, bleeding in the brain, death
Methamphetamines	Dangerous rise in body temperature, profuse sweating, confusion, rapid breathing, increased heart rate, dilated pupils, high blood pressure, kidney failure, bleeding in the brain, death

Differentiated Learning

Teaching At-Risk Students

To connect academic concepts to real-world situations, ask at-risk students to collect reports of drug use and/or poisoning from television, newspapers, magazines, and the Internet. Have them discuss the reports in class. Help them connect the concepts of drug class and effects on the body to these real-world situations.

Differentiated Learning

Teaching Gifted Students

Will random drug searches help reduce drug-related problems among students, or are random drug searches an invasion of privacy? What is your opinion? Use the following source to prepare a debate on the issue.

Source: The Fayetteville Observer, Dec. 12, 2006, Fayetteville, North Carolina (www.fayobserver.com/article?id=249321)

Explore

Challenge students to find and report on the percentage of the federal and state prison populations who are incarcerated due to a drug- or alcohol-related crime.

Teaching Tip

Ask students to bring in newspaper articles on traffic accidents involving drugs and/or alcohol. As a class, read and discuss these articles.

Anabolic Steroids

Anabolic steroids promote cell and tissue growth and division. These drugs are produced in the laboratory and have a chemical structure similar to testosterone, the male sex hormone. Anabolic steroids were originally used to treat hypogonadism, a condition in which the testes produce abnormally low levels of testosterone. Today, they are used to treat some cases of delayed puberty, impotence, and muscle wasting caused by HIV infection. In the 1930s, they gained popularity with weightlifters and bodybuilders because they act to increase body muscle and bone mass. The negative side effects of anabolic steroids range from mild side effects, such as acne, increased body hair, and baldness, to severe side effects, such as high blood pressure and cholesterol levels, impaired fertility in males, blood clotting, kidney and liver cancers, and heart attacks.

Depressants

Depressants are drugs, such as barbiturates and benzodiazepines, that relieve anxiety and produce sleep. Depressants reduce body functions, such as heart rate, by acting on the central nervous system and increasing the activity of a neurotransmitter called GABA. The result of increased GABA production is drowsiness and slowed brain activity. The user becomes very calm, which is why these drugs are used to relieve tension and promote sleep. Side effects of depressants include slurred speech, loss of coordination, and a state of intoxication similar to that of alcohol. An overdose may slow heart rate and breathing and cause coma and death. Mixing depressants with alcohol and other drugs increases their effects and health risks.

OTHER ORGANIC TOXINS

Organic toxins are poisonous substances produced by living organisms. They are usually proteins that can be absorbed by another living creature and interfere with that organism's metabolism. Poisons are generally absorbed into an organism through the intestine or the skin. A bee sting or snakebite is an example of *venom*, a toxin secreted by an animal that can be transferred to a human (Figure 9-4).

Figure 9-4. *Snake venom can be a deadly organic toxin.*

ALCOHOLS

All alcohols are toxic to the body. Methanol is not directly poisonous, but when it is converted by the liver to formaldehyde, it becomes very toxic. Ethanol, the alcohol found in many beverages, is called grain alcohol. It is produced by the fermentation of sugar in fruits, grains, and vegetables. Pure ethanol is tasteless, but it can damage human tissue.

The body converts ethanol to acetaldehyde and then acetic acid. When too much acetaldehyde accumulates in the blood, it may produce dehydration and the classic symptoms of a hangover, headache, nausea, and weakness. Chronic abuse of alcohol can cause liver damage as well as disturbed, dangerous behavior. Consumption of alcohol can depress the central nervous system as well.

BACTERIAL TOXINS

Botulism is the most poisonous biological substance known to humans. It is produced by the bacterium *Clostridium botulinum* and acts as a neurotoxin,

Science

Biology

People react differently to organic toxins found in nature. Some people go into shock or die from a bee sting or insect bite, while others are merely irritated. Unfortunately, there is no sure way to know how someone will react except experience. There are many "horror stories" of someone eating a wild berry or getting a bug bite with serious, and sometimes deadly, effects.

Science

Biology

There are an average of 110 cases of botulism in the United States each year. About 25 percent of these are food borne. Most cases involving two or more people are caused by eating home-canned food rather than eating foods from unclean restaurants or ill-prepared food.

paralyzing muscles by blocking the release of the neurotransmitter acetylcholine. If the condition is diagnosed early, then an antitoxin made from horse serum may be given. Because damage caused by the toxin is irreversible, acetylcholine release and muscle strength may take months to return, and recovery depends on how quickly the nerves sprout new endings.

This bacterial toxin is extremely deadly in very small amounts and causes painful spasms before death. The toxin may be ingested from contaminated food, such as canned vegetables, cured pork and ham, smoked or raw fish, and honey or corn syrup. People also become infected with bacterial spores that produce and release the toxin in the body. The spores that contain the toxin are sensitive to heat and may be destroyed by cooking and heating thoroughly at 80 degrees Celsius (176 degrees Fahrenheit) for 10 minutes or longer. Purified botulinum toxin (sometimes called "botox") has been safely used in medicine to treat muscle spasms, eye conditions, excessive sweating, and headaches, as well as to stimulate wound healing and as a cosmetic treatment.

Clostridium tetani is the bacteria that produce tetanus, a potentially deadly nervous system disease (Figure 9-5). The bacteria release tetanospasmin, a poison that blocks nerve signals from the spinal cord to the muscles, causing muscle spasms so severe that they can tear muscles and fracture bones. Tetanus is sometimes called "lockjaw" because spasms often begin in the jaw and may interfere with breathing. Worldwide, tetanus causes approximately 1 million deaths per year. In the United States, tetanus accounts for about five deaths per year, primarily in persons who have not been vaccinated against the disease.

Figure 9-5. *Clostridium botulinum.*

HEAVY METALS AND PESTICIDES

Applications of pesticides have been used primarily for controlling insects, mice, weeds, fungi, bacteria, and viruses that threaten plants or food crops. Pesticides are, by definition, toxic and can cause severe illness and death. Because one of the measures of toxicity of an exposure is its duration, time is of the essence in recognizing pesticide poisoning.

Metal compounds, such as arsenic, lead, and mercury, are very poisonous and have also been used for suicide and homicide. Metals may enter the body by ingestion and inhalation or by absorption through the skin or mucous membranes. Metals are stored in the soft tissues of the body and can damage many organs throughout the body. Figure 9-6 on the next page lists heavy metals and pesticides with characteristic symptoms of an overdose.

Other lethal agents include gases, such as hydrogen cyanide (used in gas chambers), carbon monoxide (nonventilated car exhausts), and potassium chloride

Digging Deeper

with Forensic Science e-Collection

Do research on how forensic toxicologists take samples from living or deceased human bodies. Go to the Gale Forensic Sciences eCollection on school.cengage.com/forensicscience and investigate the body organs and body fluids that can provide samples for toxicological testing. Such organs and fluids may include brain, liver, spleen, urine, blood, hair, stomach contents, and the vitreous humor from the eye. Determine which samples are often used in drug testing for employees and athletes. Find out which sample type is the preferred technique for measuring alcohol content in drunk driving cases. Investigate whether there any time restrictions for detecting drugs in the various kinds of samples.

Explore

Lead poisoning often occurs with no obvious symptoms and often goes unrecognized. It can cause learning disabilities and behavior problems in children. Point out that some people still live in older buildings with lead-based paints. Ask students to investigate which children would be most likely to be affected by lead and how they would be exposed to it.

Science

Chemistry

Interestingly, the body needs some heavy metals, such as zinc, copper, chromium, iron, and manganese, in small amounts. However, these same metals can be toxic in larger quantities.

Digging Deeper

Ask students to organize their research data from Digging Deeper into a chart with four columns labeled as follows: Sample Source, Drug Testing, Alcohol Content: Drunk Driving, and Time Restrictions for Testing. For more on drug testing, go to the Gale Forensic Sciences eCollection at school.cengage.com/forensicscience.

Teaching Tip

Ask students to describe the Mad Hatter in *Alice in Wonderland*. Ask: How does his behavior resemble the description of mercury poisoning on the chart?

Figure 9-6. *Table of heavy metals and pesticides, with characteristic symptoms of an overdose.*

Drug	Characteristics of Drug Overdose
Pesticides (e.g., DDT, aldrin, dieldrin)	Phosphate-containing pesticides that accumulate in fatty tissue inhibit cholinesterase, leading to excess acetylcholine, which interferes with the movement of nerve impulses and muscular contractions. Anxiety, seizures, twitching, rapid heartbeat, muscle weakness, sweating, salivation, diarrhea, tearing, coma, and death
Lead	Nausea, abdominal pain, insomnia, headache, weight loss, constipation, anemia, kidney problem, vomiting, seizure, coma, and death. Blue discoloration appears along the gumline in the mouth.
Mercury	The Mad Hatter's Disease (hat-makers in England used a mercury compound) is a progressive disorder as mercury is absorbed into the skin or lungs. Acute poisoning from inhalation causes flu-like symptoms such as muscle aches and stomach upset. Chronic poisoning causes irritability, personality changes, headache, memory and balance problems, abdominal pain, nausea, and vomiting, as well as excessive salivation and damage to the gums, mouth, and teeth. Long-term exposure can cause death.
Arsenic	Within 30 minutes of ingestion it produces abdominal pain, severe nausea, vomiting and diarrhea, dryness of the throat, difficulty speaking, muscle cramps, convulsions, kidney failure, delirium, and death. Chronic exposure produces skin lesions and changes in pigment, headache, personality changes, nausea, vomiting, diarrhea, convulsions, and coma.
Cyanide	Cyanide overdose can be fatal six to eight minutes after ingestion. Rapidly causes weakness, confusion, coma, and pink skin from high blood oxygen saturation. Produces an almond-like odor.
Strychnine	Enters the body by inhalation or absorption through eyes or mouth. Body spasms, temperature rises, violent convulsions, and rigor mortis (stiffness after death) occurs within minutes.

or sodium pentothal (used in lethal injections). These poisons produce death by inhibiting enzyme activity, interfering with production of adenosine triphosphate (ATP), which is required to provide energy for cellular function, or, in the case of lethal injections, stopping the heart by destroying the cell's potential for transmitting electrical impulses.

BIOTERRORISM AGENTS

Obj. 9.4

Ricin is a component of the waste product of the manufacture of castor oil from castor beans. It is lethal in humans in quantities as small as 500 micrograms—a dose the size of the head of a pin! Ricin poisoning can be induced in various forms. It can be inhaled as a mist or a powder, ingested in food or drink, or even injected into the body. It acts by entering the cells of the body and preventing them from making necessary proteins, causing cell death. When enough cells die, death may occur. See Figure 9-7 for methods of ricin poisoning and the characteristic symptoms.

Figure 9-7. *Table of methods of ricin poisoning and the characteristic symptoms.*

Exposure	Symptoms
Inhalation	Within eight hours of exposure, difficulty breathing. Within a few hours, fever, cough, nausea, sweating, tightness in the chest, low blood pressure, excess fluid in lungs, and death
Ingestion	Within six hours of exposure, vomiting, diarrhea, bloody urine, dehydration, low blood pressure, hallucinations, seizures, and death
Skin and eye	Redness and pain

Anthrax is caused by a bacterium, *Bacillus anthracis*, that forms endospores (Figure 9-8). A spore is a thick-walled inactive cell that can later grow under favorable conditions. Infected animals can transmit the disease through spores to humans, but human-to-human transmission has not been reported. Anthrax can enter the body by inhalation, ingestion, or skin absorption. Figure 9-9 shows characteristic symptoms of anthrax exposure.

Figure 9-8. *Microscopic view of anthrax organisms.*

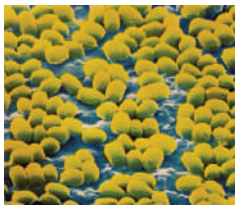

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Figure 9-9. *Table of methods of anthrax exposure and characteristic symptoms.*

Exposure	Symptoms
Inhalation	Initially produces flu-like symptoms, such as sore throat, cough, fever, and muscle aches. Symptoms become progressively worse to include breathing problems and usually results in death.
Ingestion	Nausea, vomiting, fever, abdominal pain, and severe diarrhea. Intestinal anthrax is fatal in 25 to 60 percent of cases.
Skin absorption	Raised, itchy bumps that resemble an insect bite develop into a painless sore with a black area in the center. About 20 percent of untreated cases of cutaneous anthrax result in death. Deaths are rare with appropriate treatment.

In 2001, anthrax spread through the U.S. postal system in letter-sized envelopes caused 22 cases of anthrax infection, half of which resulted in death.

Teaching Tip

Have students check newspapers and magazines for incidents in which people received suspicious substances through the mail.

Differentiated Learning

Teaching English-Language Learners

Allow students to work in a group to create a graphic organizer that classifies all of the drugs and toxins described in this chapter.

Explore

Tell students that before taking any drug, they should research that drug. What is the purpose of the drug? How much should you be taking? Are there any side effects? Are there any precautions you should be made aware of before taking the drug? Have them choose one of the following to research: Aspirin, Actifed, Allegra, Aleve, Ampicillin, Amoxicillin, AZT, Celebrex, Cortisone, Coumadin, Coricidin, Cyclosporine, Dimetapp, Erythromycin, Heparin, Imitrex, Lipitor, Lotrel, Nexium, Prednisone, Penicillin, Ritalin, Robitussin, Valium, Viagra, Xanax, Zyrtec. Have them report the following information:

- Brand name of the drug
- Generic or common name of the drug
- Is this drug prescribed or is it an over-the-counter (OTC) drug?
- Major uses of this drug
- Possible side effects
- How is the drug administered?
- Suggested dosages for different age groups
- Any drug interactions?
- Special warnings or precautions
- Is there any controversy over the use of this drug?

Also see the IRCD, Additional Materials, Chapter 9, Drug Research for information and an activity sheet.

SUMMARY

- Forensic toxicology seeks to identify poisons or drugs in criminals and victims and their likely effects on those people.
- The history of intentional poisoning goes back to ancient Greece. The chemical analysis of poisons in the body began in the 19th century.
- Poisoning is rare as a form of murder, but toxicology is important in studying cases of drug overdoses and sporting violations.
- Controlled substances fall into five groups: hallucinogens, narcotics, stimulants, steroids, and depressants.
- Poisons produced by living organisms include alcohol and bacterial toxins.
- Heavy metals and pesticides are also common poisons found in humans.
- Bioterrorism agents include ricin, a poisonous compound produced by the castor bean plant, and anthrax, a bacterium that produces potent toxins.

CASE STUDIES

Mary Ansell (1899)

Mary Ansell, an English housemaid, poisoned her sister Caroline to obtain an insurance settlement. Mary sent Caroline a cake tainted with phosphorous. Caroline died after eating the poisoned cake. Evidence of Mary's recent purchases of phosphorus and a life insurance policy in her sister's name was provided at her trial. Based on this evidence, Mary was quickly convicted and executed.

Eva Rablen (1929)

Eva Rablen loved to dance. On several occasions, her husband Carroll drove her to the schoolhouse, where weekly dances were held. The First World War had left Carroll wounded and deaf. He often remained in the car while his wife danced in the schoolhouse. Eva would frequently bring Carroll coffee and sandwiches while he waited in the car. On one such evening, Carroll was found dead after consuming his food and coffee. Initially, the death was attributed to natural causes, but later a bottle of strychnine was found below the floorboards of the schoolhouse. Eva was identified by a druggist as the person who purchased the poison a few days before the death of her husband.

When Dr. Edward Heinrich examined Carroll's body, traces of strychnine were found in his stomach, in the coffee cup, and on the seat of the car. On the way to the car, Eva bumped into a woman and spilled some of the

poisoned coffee on the woman's dress. Dr. Heinrich examined several drops of coffee left on that woman's dress and found strychnine. In the face of the mounting evidence, Eva changed her plea from not guilty to guilty to avoid the death penalty.

The Death of Georgi Markov (1978) and the Attack on Vladimir Kostov (1978)

©Jonathan Nourok/PhotoEdit

After defecting from Bulgaria, Georgi Markov moved to London. While walking one day, he was injected in the leg with ricin. The delivery method used a specially constructed umbrella with a modified tip for injection. He became gravely ill, and on the third day after the attack was vomiting blood. He suffered a complete heart blockage and died. The autopsy revealed a platinum-iridium pellet the size of the head of a pin in his leg. It had been cross-drilled with 0.016-inch holes to contain the toxin. The amount of ricin in the pellet, only two milligrams of the poison, was sufficient to cause his death.

Ten days earlier, a similar assassination attempt was made against Vladimir Kostov in Paris. Kostov's heavy clothing prevented an identical projectile from entering a major blood vessel. Instead, the pellet lodged in muscle tissue, preventing the poison from circulating as it had in Markov's body. This saved Kostov's life. On hearing of Markov's death, Kostov underwent a surgical examination, and the pellet was found before sufficient toxin could be absorbed to cause his death.

Tylenol Tampering (1982)


©Rubberball/Getty Images

Extra Strength Tylenol tablets dosed with cyanide claimed seven lives. The person(s) responsible have never been caught. It is believed that cyanide was added to the Tylenol and that the tainted bottles were placed on the shelves of several supermarkets and pharmacies in the Chicago area. In addition to the five bottles responsible for the seven deaths, three poisoned bottles were found on the shelves. Because they were from different production locations, investigators believed the tampering occurred after the product was shipped, rather than in the factory. This was the first documented example of random drug poisoning. The $100,000 reward posted by the drug manufacturer, Johnson and Johnson, has never been claimed. This incident led to the development of tamper-resistant packaging and caplets designed to protect the public.

In 1986, Stella Nickell, a Seattle woman, laced some Excedrin with cyanide and killed her husband for his life insurance. She placed three other poisoned bottles of Excedrin in the store to make it look like a random killing and killed another woman, Susan Snow, in the process. In 1988, Stella was sentenced to 99 years in prison.

Think Critically **You are an advertising executive. Select a category of controlled substance. Using your expertise, create a message to communicate the dangers of that substance to the public.**

Close

Organize students into groups and assign each group one of the following chapter topics: hallucinogens, narcotics, and stimulants; steroids; organic and bacterial toxins, including alcohol; heavy metals and pesticides; ricin and anthrax; and drug testing. Have each group summarize the key information about their topic.

Differentiated Learning

Teaching English-Language Learners

With early and intermediate language learners, make content more understandable by providing many nonverbal clues such as pictures, objects, and demonstrations. For example, you may want to show various OTC drugs and their containers to students and discuss their names and uses. As competency develops, build from language that is already understood, and use graphic organizers and hands-on learning techniques, especially with the activities.

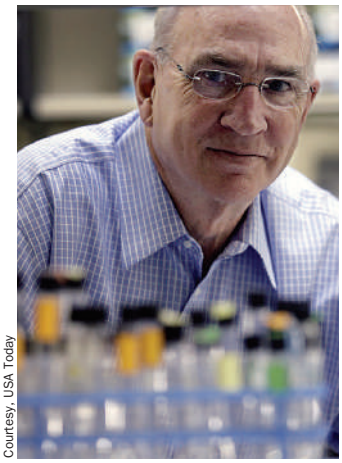
CAREERS

Some pharmacologists research drug addiction. They focus on drugs, both legal and illegal, that cause dependence. Those pharmacologists who study drug dependence focus on the mechanisms and risk factors that alter drug-taking behavior, as well as the consequences of drug exposure. Their long-term goals are to increase our ability to prevent and treat drug dependencies and reduce the harm associated with drug-taking behavior.

CAREERS IN FORENSICS

Dr. Don Catlin, Pharmacologist and Drug Testing Expert

Dr. Don Catlin recently left his position as head of the UCLA School of Medicine laboratory for a new research position. The UCLA laboratory, with more than 40 researchers, helped expose many drug-related sports scandals, by identifying players who were using performance-enhancing drugs. Catlin is one of the most respected sports and antidoping drug testers in the world, and he plans to remain active in the field of research.



Courtesy, USA Today

Dr. Don Catlin, respected sports drug tester.

Catlin became a professor in the Department of Pharmacology of the UCLA School of Medicine in 1972. In 1982, his interest in substance abuse led him to found the UCLA Olympic Laboratory to do the drug tests for the 1984 Los Angeles Summer Olympics. He also ran the drug testing for the 1996 Atlanta Summer Olympics and the 2002 Salt Lake Winter Games. His job has included testifying and defending his drug-testing methods in court.

The UCLA laboratory has provided drug education and urine tests to a growing number of sports organizations, including the U.S. Olympic Committee, NCAA, NFL, and Minor League Baseball. The lab has developed novel drug tests, such as the one used to distinguish between naturally produced and artificially taken testosterone. The laboratory is one of the world's premier places for analyzing samples from athletes to detect the use of illegal substances such as anabolic steroids, the blood-oxygen booster erythropoetin, and many other performance-enhancing drugs. It is the busiest lab of its kind in the world, with about 40,000 samples analyzed each year.

What kept Don Catlin so dedicated to the field of sports drug testing? Catlin says, "You should care about preserving something natural and beautiful. I can't think of anything more exciting than the Olympic model, where 220 countries in the world participate, and every four years they send their best to compete against the best from other countries and the best man or woman wins."

To be in the field of pharmacology, one needs a science education with graduate studies that include courses in analytical chemistry, drug metabolism, and drug pharmacokinetics. The drug-testing field requires special knowledge of legal and ethical issues. Pharmacologists can work in universities, hospitals, governmental organizations, nonprofit organizations, or pharmaceutical or related industries.

Learn More About It

To learn more about the work of a pharmacologist, go to school.cengage.com/forensicscience.

CHAPTER 9 REVIEW

True or False

1. Toxins are poisons manufactured in laboratories. *Obj. 9.3*
2. The major ways people are exposed to toxins are by ingesting them, inhaling them, injecting them, or absorbing them through the skin. *Obj. 9.2 and 9.3*
3. Today, poisoning is a very common form of murder. *Obj. 9.2 and 9.3*
4. There are six basic types of controlled substances. *Obj. 9.2 and 9.3*
5. Accidental deaths from drug overdoses are more common than deaths from poisoning. *Obj. 9.2 and 9.3*
6. Anabolic steroids increase muscle mass and have no harmful effects. *Obj. 9.2 and 9.3*
7. *Clostridium botulinum* causes lockjaw. *Obj. 9.2 and 9.3*
8. All alcohols are toxic to the body. *Obj. 9.2 and 9.3*
9. Mercury can cause the symptoms of acute poisoning. *Obj. 9.2 and 9.3*
10. Some poisons, like potassium chloride, interfere with enzyme activity. *Obj. 9.2 and 9.3*

Short Answer

Choose a part of the body or a product from the body and describe what type of drug testing could be performed on that part of the body.

Urine: testing for steroid, narcotics

Hair: testing for alcohol and drug use

Breath: testing for alcohol

Muscle: testing for anabolic steroids

11. How is the test performed? *Obj. 9.2 and 9.3*

_____

_____

_____

_____

12. How expensive is the testing? *Obj. 9.2 and 9.3*

_____

_____

_____

_____

Chapter 9 Review

True or False

1. False
2. True
3. False
4. False
5. True
6. False
7. False
8. True
9. True
10. True

Short Answer

11. Answers will vary depending on the test.
12. Answers will vary depending on the test.

13. Answers will vary depending on the test.
14. Answers will vary depending on the test.
15. Answers will vary depending on the test.
16. a. Answers will vary depending on the test.
    b. Answers will vary depending on the test.
    c. Answers will vary depending on the test.
    d. Answers will vary depending on the test.
17. Answers will vary depending on the test.

13. Is the test invasive? *Obj. 9.2 and 9.3*

_____

_____

_____

14. Can the test be easily performed on a living person? *Obj. 9.2 and 9.3*

_____

_____

_____

15. Is a skilled technician required to perform the test and to read the results? *Obj. 9.2 and 9.3*

_____

_____

_____

16. Will the test demonstrate drug usage or toxin exposure: *Obj. 9.2 and 9.3*
    a. During the past hour?
    b. During the past several hours?
    c. During the past 24 hours?
    d. During the past few months?

17. How reliable is the drug testing? What variables may affect the results? *Obj. 9.2 and 9.3*

_____

_____

_____

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ACTIVITY 9-1 *Ch. Obj. 9.1 and 9.5*

DRUG ANALYSIS

Introduction:

It is essential that drug samples obtained from suspects are identified conclusively. Positive identification of a drug requires matching the unknown sample with a known sample of the drug. In this activity, students will prepare known samples of the drug to be tested (positive control) and a blank sample containing no drug (negative control). The positive and negative controls will be used for drug comparison and identification. The "drug" we will be testing is Bertinol®, a dangerous and addicting drug that, over time, destroys the liver and intestines. The test for the identification of a drug employs a chemical indicator that changes color in the presence of the drug.

Scenario:

Because of a recent incident involving the sale of the illegal drug Bertinol to junior high students, a "drug dog" was used to detect drugs in the lockers of four suspects. The police dog did detect the presence of white powders in the lockers of the four suspects. Did this white powder contain the drug Bertinol? The drugs were confiscated and sealed in a plastic vial and wrapped in evidence envelopes. The evidence envelopes were sent to the lab for positive identification.

Your task is to perform a drug test using a chemical indicator for the drug Bertinol. You will need to report your findings to the police. If any of the white powders test positive for Bertinol, the police will have reason to bring in the suspect(s) for further questioning.

Objectives:

Upon completion of Activities A and B, students will be able to:

1. Construct a positive control for drug testing.
2. Construct a negative control.
3. Describe the importance of both types of controls.
4. Demonstrate the role of a positive and negative control in drug testing.
5. Perform a simulated drug test on four white powders.
6. Determine if any of the white powders contain the drug Bertinol.

Safety Precautions:

A carefully maintained clean area should be set aside for testing of drugs. All materials used in this activity are harmless, but it is essential to maintain appropriate techniques in handling all samples. *Treat all samples as if they were actual samples of the drug*. Maintain the chain of custody. Wear safety goggles and dispose of all materials in the manner described by your instructor.

Vocabulary:

Positive control A known sample of the material tested with the chemical indicator used to show a reaction of the known material. A positive control reaction is used to compare with any unknown sample reactions.

ACTIVITY 9-1

Background

In this activity, students conduct a test to identify a simulated drug. A chemical indicator is used that changes color in the presence of the drug.

Safety Precautions

1. Review the safety precautions with the students before the start of the activity.
2. Post the procedure for disposal of materials in a prominent place.
3. Check that all students wear goggles.
4. Students should also wash their hands after handling drugs.

Procedures

1. Print, copy, and distribute Activity Sheet 9-1 from the IRCD.
2. Make sure students read all directions *before* beginning the activity.
3. Demonstrate the use of a graduated cylinder or pipette, and the toothpick transfer process, before beginning the activity.
4. Remind students of the need for positive and negative controls.
5. A new toothpick should be used with each new sample.

Negative control (blank) A sample that does not contain the drug to be tested and should therefore yield a negative test.

Time Required to Complete Activity:

45 minutes to complete both Activities A and B if working in groups of two

Materials:

(per group of two students)
6 empty clean vials with caps
marking pen
positive control envelope containing the drug Bertinol
negative control envelope containing a white powder that does not contain Bertinol
4 evidence envelopes containing white powder residues obtained from each of the four suspects
50 mL rubbing alcohol (70 percent propyl alcohol by volume) or ethyl alcohol
10 mL graduated cylinder or 5 mL pipette
flat wooden toothpicks
25 mL of Bertinol drug test solution in dropper bottles
tape

Procedure:

Part A: Creating the Positive and Negative Controls

1. Label one empty vial Negative Control.
2. Label the second vial Positive Control.
3. Into each vial, add 5 mL of rubbing alcohol.
4. Using the broad, flat side of a toothpick, remove a pinhead-sized amount of Bertinol from the envelope labeled Positive Control. Add this pinhead-sized amount of Bertinol to the vial labeled Positive Control.
5. Using the broad, flat side of a toothpick, remove a pinhead-sized amount of the white powder from the envelope labeled Negative Control. Add this pinhead-sized amount of white powder to the vial labeled Negative Control.
6. Add three drops of Bertinol drug test solution to the Negative Control vial.
7. Add three drops of Bertinol drug test solution to the Positive Control vial.
8. Observe and record the color changes in the Data Table.
9. Save these vials for comparison with the suspects' samples in Procedure B.

Part B: Comparing Samples

1. Label the four vials as follows: Suspect 1, Suspect 2, Suspect 3, and Suspect 4.
2. Using the graduated cylinder or pipette, add 5 mL of rubbing alcohol to each vial.
3. Using a clean, flat toothpick, transfer a pinhead-sized amount of the white powder from Evidence Envelope 1 to your vial labeled Suspect 1. Leave the toothpick in the Suspect 1 vial. It will be used later for stirring.

4. Reseal the Evidence Envelope properly and sign your name to maintain the chain of custody.
5. Repeat the procedure for each of the other Evidence Envelopes (i.e., Suspects 2, 3, and 4).
6. Leave the toothpicks in the suspect vials to stir the contents of each vial until dissolved. Be careful not to mix up the toothpicks.
7. Add three drops of Bertinol drug test solution to each of the four vials and stir with the individual toothpicks.
8. Observe any color changes. Record your results in the Data Table.
9. Compare test vials with the Positive Control and Negative Control vials. Do any of the evidence powders obtained from the four suspects contain the drug Bertinol?
10. Discard all liquids as described by your instructor except the two control vials.

Data Table: Drug Analysis

Sample	Appearance of Solution
Positive Control	
Negative Control	
Suspect 1	
Suspect 2	
Suspect 3	
Suspect 4	

Questions:

1. Explain the role of the positive and negative controls.
2. What measures were taken to avoid contamination of the drug samples?
3. Did any of the four suspect's white powder test positive for the presence of the drug? Explain your answer.
4. When all students in a class compared their results, they found all but one group had identical results. Determine three possible sources of error in technique that might have produced the difference in results.
5. Describe three ways to increase the reliability of this lab.
6. A student noted that when class results were compared, not every group had the same shade of color in their vials. What might account for the differences in color intensity?

Answers

Check students' data tables.

Questions

1. Sample answer: They are used for purposes of comparison. These controls tell us what color changes to expect.
2. Sample answer: Using individual toothpicks, working in a clean area, and labeling all materials carefully.
3. Answers will vary.
4. Sample answers: improper handling of containers; improper handling of materials, including adding the wrong reagent; not stirring all vials equally; contamination of the drugs; not adding enough drug powder or the Bertinol drug testing solution.
5. Sample answers: use larger samples or repeat the experiment; use more precise methods of measurement in preparing the drug tests; use the same time intervals to time the reactions.
6. Sample answer: different concentrations of drug, indicator, or both, or differences in the reaction time of the drug with the indicator.

Background

In this activity, students test for the presence of the drug Bertinol in urine.

Safety Precautions

1. Review the safety precautions with the students *before* the start of the activity.
2. Post the procedure for disposal of materials in a prominent place.
3. Check that all students wear goggles.
4. Tell students to rinse their hands thoroughly for several minutes if any reagents spill on their skin.

Materials

1% phenolphthalein solution, 200 mL
15% NaOH solution, 200 mL
several drops of red food coloring in 100 mL of water
several drops of yellow food coloring in 100 mL of water
distilled water
6 droppers per team labeled
- Positive urine
- Negative urine
- Student urine 1, 2, 3, 4

Procedures

1. Print, copy, and distribute Activity Sheet 9-2 from the IRCD.
2. Make sure students read all directions *before* beginning the activity.
3. Prepare the following solutions.
   - *Synthetic urine.* To 200 mL of distilled water add three or four drops of yellow food coloring and one drop of red food coloring (adjust the quantities to best represent the color of urine). This will be your stock urine solution.
   - *Positive urine sample and student urine 1.* Add 2 to 3 mL of phenolphthalein solution to 200 mL of urine sample. This will be the suspect's urine sample.
   - *Negative urine sample and student urines 2, 3, 4.* Add 2 to 3 mL of synthetic urine only.
   - *Bertinol drug indicator.* Use 15% NaOH solution for your Bertinol drug indicator. Sodium hydroxide is caustic, so handle it carefully, avoiding contact with skin and eyes.
4. After the solutions are produced, place in labeled dropper bottles. The urine samples for the class can either be dispensed in individual dropper bottles for each group, or they can be located in one central location in the room. Students could go to the central location to obtain their samples for each of their individual tests.

ACTIVITY 9-2 *Ch. Obj. 9.2*
URINE ANALYSIS

Introduction:

A student suddenly becomes ill during class. She demonstrates many of the symptoms of having used the drug Bertinol. When questioned, she says she had spent the previous night with three of her friends, none of whom used drugs or became ill. All four girls were asked and agreed to give a urine sample.

Objectives:

By the completion of this activity, students will be able to:
1. Prepare positive and negative controls for testing the drug Bertinol.
2. Perform a urinalysis on the four different students' urine.
3. Determine if any of the students' urine contains the drug Bertinol.

Safety Precautions:

A carefully maintained clean area should be set aside for testing of drugs. All materials used in this activity are harmless, but it is essential to maintain appropriate techniques in handling all samples. *Treat all samples as if they were actual drug samples.* Maintain the chain of custody where directed. Wear safety goggles and dispose of all materials in the manner described by your instructor.

Time Required to Complete Activity:

45 minutes working in groups of two

Materials:

(per group of two students)
Activity Sheets for Activity 9-2
6 empty vials
positive "urine" sample with the drug Bertinol for the positive control
negative "urine" sample without the drug Bertinol for the negative control
"urine" samples from four students
marking pen
Bertinol drug indicator solution
six 10 mL graduated cylinders or six 10 mL pipettes for "urine" samples
2 droppers

Procedure:

Part A: Preparation of the Positive and Negative Control Vials
1. Label one vial as the negative control.
2. Add 5 mL of negative urine to the negative urine vial.
3. Add five drops of the Bertinol drug indicator solution to the negative urine vial and swirl gently.
4. Observe your results and record them in the data table.

5. Repeat the process for steps 1 to 4 for the positive control, except this time add five ml of "urine" from the positive urine sample and add 5 drops of Bertinol drug indicator. Record your results in the data table.

Part B: Urinalysis Testing of the Students' Urine

1. Label four vials: Student 1, Student 2, Student 3, and Student 4.
2. Transfer 5 mL of urine from Student 1 to your vial labeled Student 1.
3. Add five drops of the Bertinol drug indicator solution to each of the students' vials.
4. Repeat the procedure for each of the other samples from Students 2 through 4. Use a sterile pipette each time you transfer the urine from the student urine samples to the vials to avoid contamination.
5. Observe the results.
6. Record your results in the Data Table, comparing student urine samples with the positive and negative urine test vials.
7. Discard all liquids as described by your instructor.

Data Table: Urinalysis

Urine Sample	Appearance of Solution
Positive Urine	
Negative Urine	
Student 1	
Student 2	
Student 3	
Student 4	

Questions:

1. Based on your test results, did any of the girls test positive for the drug or the drug metabolites? Justify your answer.
2. Why should the tests be conducted using designations Student 1, Student 2, and so forth rather than using the student's name?
3. The reliability of urinalysis testing has sometimes been questioned, because there is a possibility of someone altering the test results. Insurance companies frequently will request a urine sample from a prospective client. As a bodily fluid, the urine is used to detect drug use and health conditions such as diabetes. A person using drugs or who has sugar in their urine may be assessed a higher insurance

Answers

Check students' data tables.

Questions

1. Student 1. The color of the urinalysis test was pink. This matches the color of the positive control urine sample.
2. Sample answer: To prevent bias in testing and protect the rights of those tested.
3. To verify that the urine sample was just voided and not a urine sample that had been stored, the temperature of the urine was taken. The temperature of the urine should be body temperature, 37 °C or 98.6 °F.

premium than a person who is drug and disease free. Other than actually watching someone produce the urine sample, the agent from the life insurance company gives the person requesting life insurance a cup and requests a urine sample. When the urine sample is given to the insurance agent, a thermometer is inserted into the urine. Why would the insurance agent want to know the temperature of the urine?

Further Study:

1. To help reduce student drug use, some schools have decided to test the students' urine for the presence of drugs. Research the following information about drug testing in junior high and senior high schools
   a. High school coaches are asked to note symptoms of steroid abuse among their athletes. What would be some warning signs that the athletes were abusing steroids?
   b. List the drugs commonly tested for in a high school urinalysis.
   c. Investigate companies that sell urinalysis kits to high schools:
      - How expensive are the drug testing kits?
      - Do these kits require a trained lab technician to read the results?
2. Other methods exist for testing someone for the presence of drugs other than a urinalysis.
   a. What are the other methods?
   b. Compare and contrast the different types of methods used to detect the presence of a drug. Include in your answer:
      - Which methods detect the current use of drugs?
      - Which method is best used to detect drug usage over a period of two months?
      - Which methods are less invasive?
      - Which methods are less likely to be tampered with or altered?
3. The U.S. Supreme Court has ruled that mandatory drug testing for all students violates the Fourth Amendment of the U.S. Constitution.
   a. Summarize the contents of the Fourth Amendment.
   b. Explain how this amendment applies to mandatory drug testing of all students.
   c. Research when the Supreme Court rendered this decision.

Further Research and Extensions

Encourage students to investigate how to analyze different body parts or body fluids for the presence of drugs or toxins. Remind them to keep the following questions in mind as they research each method:

1. How is the test performed?
2. How expensive is the testing?
3. Is the test invasive?
4. Can the test be easily performed on a living person?
5. Is a skilled technician required to perform the test and to read the results?
6. Will the test demonstrate drug usage or toxin exposure:
   - During the last hour?
   - During the last several hours?
   - During the last 24 hours?
   - During the last few months?
7. How reliable is the drug testing? What variables may affect the results?

ACTIVITY 9-3 *Ch. Obj. 9.2 and 9.3*

DRUG IDENTIFICATION

Scenario:

Neighbors at the College Apartments complained that the person in room 202 had his television continually running with the volume turned up too loud. The people in rooms 201 and 203 said the sound kept them awake all night. When the neighbors tried knocking on the door of room 202, no one answered. They became concerned and called the police.

When the police arrived, they discovered that the young man had apparently died while sitting in front of the television. While working the crime scene, the police discovered 15 identical white pills on the table next to the victim. Did a doctor prescribe the drugs for medication? Are these over-the-counter drugs purchased without a prescription? Did the person use illegal drugs? How many of these drugs did the victim take? Was this death accidental or a suicide?

The first step is to determine what drugs the 15 pills contain. In this activity, you will perform preliminary tests on "drugs" to help determine their identity.

Background:

When samples suspected of being illegal drugs are brought into a laboratory, spot tests are often performed. These tests rapidly show results and are used to identify some of the most common drugs. The tests include:

Name of the Drug Test	Drug Identified	Positive Reaction
Marquis	Opium alkaloids such as heroin, morphine, codeine, or ecstasy Amphetamines Speed OxyContin	purple orange orange-brown gray
Cobalt thiocyanate	Cocaine	blue flaky precipitate
p-Dimethlyamino-benzaldehyde (p-DMAB)	LSD	blue
Duquenois	Marijuana	purple
Cobalt acetate/ iospropylamine test	Barbiturates	red-violet

Because most of these drugs to be tested are controlled substances, we will substitute similar tests, which would parallel real testing situations. The drugs in question for this case include aspirin, acetaminophen (Tylenol), naproxen (Aleve), and ibuprofen (Motrin).

ACTIVITY 9-3

Background

In this activity, students conduct spot tests to identify specific drugs.

Safety Precautions

1. Review the safety precautions with the students *before* the start of the activity.
2. Post the procedure for disposal of materials in a prominent place.
3. Check that all students wear goggles and gloves.
4. After this activity, it is important that students wash their hands and clean all counters and desk surfaces thoroughly.
5. The reagents used in this activity are caustic! The teacher should clean the lab dishes used by flooding with water and then washing and allowing it to air dry.

Materials

mortar and pestle
5 small covered plastic containers (film canisters) or microtubes
wooden toothpicks
Aspirin, Tylenol, Motrin and Alleve
Marquis Solution, Tannic Acid, Nitric Acid, and Ferris Chloride

Procedures

1. Print, copy, and distribute Activity Sheet 9-3 from the IRCD.
2. Make sure students read all directions *before* beginning the activity.
3. To produce samples of the drugs to be tested, it is suggested that you use a mortar and pestle to finely grind all of the pills. Try to find drugs that do not contain any color. If any pills are coated with a colored substance, remove all traces of color from the drug.
4. Use empty film canisters or small microtubes to store the drugs. Be sure to label each of the drugs.

Safety Precautions:

1. Anyone working at or near the testing station MUST wear safety goggles and gloves. The chemicals used are hazardous. They will be used in minute amounts.
2. Place newspapers on the desktops where testing is to be conducted.
3. Wash your hands thoroughly after testing is complete.
4. Discard all chemicals as directed by your instructor.
5. Thoroughly clean all counters and desk surfaces where testing has been completed.

Materials:

(per group of three to four students)
1 plastic well tray (24 wells per tray)
drug testing reagents in dropper bottles
Marquis, tannic acid, ferric chloride, nitric acid
samples of aspirin, Tylenol, Motrin, and Aleve
colored pencils
1 (5 × 8) index card
1 pair of scissors
1 pair of safety goggles per person
1 pair gloves per person

Procedure:

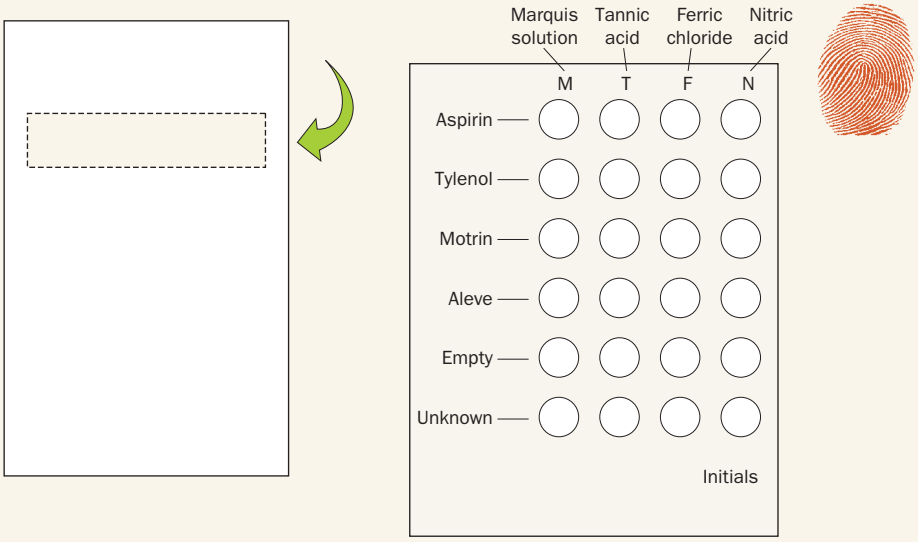
Part A: Preparing the Wells

1. Prior to testing, your instructor has prepared the unknown samples. Please treat these samples with care to avoid contamination. Wear safety goggles and gloves when performing this lab or standing in the vicinity of its performance.
2. Obtain a 5 × 8 card and trace and cut out the outline of the plastic mini-well tray. Place the plastic mini well tray on top of the 5 × 8 card. (See the example on the next page.)
3. Cut out a horizontal section of the 5 × 8 card the width of four rows of wells as indicated in the diagram on the next page to form a slotted card. This 5 × 8 card will be used to prevent contamination of one drug with the other while filling your wells. Put the slotted card aside for later use when adding your drugs to the mini well tray.
4. Obtain a second 5 × 8 card. Turn it so that the blank side is up. Place a mini 24-well tray on top of the card.
   a. Trace an outline of the mini tray on top of the 5 × 8 card.
   b. On the four-row side of the plastic mini tray, write the first letter (M, T, F, and N) for each of the chemical reagents.
   c. On the six-row side of the plastic mini tray, write the name of the "drug" to be tested in the first four rows.
   d. Leave the fifth row blank.
   e. Write "unknown" in the sixth row
   f. Record your initials in the lower right-hand corner of the 5 × 8 card.

Part B: Adding the Drugs to the Test Wells

1. The drug samples have been placed at different stations in the room. You are to take your plastic mini well tray with its lid and your labeled 5 × 8 card to each of the stations. Place the labeled 5 × 8 card behind

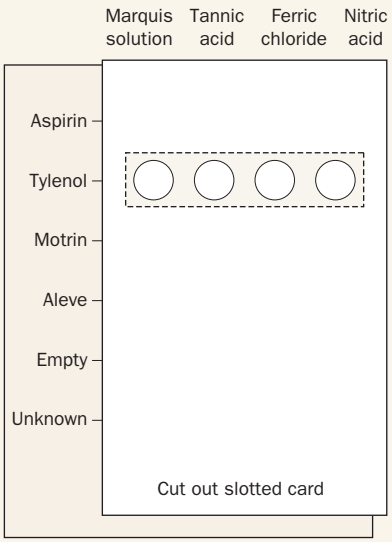
5. You can either provide each team with separate containers of the drugs in film canisters or microtubes, or set up one location in the lab where students can obtain their drug samples.
6. Select one of the drugs to be your unknown. It is more interesting if different groups have a different unknown so they can later review the class results. Ask different teams to analyze each other's drug test and try to identify their unknowns.
7. Ask each team to present their conclusions and justify their answers.
8. Students may take a digital photo of their lab results and include this picture as part of a lab report. Also, photos of an actual test could be used as part of a quiz or exam at a later date.



the plastic wells to ensure that you add the correct drug to the correct well.

2. You will add each of the drugs to their prescribed well. Aspirin will be added in the first row under Marquis, under Tannic Acid, under Ferric Chloride, and under Nitric Acid. There should be four wells filled with aspirin from left to right as indicated by the diagram. Follow the same procedure with each drug. To avoid contamination, use your cut-out slotted 5 × 8 card. Place the card over the plastic mini wells so that the cut-out row is correctly positioned for the drug that you will be adding. This way, the other rows are covered and will not become contaminated.

   The drugs to be tested (Aspirin, Tylenol, Motrin, Aleve, and the unknown) will be located at a designated lab station. Each station will have a small vial of white powder and a toothpick.
3. Using the flat end of the toothpick, place a pinhead-sized amount of aspirin powder into the four wells as indicated by the diagrams. Wipe off the 5 × 8 slotted card with a clean paper towel after adding each row of drugs.
4. Repeat step 3 with each of the other three remaining powders. Place powders in mini wells as shown in the diagrams.



Preparation of Drug Testing Solutions

(Prepare enough fresh solutions to last for the year. At the end of the school year, dispose of any unused solutions. Old, outdated solutions will discolor and interfere with readings.)

Marquis solution: 5 mL H_2SO_4 + 5 drops of formaldehyde—turns pink

Tannic acid solution: dissolve 10g tannic acid in 90 mL water

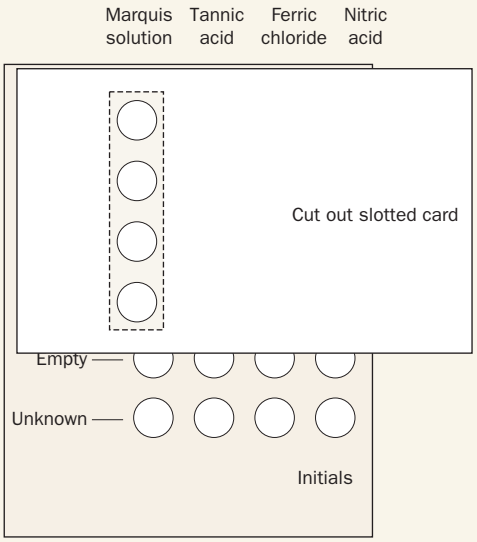
Ferric chloride solution: 2 g ferric chloride dissolved in 100 mL water

Concentrated nitric acid: straight from the bottle or diluted 1:1 with water

5. Using a toothpick, place a pinhead-sized amount of the unknown powder in row 6.

(If the lab needs to be completed on a different lab period, cover your mini wells with the plastic lid. You can add the chemical reagents during your next lab period.)

Addition of Chemical Reactions



1. Into column M, add two drops of Marquis solution to each of the five different drugs. Use the slotted card to shield the other rows to avoid contamination. You will need to rotate the slotted card in a vertical position to align with the columns.
2. Into column T, add two drops of tannic acid solution to each of the five different samples. Use the slotted card to shield adjacent wells from contamination.
3. Into column F, add two drops of ferric chloride solution to each of the five different samples. Use the slotted card to shield adjacent wells from contamination.
4. Into column N, add two drops of nitric acid solution to each of the five different samples. Use the slotted card to shield adjacent wells from contamination.
5. Gently agitate the mini tray, being very careful not to spill any of the mixtures.
6. Observe any changes that occur in the mini wells after adding the reagents. Record the changes in the Data Table 1. In particular, note

Data Table 1: Drug Testing Results

Row	Drug Tested	Marquis (Column M)	Tannic Acid (Column T)	Ferric Chloride (Column F)	Nitric Acid (Column N)
Row 1	Aspirin				
Row 2	Tylenol				
Row 3	Motrin				
Row 4	Aleve				
Row 5	Unknown				

changes in color, bubble formation, or precipitation. Use NR if no reaction occurred.

7. Sketch the appearance of your results on Data Table 2. Use colored pencils to indicate any color changes.
8. Examine your unknown drug. Compare the reactions of the unknown drug with the four known drugs. Based on these tests, can you identify the unknown drug?

Questions:

1. Refer to the opening scenario about the young man found dead in front of his television with 15 white pills next to him. After completing these preliminary tests, how could you determine if the victim took Aspirin, Tylenol, Motrin, or Aleve?
2. Justify your answer using supporting data from your experiment.
3. How would it be possible to determine if the victim took an overdose of pills? What procedures would be done at the autopsy to determine how much of these drugs the victim took?
4. Why was it important to wear both goggles and gloves when doing this experiment?

Data Table 2: Sketch Your Results
Use colored pencils to indicate color changes.
Write NR to indicate no reaction.

	Marquis solution (M)	Tannic acid (T)	Ferric chloride (F)	Nitric acid (N)
Aspirin				
Tylenol				
Motrin				
Aleve				
Empty				
Unknown				

Initials

Further Study

1. Investigate how forensic scientists test for the presence of the following drugs:
   a. Cocaine
   b. Heroin
   c. Amphetamines
   d. Barbiturates, rohypnol, PCP, glue sniffing
2. If a person is found unconscious as a result of an overdose of pills, he or she may be taken to a hospital to have the stomach pumped.
   a. What is this procedure?
   b. Is there any danger in having this procedure done?
   c. Would a stomach pump be of value if someone had injected the drug into his or her system? Explain your answer.

Answers

Check students' data tables. For Data Table 2, students should shade in each test area with the appropriate color. See the Teacher Notes for Activity 9-3 on the Instructor Resources CD for a photograph of test results.

Questions

1. Answers will vary.
2. Sample answer: Analyze the victim's stomach contents, urine, and blood.
3. The materials used are extremely caustic. Pumping the stomach could burn the esophagus, mouth, tongue, and other parts that come in contact with the stomach contents.
4. Eyes and hands need to be protected from toxic chemicals at all times.

Further Research and Extensions

Students might be interested in researching controversial drug-related deaths in history. Ask them to research the question: "How did Napoleon die?" Information available from multiple data sources provides conflicting conclusions about whether Napoleon died from natural causes or was poisoned. Biographies by Alan Schom (1998) and Frank McLynn (2003) also support different theories. Other possible research topics include Socrates and Cleopatra.