Forensic Chemistry

The methods and tools of science can be used to decide questions arising from crime, such as "How did a murder victim die?" or "Who was the murderer?" The application of science to solving crimes is called *forensic* science, which can be subdivided into the various areas of science. Forensic medicine, for example, employs the methods and tools of medicine, such as autopsies, to determine a cause of death. Similarly, forensic chemistry employs the methods and tools of chemistry, such as the analysis of materials, to identify criminal suspects or, perhaps, criminal intent.

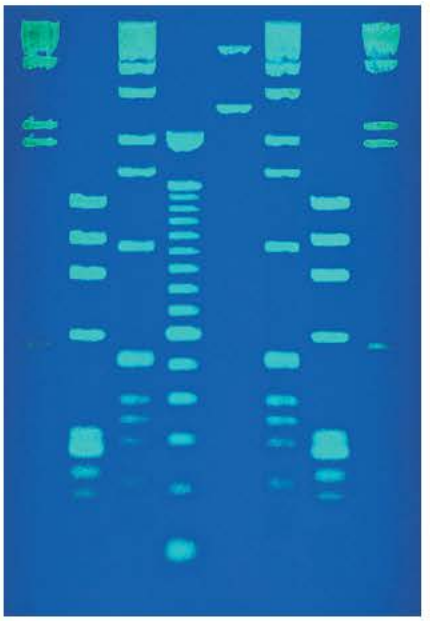
The pioneer who laid the cornerstone of modern forensic science was the early 20th-century criminologist Dr. Edmond Locard (1877–1966). Known as the Sherlock Holmes of France, Dr. Locard established the first police laboratory in Lyon, France, in 1910. His most widely recognized contribution has come to be known as the Locard Principle, which can be summarized as follows: "With contact between two items, there will be an exchange." According to this principle, a burglar cannot enter a house without leaving some trace of his presence, such as fingerprints or, perhaps, bits of hair. Knowing this, the burglar wears gloves and a cap. But the exchange of materials goes far beyond fingerprints and bits of hair. Consider the tiny grains of soil from the burglar's shoes or microfibers that shed from the burglar's clothing, including the gloves and cap! Furthermore, the burglar also carries bits of the crime scene, such as fibers from a carpet or furniture, with him as he leaves. In the words of Dr. Locard, "Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him."

▲ Dr. Edmond Locard

The trained forensic chemist collects these bits of matter from the scene of the crime or from the suspect. The matter is then identified by assessing its properties, such as chemical composition or melting point. Once identified, this physical evidence may be used to support or refute the guilt of the suspect.

Samples of hair, skin, or semen left at the scene of the crime can be examined for DNA content. As we describe in Chapter 13, DNA is the biomolecule that holds a person's genetic information, which is unique for each individual. The amount of DNA recovered from a crime scene is often quite small. The tools of genetic engineering, however, allow the forensic chemist to use a minuscule amount of collected DNA as a template for the production of much larger amounts of identical DNA. This larger quantity of DNA can then be analyzed for patterns that may be identified as belonging (or not belonging) to the criminal suspect.

Modern analytical tools allow chemists to detect and identify chemicals at ultralow concentrations. One of the most widely used and sensitive analytical instruments is the *mass spectrometer*. Within the mass spectrometer, a sample molecule is subjected to harsh energy, which breaks the molecule into fragments. These fragments are then given an electric charge and accelerated via magnets down the length of a tube. The fragments separate from each other because more massive fragments travel slower while the lighter ones



▲ DNA can be fragmented and the fragments then separated to yield a pattern characteristic of an individual.

travel faster. The fragments, sorted by mass, produce a pattern that is characteristic of the original molecule. An unknown molecule can thus be identified by comparing its fragmentation pattern to a catalog of known fragmentation patterns. The wonder of the mass spectrometer is its great sensitivity—if you can see the sample injected into a mass spectrometer, it is way too much!

The mass spectrometer is often used in tandem with other analytical tools, such as the *gas chromatograph*, which volatilizes mixtures and separates them into their individual components. Each component is then analyzed with the mass spectrometer. These are the tools of choice for testing bodily fluids for ingested compounds, such as illicit drugs or sports-enhancing steroids. Instruments at the International Olympics, for example, are standardized to detect hundreds of different agents that are prohibited for use by Olympic athletes.

A type of mass spectrometer is also employed at airports to check for compounds that may be used as explosives. The technician rubs a swab inside a piece of luggage and then places the swab within the highly sensitive spectrometer, which tests for a wide assortment of potentially dangerous compounds. For luggage, the spectrometer is used in conjunction with an X-ray machine that identifies the density of the contents. Many explosives have a density comparable to water, which is a reason why passengers are discouraged from packing water or liquid toiletries into their luggage. These X-ray machines are also able to assess the average atomic number of the atoms within the luggage. This is helpful because the chemicals of explosives tend to be made from nitrogen (atomic number 7). A region of the luggage containing an average atomic number of around 7 likely contains explosive materials.

Modern technology used by forensic scientists is not foolproof or without its limitations. Collected material evidence needs to be taken in context and weighed against other factors, such as witness accounts and the possibility that physical evidence has been tampered with—intentionally or unintentionally—prior to being collected. That said, modern technology is a very powerful tool for the forensic scientists whose primary goal is the accurate reconstruction of criminal events as they occurred in the past with the hope that these events can be deterred from occurring again in the future.

CONCEPT CHECK

Would it be a good idea for a burglar to own a type of dog that sheds?

CHECK YOUR ANSWER For the burglar this would be a bad idea, because fur from the dog could easily end up at the scene of the crime, in accordance with Locard's principle. For the greater society, however, if this dog fur led to the just conviction of the burglar's crime, then the burglar's owning the dog would be a good thing.

Mass spectrometer at a security checkpoint

Think and Discuss

1. A dog trained to sniff out fuel is brought to the remains of a building suspected to have been burned down by an arsonist. The dog barks excitedly in evidence of residual fuel at one and only one location. Does this suggest arson? What if the dog found residual fuel in two locations? Why are cases of arson frequently difficult to solve?

2. A woman is dropped off at her apartment by her boyfriend after a night of intimate romance. Entering her bedroom, she surprises a burglar, who then attacks and strangles her to death before fleeing. DNA evidence found on the woman implicates her boyfriend as being guilty of both rape and murder. How can the boyfriend prove beyond a reasonable doubt that he is innocent? How might the outcome of this case have been different if it had occurred 100 years ago?

3. According to the Innocence Project, a group that uses DNA testing to right wrongful convictions, police lineups and similar forms of eyewitness identification are the leading cause of wrongful convictions across all DNA exonerated cases. Why might this be so? What might be done to improve the reliability of police lineups?

4. A deductive argument asserts that a conclusion necessarily follows from the truth of a premise. For example, all cats are mortal. Fluffy is a cat. Therefore, Fluffy is mortal. An inductive argument asserts that a conclusion follows, not necessarily but probably, from the truth of the premise. For example, all the cats you have ever seen are black. Therefore, all cats are black. Which of these forms of argument is used more often in a court of law? Which is used more often in science?