Skeletal remains with botanical evidence in nasal passages.

By the end of this chapter, you will be able to:

5.1 Describe different forms of forensic botanical evidence.
5.2 Discuss how botanical evidence can help solve crimes by linking a person or object to a crime scene, establishing a postmortem interval, or aiding in the location of gravesites.
5.3 Discuss the history of forensic botany.
5.4 Explain the terms plant assemblage and pollen fingerprint or pollen profile.
5.5 Summarize the roles of gymnosperms, angiosperms, seedless plants, and fungi in terms of providing botanical evidence.
5.6 Explain why botanical evidence is often overlooked.
5.7 Summarize the differences between botanical evidence collection and habitat sampling.
5.8 Describe the correct procedures for collecting, labeling, and documenting botanical evidence.
5.9 Explain why a forensic botanist should consult with local individuals, meteorologists, and entomologists, anthropologists, and wildlife specialists when processing a crime scene.

VOCABULARY

- angiosperm: a flowering plant that produces seeds within a fruit
- assemblage: group of plant species in an area dominated by one species that share the same habitat requirements
- forensic botany: the application of plant science to crime-scene analysis or the resolution of criminal cases
- forensic palynology: the use of pollen and spore evidence to help solve criminal cases
- gymnosperm: a plant with "naked" seeds that are not enclosed in a protective organ (fruit); most are conifers
- palynology: the study of pollen and spores
- pistil: the female reproductive part of a flower where eggs are produced
- pollen "fingerprint": also called a pollen profile, the number and type of pollen grains found in a geographic area at a particular time of year
- pollen grain: a reproductive structure that contains the male gametes of seed plants
- pollination: the transfer of pollen from the male part to the female part of a seed plant
- postmortem interval (PMI): the time elapsed between a person's death and discovery of the body
- spore: an asexual reproductive structure that can develop into an adult plant in certain protists (algae) and fungi
- stamen: the male reproductive part of a flower consisting of the anther and filament where pollen is produced.
INTRODUCTION Obj. 5.1, 5.2

Seeds and spores attached to clothing, pollen inhaled into nasal cavities, diatoms found in a drowning victim's lungs, vegetables found in the stomach contents of a victim, annual rings in the wood of a ladder, lichen found in the cuff of a suspect's pants, a plant growing out of the eye sockets in a buried skull, and plants recovered from the undercarriage of a car—all are examples of botanical evidence that was used to solve crimes. Seeds, leaf and grass fragments, pollen, spores, and lichen fragments can easily blend into the background and be overlooked by criminals due to small size. An individual pollen grain, the male reproductive structure of a seed plant, is as small as a pinpoint, though you may see collected pollen grains on cars and lawn furniture in the spring. Spores, the reproductive structures of algae, some plants, and fungi, are tiny. Many plant structures, such as pollen and seeds, have burrs or hooks with angled edges that enable them to easily attach to hair, blankets, and clothing. Plant cell walls made of cellulose persist for a long time. Pollen grains, for example, have tough cell walls that can last for decades under some conditions, making them useful in forensic investigations. Forensic botanists use botanical evidence to help locate a crime scene or a grave site, determine if a body was moved, link a suspect to a crime scene or victim, or to confirm or refute an alibi.

Forensic botany, a relatively new area of forensics, is the application of plant science to crime-scene analysis for use in legal cases. Forensic botany can be used in civil cases to determine who is responsible, for example, for root damage to sewer lines, livestock that have been poisoned by non-native plants, or landscaping contract disputes. However, this chapter focuses on how botanical evidence is used to solve criminal cases.

When crime-scene investigators arrive at a crime scene, their job is to observe and document anything that may help solve a crime. Botanical evidence may help answer the following questions:

- Where did the crime occur? What was the geographical region? Was the crime committed in an open field? Forest? Desert? At a high elevation or in a valley? In fresh water or on a sandy ocean beach?
- When was the crime committed? When was a specific person, vehicle, or article at a crime scene? Did the crime occur within the past few hours, yesterday, last week, or a year ago or longer? Was the crime committed during day or night, spring or fall?
- Who was with the victim, or at the crime scene, at or near the time of death?
- Where was the victim at the time of death?
- What did the victim eat before dying?
- Was the body moved?
- How long has it been since the victim died, the postmortem interval (PMI)? How long was a body buried?
- Is it possible to link a suspect or victim to a specific crime scene or to exclude a suspect based on botanical evidence?

- Can you verify or refute a person's alibi?
- Forensic botany is usually divided into subdivisions. In this chapter, you explore how the following areas of study have been used to solve crimes:
  - Systematics—Classification of plants
  - Ecology—Study of how plants are affected by their environment and other living things
  - Dendrochronology—Study of tree rings
  - Limnology—Study of aquatic environments
  - Palynology—Study of pollen and spores
  - Molecular biology—DNA technology

HISTORY OF FORENSIC BOTANY Obj. 5.2, 5.3

The first mention in history of forensic botany was in Plato's Phaedo of 399 B.C. and describes Socrates' self-administered death sentence of poison hemlock, Conium maculatum. Legal acceptance of forensic botany evidence first occurred as a result of evidence presented during the trial of the alleged kidnapper of the son of famous aviator and national hero Charles Lindbergh (Figure 5-1). The kidnapper's body had been found buried in the New Jersey woods 4 miles from the Lindbergh home. In 1935, Richard "Bruno" Hauptmann, an escaped German convict, was arrested after passing a marked bill from the ransom money. The jury convicted Hauptmann after hearing botanical evidence that linked him to the crime scene.

Arthur Kochler, an expert on wood, provided testimony at the January 1935 trial that linked Hauptmann with the ladder found at the crime scene. Kochler claimed that the homemade ladder used in the kidnapping was produced from the wood found in Hauptmann's home. The expert witness identified four different types of wood that were used to construct the ladder. He demonstrated that the wood, microscopic structures of the wood in the ladder, the sawdust, and the planing marks on the ladder were all consistent with the wood found in Hauptmann's home. (A planer is a tool used to shape wood.)

Kochler convinced the jury that the rail of the ladder was made from floorboards found in the attic of Hauptmann's home. He compared the size of the cut wood in the attic to the size of the ladder rail. He discovered the nail marks made by old-fashioned square nails were consistent with the nail marks in the ladder. The annual rings found in the wooden ladder also were consistent with the annual rings found in the floorboards of Hauptmann's home.

The wood expert explained that annual rings in a tree are made of xylem cells (cells that help transport water). The larger spring growth rings are usually lighter than the darker xylem cells produced in the summer.
The ring one notices in a tree cross section is a ring formed by the larger spring xylem cells alternating with the smaller, darker, and thicker-walled summer xylem cells. (See Figure 5-2). The size of each annual ring is affected by local weather conditions, the amount of competition from other area plants, and the local soil type. Thus, if two different pieces of wood had the same annual ring markings, it indicates that the wood was cut at the same time in the same area.

As well as examining the growth rings, Koehler was able to trace the origin of the wood in Hauptmann's attic by examining small planing marks in the wood. A mill in McCormick, South Carolina, had a defective planer that produced planing marks consistent with those on the wood in Hauptmann's attic. The wood was traced from the S.C. mill to the National Lumber and Millwork Company in Bronx, N.Y., just 10 miles from Hauptmann's home. The shipment of wood occurred between 1929 and 1932 when Hauptmann was a known customer of the Bronx Mill. This trial was the first time that botanical evidence was accepted in a court in the United States.

Since 1935, the use of botanical evidence to solve crimes has been effective but underutilized due to a lack of training. In Europe in 1939, soil samples containing pollen from the surrounding plants were used to connect a suspect to a crime scene. Max Frei, a Swiss criminalist, was able to link a suspect to a murder weapon when he found pollen consistent with that at the crime scene in the grease of the gun. In the 1960s and early 1970s, few law enforcement officers were aware of forensic botany. Still today, due to a lack of awareness and training, many crime-scene investigators do not notice or effectively collect botanical evidence. An exception is New Zealand, which has aggressively and effectively used forensic botany for many years.

Use of botanical evidence in the United States is increasing. However, in part to the work of many botanists turned forensic investigators. Dr. David W. Hall, a renowned forensic botanist at the University of Florida, who is also a consultant, an expert in plant identification and ecology, and author of eight books, and botanist Jane Bock of the University of Colorado, have helped solve many crimes. In 1986, Dr. Hall was the first forensic botanist to be admitted to the American Academy of Forensic Sciences, an organization founded by many forensic pioneers. Throughout Dr. Hall's career, he has been actively involved in educating forensic botanists, law enforcement officers, and lawyers in how to collect and document botanical evidence.

In 1993, Dr. Hall taught forensic botany as part of the training for FBI agents at the National Academy at Quantico, Virginia. Since the late 1990s, many more law enforcement officers and lawyers are being instructed in forensic botany. With the advent of several crime-related television programs, the general public has gained an awareness of the value of plant evidence.

HOW FORENSIC BOTANY IS USED TO SOLVE CASES

Understanding plant ecology and how a plant interacts with its environment and other plants is an important job of the forensic botanist. Plants grow in assemblages, groups of plants usually dominated by one species (Figure 5-3). Assemblages share the same habitat requirements such as soil type, moisture, sunlight or shade, wind, altitude, and latitude and longitude. A forensic botanist can identify individual plants from tiny fragments found on bodies, automobiles, and other objects. Careful collection of plants, including seeds, fruits, and flowers, along with photos and descriptions of the plants and their environment, facilitates the identification of the plants and their location. Once a plant is identified, the forensic botanist has a better understanding of the type of environment where the plant originated. It is possible to exclude possible crime scenes based on the habitat requirements of the recovered plant. Knowing a crime scene's assemblage of plants can help identify its location.

Figure 5-3 Different environments exhibit different plant assemblages, even in the same region (both photos, Rocky Mountain National Park).

NATALIE MIRABEL, LEFT HAND CANYON, COLORADO, 1999
Dr. Jane Bock, University of Colorado botanist turned forensic scientist, was called to investigate a murder. The body of Natalie Mirabel was found in a canyon off a road leading up into the Rocky Mountains. Her husband, Matthew, had an alibi: he was at home with their daughter. Botanical evidence found in his car's undercarriage, floor mats, and pedals showed that Matthew's car had recently been in an area with plants growing in higher elevations like those found in the canyon, and not the type of plants found growing near his home (Figure 5-4). A combination of motive (a new life insurance policy) and multiple forms of circumstantial evidence (botanical, wife's blood on his gloves, his DNA under the wife's fingernails) led to his conviction for his wife's murder.

SAMANTHA FORBES FREEPORT, BAHAMAS, 1999
While a tropical storm passed over the city of Freeport, Samantha Forbes was seen leaving a bar with two men. The next morning her body was found on a local golf course. Due to the storm, little evidence...
was recovered at the crime scene. When the two suspects were questioned, the police recovered a tiny fragment of a blade of grass from one of their socks. Could this fragment of grass link the suspect to the crime scene? Dr. Jane Bock was able to identify the grass as Almendron Berendia, a grass that had been specifically selected for that golf course. No other golf course on Grand Bahama Island used this type of grass. This evidence helped convict one of the two suspects.

**GOLD HEAD BRANCH MURDER, CLAY COUNTY SHERIFF’S OFFICE, FLORIDA, 1991**

A five-inch turkey oak seedling bent to the ground by an isolated human tibia (leg) bone provided the first clue for forensic botanist Dr. David Hall (Figure 5-5). He was trying to estimate how long the human bone had been separated from the rest of the skeletal remains that were recovered by the crime-scene investigators. The bone was found after the detectives called in the National Guard to perform a massive line search to find two missing bones. When Dr. Hall lifted the bone off the seedling, a turkey oak leaf was found. Where the bone had rested on the leaf, a line of dead cells matching the size and shape of the human bone was visible. Without sunlight, leaf cells cannot produce chlorophyll, and they die. Dr. Hall estimated the time it took for the shading to kill the leaves. This provided the first time interval.

The leaf was fully formed without any malformations, which indicated to the forensic botanist that the bone was dropped on the leaf after the leaf was formed. By speaking to the local park rangers and inhabitants of the area,

Dr. Hall estimated when budding occurred and when the leaf would have reached its full growth. This information provided him with his second time interval.

Animals are known to scatter bones and carry them away from the rest of a skeleton. After checking with the University of Florida wildlife and bone experts, Dr. Hall determined that the blue marks found on the tibia were consistent with those of a large dog. Based on information from the local medical examiners, a third time interval was estimated from the amount of time required for decomposition to reach a point where a dog of that size could pull a tibia away from the rest of the skeletal remains.

Dr. Hall added the three time intervals together and then subtracted that sum from the time that the skeleton was found. The result placed the deposit of the remains during a rather cold winter, which would slow down the decomposition rate of the body. Dr. Hall adjusted his time interval, factoring in the cold temperature. The detectives checked with the missing persons’ bureau and learned there was a report of a missing person a week before Dr. Hall’s estimate. The skeletal remains were confirmed to be those of the missing person.

## DROWNING VICTIMS

Obj. 5.1, 5.4, 5.5

When a person drowns, he or she inhales water into the lungs and body tissues. Algae and diatoms are nonvascular photosynthetic organisms, important producers found in fresh water, salt water, and mud. (Diatoms are relatives of algae that have cell walls containing silicon dioxide, or silica.) By comparing the number and proportion of algae and diatoms in a drowned person’s lungs and body tissues, it is possible in some cases to determine where he or she drowned. A postmortem interval can be estimated based on the number of diatoms found in the body. Fewer than 20 different species indicate a recent drowning; more than 50 species indicate a longer postmortem interval.

An assemblage of algae and diatoms can help identify a specific body of water as a crime scene, just as an assemblage of plants can identify specific woods or a field. Diatoms have distinctive shapes that are easily identified under a light microscope. Unique refractive patterns are produced by their silica cell walls (Figure 5-6). Because they are resistant to decay, they provide a long-lasting source of evidence.

### POND ATTACK CASE STUDY

Two young boys were attacked while fishing in a pond in Connecticut. The assailant beat both boys with a baseball bat, bound them with duct tape, and left them to drown. One boy escaped and helped his friend. Mud found on the boys’ sneakers contained the same diatoms and algae that were found in the pond. When a suspect was apprehended, police collected mud from his sneakers and found that they, too, had algae...
and diatoms similar to those found at the crime scene.

All three samples contained a of the 15 different species of algae and diatoms common to that pond. All samples contained the most numerous algal *Mallomonas caudata*. Freshwater diatoms of the genus *Eunotia* (Figure 5-7) were found in all samples. However, the convincing evidence that linked the suspect to the crime scene was that the proportion of different forms of algae and diatoms was consistent in all three samples. Nevertheless, because diatoms can be present in living tissues and in the bodies of people whose cause of death is not drowning, forensic analysis of diatoms is controversial in the United States.

**INFORMATION FROM GASTRIC CONTENTS**

Obj. 5.1, 5.2, 5.5, 5.6

Many of you have watched TV crime programs in which the stomach contents (gastric contents) are emptied and examined as part of an autopsy. What are the examiners looking for? What part of a meal can withstand the action of digestive juices? How will gastric contents help solve a crime? Dr. Jane Bock, forensic botanist, understood that plant cells with their cellulose cell walls could easily withstand digestion. She and her graduate students created a lab manual to assist in the identification of plant cells in a person's last meal and to estimate postmortem intervals based on the degree of digestion. The graduate students' job was to chew onions, olives, spinach, okra, lettuce, and tomatoes (separately) and prepare microscopic images of the chewed cells that could be used for comparison with the plant cells found in a victim's stomach or intestines.

Suppose the victim's last meal consisted of tomatoes, chili beans, black olives, onions, and hot peppers; or perhaps the meal was burgers, fries, and a shake. The meal could be traced to the local Mexican restaurant or to a fast-food restaurant. If some of the meal was still in the victim's stomach when the body was recovered, the police could use that information to estimate the postmortem interval. Knowing where the victim had been prior to death helps the investigators because they know where to start questioning people who last saw the victim.

**THE BODY COVERED BY WILTED SUNFLOWERS**

Obj. 5.1, 5.2, 5.5, 5.7

Who is the victim whose decomposing body was left abandoned on the roadside, covered by wilted, uprooted sunflowers? How long has the body been in that area? The only clues seem to be the wilted sunflowers. The question to ask: How long would it take for sunflowers, such as those in Figure 5-8, to wilt in that environment? The answer could help estimate the postmortem interval.

To find out, pick more sunflowers from the same area, put them in a similar environment, and observe the number of days required to reach the same state of wilting as the flowers found covering the body. This was the procedure performed by Dr. Jane Bock of the University of Colorado. Based on her experiment, she estimated that the body had been abandoned for seven days, which was consistent with the insect evidence. Using missing person information, the identity of the victim was determined.

**SECRETS FROM A GRAVE**

Obj. 5.1, 5.2, 5.9

A series of kidnappings has occurred. Several victims' remains have been recovered from a shallow grave. When another person in the area goes missing, the police search for the missing person and for evidence of a recent grave.

How do you recognize a gravesite? If it is an old one, then the actual site sinks into and fills the grave as the ground settles. If the gravesite is new, a mound of soil will be visible near the grave, perhaps totally devoid of any plants. Broken branches may indicate recent activity.

When ground has been dug for a grave, existing vegetation is removed. Because of changes resulting from the new gravesite, the type of plants that inhabit that particular area will be different from the established
dominant plants around the area. The disturbed soil is aerated by digging, thus allowing more oxygen to the roots and more water to flow into the area. Due to the turning of the topsoil, the soil becomes enriched. Different plants will grow in the area, and the gravestones will look different from the area around it. (See Figure 5-9.)

Other clues can be spotted at the gravestones. If the grave was dug using a shovel, tool marks may be visible along the edge of the gravestone, along with broken tree or plant roots. Bright green leaves in the soil would indicate that the ground was recently overturned. If new growth has started, estimates can be made of how long ago the gravestone was disturbed based on annual rings of roots or the development of new growth. In 1960, anthropologist Clyde Snow estimated the time of death of a victim as late June or July based on the size of the soybean seeds found on the dead plants under the skeleton. (Snow's evidence was admissible in court in 1960, but because he was testifying outside his field of expertise (anthropology), this botanical testimony would be inadmissible today.) Smaller botanical evidence such as pollen, spores, seeds, and lichen fragments are also useful. Often, these smaller items are easily transferred to a suspect and can be used to link the suspect to the crime scene. Their presence could also indicate that a body was moved from a different site.

BOTANICAL CRIME-SCENE ANALYSIS

The crime scene for a forensic botanist can be anywhere a crime was committed: forest, desert, tropical rain forest, pond, lake, street, or inside a car or home. Recall that Locard's Principle of Exchange states that evidence from one area can be transferred to another.

A forensic botanist follows all the procedures for evidence collection, documentation, photographing, recording, and maintaining chain of custody discussed in Chapter 2. In this section, you will study special concerns of the rest of the crime-scene processing team in terms of processing a crime scene for botanical evidence.

After the examiner has scanned and walked through the scene, photographs are taken of the crime scene both from a distance and close up. A crime-scene artist prepares a preliminary sketch of the crime scene. Both the photographer and the recorder are responsible for documenting each photo. The recorder documents information about the crime scene such as the following:

- Case number
- Name of the agency processing the crime scene
- Names of investigators at the crime scene
- Crime-scene location, including longitude and latitude, compass readings of the crime scene, and distance from fixed locations or datum points such as trees or buildings

- Description of the crime scene
- Descriptions of any biological materials at the crime scene
- Habitat assessment (deciduous forest, desert, open field, lake, pond, building, etc.). The description should include both the crime-scene and the areas around the crime scene.

A general description of the dominant plants should be included, along with notations on the presence of broken branches or disturbed plants. Environmental conditions such as temperature, cloud cover, sun, humidity level, type of soil, wind speed, and so forth should be noted.

In addition to the usual photos of the crime scene noted in Chapter 2, the crime-scene photographer (Figure 5-10) should take images of the following:

- Dominant plants and other plants found both at the crime scene and in the area around the crime scene
- Possible entrances or exits from the crime scene as evidenced by depressed grasses
- Broken branches or disturbed plants with both micro and macro lenses
- Plants that seem to be unusual for the area
• Plants that are found in the following locations:
  - Plants covering a body, vehicle, or object
  - Plants on a body, vehicle, or object
  - Plants under a body, vehicle, or object
  - Plants between objects and a body

**SEARCHING FOR AND MAPPING BOTANICAL EVIDENCE** Obj. 5.8

Figure 5-11 Even a broken branch at a crime scene may be documented, photographed, and labeled as botanical evidence.

When evidence of any kind is discovered, whether it is botanical, such as the broken branch in Figure 5-11, or another type, it is important to know what and how much to sample and how to package and label it. Failure could result in contamination or destruction of the evidence or inadmissibility of the evidence in court. As you recall from Chapter 2, when evidence is discovered, it is marked with a flag that is then numbered. A recorder documents the evidence items in number sequence, while a photographer photographs the items. The recorder documents the exact location of each evidence item. Each item gets its own properly completed Evidence Inventory Label. In the case of botanical evidence, the recorder should enter the following information on the label:

- Description of plant (tree, shrub, vine, pollen, flower, woody or herbaceous, algae, etc.)
- Height of plant if the entire plant was not collected
- Color and shape of flowers, fruits, seeds, stems, leaves, etc. so forth

All evidence should be mapped by establishing a datum point. Measurements and directions are taken from the datum point to a corner stake of the crime scene, marking the subdatum point. (Refer to the Chapter 2 section Mapping the Crime Scene.)

**BOTANICAL EVIDENCE COLLECTION** Obj. 5.6, 5.8

More than one person can search for botanical evidence, but only one person should do the actual collecting to avoid duplication of specimens. Several people can assist with the labeling and packaging of the evidence. Besides collecting evidence, it is important to collect at least 10 different types of plants from the area’s assemblage, called a habitat sample, including any unusual plants. This sample helps the forensic botanist determine if any botanical samples on a body could have been transferred from a primary crime scene. Samples should never be stored in plastic, nor should they be frozen. Botanical evidence is best placed in paper. Using a pencil, label the paper with the case number and evidence number. Note what part of the plant was collected and indicate color and shape of the plant part, especially for flowers and fruits. Photographs of the evidence are taken before collection in situ and again in the paper showing the case and evidence number.

Plants can also be temporarily stored using a plant press (Figure 5-12). Place blotter paper on the plant press, followed by newsprint, plant, newsprint, blotter paper, and the plant press. More layers of blotter paper and newsprint should be used for herbaceous plants that contain more water. General guidelines for collection of different types of plants include the following:

- Woody plants: collect at least eight to twelve inches of the plant showing several leaves with variation in size, color, and leaf arrangement.
- Tall plants or vines should be zigzagged, and not coiled, in paper.
- Small plants or plant fragments should be stored in large pieces of newsprint.
- Broken branches should be cut at least an inch above and below the broken area.
- Collect roots when possible.
- Fruits can be sliced and placed in thick newsprint or between sheets of wax paper if the fruit has a high sugar content.
- Larger dry items such as pinecones can be placed in a box or large paper bag (with the bottom flap closed).

**POLLEN AND SPORES IN FORENSICS** Obj. 5.1

Pollen and spores provide clues to when and where a crime occurred and whether the body was moved from the scene of the crime. The victim’s clothes may actually hold evidence that provides information about the crime scene. Trace evidence, such as plant material, can provide clues about a crime’s location, such as whether the crime was committed in the city or country. It can also provide clues that the crime occurred during a particular season of the year. In some instances, the evidence can even help determine when the crime occurred, such as during the day or night.

Several specialized forensic fields are devoted to studying biological evidence at a crime scene. One of these fields is forensic palynology, the study of pollen and spore evidence to help solve criminal cases. Pollen (Figure 5-13) and spores have different functions, but they have similar characteristics, such as being microscopic and having a resistant cell wall. These characteristics make them very useful for crime-scene investigations.

Figure 5-12 Wooden plant press.

Did you know?

Pollen grains can be extracted safely from rocks that are millions of years old. This is a valuable characteristic not only for palynologists, but also for oil companies and archaeologists.

Figure 5-13 A false-color scanning electron microscope (SEM) photograph of pollen grains.
The use of pollen and spores in forensic investigations is based on Lecard’s Principle of Exchange, which you studied in Chapter 2. Recall that every contact between two objects or persons leaves a trace. Suspects pick up microscopic evidence that helps investigators link them to a crime scene.

**POLLEN PRODUCERS** Obj. 5.4, 5.5

Knowledge of pollen (and spore) production is an important factor in the study of forensic palynology. By understanding pollen production patterns for plants in a given location, one can better predict the type of pollen “fingerprint” to expect in samples that come from that area. A pollen fingerprint or pollen profile, is the number and type of pollen grains found in a geographic area at a particular time of year.

The plant kingdom can be classified into two groups based on how they reproduce: nonseed plants and seed plants. The earliest plants were nonseed plants. They reproduce by dispersing, or spreading, spores. Nonseed plants existing today include ferns, mosses, liverworts, horsetails, and club mosses. Some of the more recently evolved seed plants also produce spores, but their primary means of reproduction and dispersal is by seeds. During their life cycles, seed plants produce cones or flowers that make pollen to disperse male-gametes. Seed plants existing today include the gymnosperms and the angiosperms. Seed plants are the predominant land plants, so they are the most likely plants to leave evidence at a crime scene.

**Gymnosperms**

The seeds of gymnosperms, the oldest seed plants, are exposed and are not enclosed in a protective organ (fruit). Gymnosperms include cycads, ginkgoes, and the conifers. Conifers (cone-bearing plants) are the largest of the gymnosperms (Figure 5-14). They include pines, spruces, firs, junipers, and other evergreen plants.

Many conifers produce their seeds within a hard, scaly structure called a cone. There are female cones and male cones (Figure 5-14). Female cones, which are typically larger than male cones, contain eggs inside structures called ovules. The male cones of conifers release large amounts of pollen grains, which are spread by wind currents to the female cones. This process is called pollination. Sperm cells from pollen grains fertilize the eggs inside the ovules on the female cones. A seed develops from a fertilized ovule. The vast amounts of pollen released by male cones is a great benefit to forensic palynology.

**Angiosperms**

Angiosperms are the flowering plants, and they produce seeds within an organ called a fruit. Angiosperms are very diverse and include corn, oaks, maples, and the grasses. There are about 300,000 angiosperm species known, and they are found in almost all habitats. Because angiosperm plants are found in so many places, most crime scenes contain angiosperm pollen.

The basic reproductive unit of an angiosperm is the flower (Figure 5-15). The pistil is the female part of a flower that produces eggs. The stigma is the part of the pistil where pollen lands. A pollen tube produced by a pollen grain grows down the long, thin style until it reaches the ovary.

The male part of the flower, or stamen, is responsible for pollen production. The long, thin filament of the stamen elevates the anther that produces pollen sacs. Following pollination, one of the released sperm cells successfully fuses with an egg; the ovule becomes a seed, and the ovary develops into a fruit. Figure 5-16 shows an avocado seed encased within the fruit.

**Types of Pollination**

Pollen and spore dispersion patterns are important in forensic studies for analyzing palynological samples that come from the crime scene.

In all seed plants, before a sperm can fuse with an egg during fertilization of a seed plant, pollination must occur. Pollination can involve one or more flowers. In flowering plants, pollination involves the transfer of pollen from an anther to a stigma within the same flower is known as self-pollination, as found in pea plants. If pollination involves two distinct plants, it is known as cross-pollination. Note that some plants can both self- and cross-pollinate. Cross-pollinating plants generally produce less pollen than intraspecific pollination because of the efficiency of self-pollination. Thus, the pollen of self-pollinating plants is generally less useful in forensic studies because it exists in a relatively small volume and does not travel far. Of course, wind transfer onto clothing or skin is possible from brushing up against a self-pollinating plant.

**Methods of Pollination**

Pollen can be carried by wind, animals, or water. Wind-pollinated plants release large amounts of pollen from small and nonfragrant flowers, or cones. Producing large amounts of pollen increases the chance of the pollen reaching a female reproductive part. As a result, wind-pollinated plants are often dominant in the pollen profile of a crime scene. However, for the same reason, wind-pollinated plants may actually be overrepresented in collection samples. They may be less effective for determining direct links between individuals and places.

Other flowering plants are pollinated by animals, such as insects, birds, bats, and even monkeys. These plants have fragrant or showy flowers to attract pollinators.
attract the animals (Figure 5-17). Animal-pollinated plants also make adhesive and durable pollen because it must adhere to the animals. Durable pollen grains are more likely to be collected during evidence collection. Moreover, this kind of pollen can provide strong evidence of contact because pollen may be transferred only by direct connection with the plant or the surface on which the plant has made contact. However, animal-pollinated plants tend to produce less pollen than wind-pollinated plants because animal carriers directly transfer the pollen more efficiently. Thus, animal-dispersed pollen may be underrepresented in the pollen profile of a crime scene.

Seed Dispersal

Seed development occurs after pollination. Plants have evolved diverse ways to disperse their seeds. Animals eat seeds that are surrounded by fleshy fruits. The seeds pass through the digestive tract of the animals and are distributed via their feces. In contrast, dandelion seeds are dispersed by the wind and take flight. Other seeds are surrounded by dry fruits with burrs that stick to animal hair or people's clothing. By examining a victim or suspect for unusual seed evidence, it is sometimes possible to link a person to a crime scene.

SPORE PRODUCERS Obj. 5.5, 5.6

Spores are asexual reproductive structures produced by a variety of organisms, including algae, fungi, and plants (Figure 5-18). Like pollen and seeds, spores are very small, produced in large quantities, easily transferred, and easily overlooked by perpetrators, making them useful for forensic work. Identification of individual spores and recognition of a spore profile (spore fingerprint of a specific area) help to identify specific locations and provide clues that can link a person to a crime scene.

Spore Dispersal

Spores are dispersed in a variety of ways. Algae release spores directly into the water or into the air. Fungi such as mold grow in moist, dark areas and may depend on wind or water dispersal, depending on species. Mushroom spores scattered by wind are released under their caps from structures known as gills, shown in Figure 5-18. Seedless land plants such as ferns and mosses release their spores in structures known as sori or sporangia (Figure 5-19).

Some fungi have evolved mechanisms to enhance spore dispersal, such as spore ejection and animal dispersal. Pilobolus fungi eject masses of spores, while puffball fungi, such as the one you see in Figure 5-20, release spores when disturbed. Edible truffle fungi are eaten by foraging animals, though humans have to pay for the pleasure. Fungi spores pass through animal digestive tracts and are distributed to a new area in feces.

Bacterial Spores: An Exception

Some bacteria produce spores. When environmental conditions are unfavorable, some bacteria form thick-walled, resistant spores, called endospores. Endospores are different from the spores produced by fungi, algae, and plants because endospores are not used in reproduction, and a bacterium can produce only one endospore at a time. Endospores are of interest in forensics because several types of bacteria that make endospores can cause diseases, such as anthrax and botulism. But bacterial endospores are a topic of forensic microbiology, so even though they are sometimes called spores, they are not covered in this chapter.

POLLEN AND SPORE IDENTIFICATION IN SOLVING CRIMES Obj. 5.2

Pollen and spore identification can provide important trace evidence in solving crimes, but it can be challenging. However, viewed under a microscope, the hard outer layer of a pollen grain or spore has a unique and complex structure.
Distinguishing features include size, shape, wall thickness, and surface textures, such as spines. For example, larger pollen grains such as that of corn cannot travel far and can only drift with the wind about one-half mile. So someone with corn pollen on him or her has probably been close to a cornfield or a cornflower.

Wind-dispersed pollen grains are relatively simple, with thin cell walls, and are easily preserved for identification. In contrast, animal-dispersed pollen is usually large, sticky, highly ornamented, thick-walled, and also easily preserved for identification.

Pollen and spores differ in other ways important to forensic scientists. Most important, spores are much smaller and more difficult to identify than pollen grains and spores are produced in far greater numbers than pollen (Figure 5.21). An advantage of spore analysis over pollen is that it is possible to grow a new organism from a spore and thus identify the species.

Pollen and spore production is seasonally and geographically specific. Thus, pollen and spore evidence from a crime scene can lead to useful information about the crime. Also, if pollen, spores, or both found on the victim are not native to the crime scene, it may indicate that the body was moved.

Pollen and spores also play an important role in solving crimes because they are very small, or even microscopic, and difficult for a perpetrator to eliminate at a crime scene. The resistant nature of most pollen and some spores allows them to avoid dehydration and degradation. In fact, they can be found in dry sediment from millions of years ago. Pollen, especially from animal-pollinated angiosperms, usually has sharp edges that enable it to better adhere to its animal pollinator, and thus, a perpetrator can easily pick up evidence on his or her shoes and clothes that cannot be seen and that will not go away.

**Pollen and Spore Evidence at Crime Scenes**

Pollen and spore collection should be done by a forensic palynologist if possible. It is critical that forensic palynologists carefully and methodically collect and store samples while avoiding contamination. Contamination is a major problem and can result in the evidence being judged inadmissible in court.

**FINDING POLLEN AND SPORES**

Pollen and spores are all around us. The following list identifies some places crime-scene investigators look for pollen and spore evidence:

- Living and decaying plant material
- Soil, dirt, mud, and dust
- Hair, fur, and feathers
- Clothing, shoes, blankets, rugs, baskets, carpet, and rope
- Victim's skin, hair, nails, digestive tract, exfoliated, and wounds
- Paper, money, and packaging material
- Vehicles, including tires, windshield, air filter, and undercarriage
- Furniture
- Air filters of homes and airplanes
- Cracks and crevices in floors, walls, roofs, and fences
- Drug wrappings or containers
- Honey and other food

It is especially important to sample soil, dirt, and dust because they are usually abundant at crime scenes, and they often contain abundant pollen and spores. Dirt collected from a victim's body or belongings might help identify the location of the crime. Some unusual materials that can contain pollen and spores include enamel-painted wood, painted works of art, grease on guns, stuffed animals, and foot impressions.

**COLLECTING POLLEN AND SPORES**

Ideally, the forensic palynologist should be called to the crime scene(s) immediately to minimize contamination and destruction of the evidence. He or she collects evidence samples as well as control samples at all potential crime scenes during the investigation. Control samples are specimens of surface dirt from the region where a crime was committed. Control samples document the pollen and spore profile of the area so there is a comparison for evidence samples.

All samples are collected by a forensic palynologist wearing gloves and using clean tools, such as paintbrushes and cellophane tape. Each sampling instrument is cleaned after each sample is taken, or a new one is used each time. All samples should be placed into new, dry, sterile (if possible) containers, such as paper bags or paper envelopes, and then dried to prevent decomposition. Plant presses with blotter paper and newspaper temporarily store plant evidence in the field. Site and vegetation surveys, as well as photographs, should also be taken to help analyze samples, explain how samples were collected in court if necessary, and determine the processing techniques to be used in extracting pollen and spores from the samples. And as you learned in Chapter 2, it is always vital to secure the evidence and maintain an accurate chain of custody.

**ANALYZING POLLEN AND SPORES**

After pollen and spores are processed and chemically extracted from samples in the laboratory, forensic palynologists examine them using microscopes (Figure 5.22). Pollen and spores are best viewed with transmitted light or phase contrast microscopes.
Additional details of surface features may require the use of a scanning electron microscope (SEM). To identify pollen and spores, specialists use pollen and spore reference collections that represent native species and species from other geographic regions. Preliminary identifications may be made by reference to drawings and photographs in atlases, journal articles, Websites, and books. After scientists narrow their search with illustrations, they refer to herbariums to compare actual plant material, pollen, and spores.

Once the pollen evidence has been collected, processed, analyzed, and interpreted, it is presented in court so that a jury can assess the value of the evidence. Palynology is best used to confirm certain aspects of the crime; that is, pollen and spore evidence is unlikely to be the primary or only evidence in a crime.

**SUMMARY**

- Forensic botany and forensic palynology can provide information about the geographic origin of a crime and the time or season when it took place.
- Knowing a crime-scene’s assemblage of plants can help narrow down its location.
- Forensic botany can help solve crimes based on plant evidence found on or in a victim, on the suspect(s), or at the crime scene(s).
- Pollen is a reproductive structure containing male gametes that is produced by seed plants. Spores are reproductive cells produced by algae, fungi, and nonseed plants such as ferns and mosses.
- Seed plants including gymnosperms (cone-bearing plants) and angiosperms (flowering plants) produce pollen.
- Plants may disperse pollen in the wind or by the movements of animals.
- Pollen from wind-pollinated plants is more common in forensic samples, but pollen from insect-pollinated plants tends to provide more specific information about location.
- Pollen evidence collected at a crime scene must be compared with baseline samples from the area.
- Collection of all botanical evidence must be performed carefully to avoid contamination.

**CASE STUDIES**

**Dr. Max Frei**

*(1960s)*

Dr. Max Frei, a noted Swiss criminalist, often used pollen as a forensic tool to link suspects to events or to crime scenes. In one case, pollen found in the gun oil of a weapon linked the firearm to the murder scene. Frei also used pollen analysis to document forgery. He found fall-pollinating cedar pollen stuck to the ink used to sign a document. The document was dated during the month of June. Because the document contained pollen only visible in the fall, the document could not have been signed in June. Frei examined the Shroud of Turin, a garment believed to have wrapped the body of Jesus after his crucifixion. Frei’s pollen analysis did link the shroud to pollen unique to Israel.

**“Otzi the Iceman”**

*(1991)*

Two hikers in the mountains on the border between Italy and Austria found the frozen remains of a man who has come to be known as Otzi. Otzi was estimated to be 5,300 years old and probably died in his 40s. At the time, Otzi was the oldest frozen mummy ever found. Upon thawing, Otzi’s intestine was examined and hop hornbeam pollen was found in it. Hop hornbeam flowers only in May and June, so Otzi’s death must have occurred in the spring.

**Dr. Dallas Mildenhall**

*(1997)*

A Colin McCahon painting valued at $1.25 million was stolen from the Visitor’s Center, Lake Wai-o-te-ma, New Zealand. A year later, the painting was returned. Dr. Dallas Mildenhall, a New Zealand pollen expert, used pollen evidence collected from the artwork to provide clues to where the painting had been stored. A typical pollen signature, or fingerprint, taken from an area includes pollen from the dominant plant and five or six secondary species of plant and as many as several hundred trace pollen species. Dr. Mildenhall compared the pollen signature from the stolen art to known pollen signatures from other areas to determine where the painting had been stored.
On September 9, 2004, the BBC News headline read: “Pollens helps war crime forensics.” Forensic experts working in Bosnia had used pollen to help convict Bosnian war criminals. Professor Tony Brown used pollen analysis to link mass graves in Bosnia to support the claim of mass genocide. Bosnian war criminals tried disguising their acts of genocide by exhuming mass graves and reburying bodies in smaller graves, claiming they were the result of minor battles. Soil samples were taken from skeletal cavities, inside the graves, and from around the suspected primary and secondary burial sites. Pollen from the soil samples was cleaned with powerful chemicals before being analyzed, and the mineralogy of the soil was examined. Once complete, comparisons could be made between different samples, and this ultimately led to links between primary and secondary burial sites.

Professor Brown noted one primary execution and burial site was in a field of wheat. When bodies were found in secondary burial sites, they were linked to the primary location through the presence of distinctive wheat pollen and soil recovered from the victims.

Imagine you are a reporter accompanying either Dr. Frei or Dr. Tony Brown during their investigations. Write a news story about their work.

Dr. Lynne Milne is a palynologist who spends most of her time working in the field of forensics. She is a lecturer in the Centre for Forensic Science at The University of Western Australia (UWA). There, she supervises Master’s and Ph.D. students in the field of forensic palynology. Her work also involves teaching police about forensic palynology, as well as conducting casework for state and federal police.

Dr. Milne has spent a great deal of time promoting the field of forensic palynology in the media. She has published a book describing her forensic palynology murder and rape cases. In the book, she also includes other criminal cases and mysteries that palynology has helped solve. Milne states, “Like DNA and fingerprinting, palynology can link a person to a crime—but it can also help in investigations for which DNA and fingerprinting are not applicable. For example, palynology can help direct police to an area where a person who committed a crime may live and work, and can determine where illicit drugs and illegally imported goods have come from.”

Her typical workweek may include meeting with police; attending a crime scene; working with other forensic scientists such as soil and fiber experts; collecting samples and doing a vegetation survey at a crime scene; collecting reference pollen samples from the herbarium; processing pollen, soil, and other samples; analyzing prepared pollen samples; writing a police report; and teaching and helping students with their projects in the field or laboratory.

Dr. Lynne Milne enjoys her job because it is never boring and can be extremely rewarding to help solve crimes and other mysteries. She says, “Pollens is often very beautiful, and it always has a story to tell. I enjoy the supersleuth aspects—working out past vegetation, patterns in evolution, and helping to solve crimes.”

Dr. Milne’s advice to those wishing to pursue a career in forensic palynology is to obtain an undergraduate degree in botany, geology, geography, or archaeology. Several colleges and universities in the United States and Canada offer courses in forensic palynology. A science degree would allow a person to work under the supervision of an experienced palynologist. Much of the real training will be on the job. A Master’s or Ph.D. degree in a related area of study would be the next step for eventually conducting one’s own forensic cases.
CHAPTER 5 REVIEW

True or False

1. A skilled botanist may be able to identify a type of habitat from a fragment of a plant. Obj. 5.7
2. Plant cells found in the gastric juices cannot be identified after 3 hours. Obj. 5.1, 5.2
3. A limitation of forensic botany is that all living matter decomposes quickly. Obj. 5.1, 5.2
4. A forensic botanist must look not only at the different species in an area, but must also calculate the percentages of each species when comparing two locations. Obj. 5.7
5. Annual rings are formed as a result of differences in color of the lighter springwood and the darker winterwood. Obj. 5.1
6. The datum point in a crime scene is a reference point from an immovable object. Obj. 5.8
7. The photographer should take distant and close-up images of the crime scene as well as photos of the habitat and all botanical evidence. Obj. 5.8
8. Information obtained from weather-reporting stations and people living in the immediate area are not factored into a forensic botanist's report. Obj. 5.9
9. Pollen present on the victim that is consistent with pollen from a suspect provides strong evidence that the suspect is guilty. Obj. 5.2, 5.5
10. Botanical evidence should not be stored in a plastic bag. Obj. 5.8

Multiple Choice

11. Botanical evidence is a valuable source of evidence because
   a) it is easily overlooked by perpetrators
   b) many plants have adaptations that make them easily transferred
   c) the collection of plants in an area can help identify an area
   d) all the above

12. Diatoms
   a) are visible to the naked eye
   b) have a cell wall composed of rigid cellulose
   c) are found attached to rocks and plants in bodies of water
   d) are used to assist in crime scenes involving insects

13. All of the following should appear on an evidence label except Obj. 5.8
   a) postmortem interval
   b) date, time
   c) name of collector
   d) case number

14. Which procedure is incorrect when collecting botanical evidence? Obj. 5.8
   a) zigzag long vines as opposed to rolling them
   b) collect broken stems by cutting one inch above and below the broken area
   c) include roots of plants as part of botanical evidence
   d) include the color of any flowers or fruits

15. Compare and contrast an assemblage and a pollen fingerprint by defining both and giving examples of each from the chapter.

16. Refer to the Gold Head Branch Murder in Clay County, Florida, cited in the textbook. The victim was ultimately identified using missing person's records, but only after a time interval was established. Cite specific evidence from the case study that explains the role of each of the following: Obj. 5.9
   a) National Guard
   b) Dr. David Hall, forensic botanist
   c) Local park rangers and inhabitants of the area
   d) Wildlife expert
   e) Medical examiner
   f) Detectives
   g) O'Fice of Missing Persons

17. "Plants provide a biological clock that provides evidence as to when a person died, or the postmortem interval." Using two different case studies from the textbook (other than the Gold Head Branch Murder) provide specific evidence that supports this claim. Include in your answer a description of the botanical evidence and how it was used to help estimate the postmortem interval. Obj. 5.2

18. It seems that it would be an impossible task to find the location of a gravesite in the middle of an overgrown field or forest. However, many botanical clues help reduce the size of search sites. Describe ways to locate both a recent and an older gravesite based on botanical evidence cited in the chapter. Obj. 5.2

19. a) How would a forensic botanist use habitat sampling to help solve a crime? What type of information will this sampling provide? Obj. 5.7
   b) Provide a list of botanical evidence that you might collect from an area near either your home or school.
      i) Include the type of evidence (algae, seaweed, cactus, shrub, tree, corn, flowers, palm tree, pine trees, maple trees, vines, ground cover, weeds, lichen, moss, fern, fungus).
      ii) Identify the dominant species, if possible.
      iii) Include the colors of flowers, seeds, or fruits.
20. Do you feel that there was sufficient evidence to convict Hauptmann based on the wood expert’s testimony in the Lindbergh kidnapping case? Use specific evidence from the case study to support your claim.

Obj. 5.2, 5.3

Going Further

Research one of the following topics

1. Pollen allergies
2. Why diatom evidence is not generally accepted in the United States as evidence of drowning
3. Decline in pollinators and the potential effect on the world food supply
4. The use of diatomaceous earth as a nontoxic pesticide
5. Develop a dichotomous key to help identify local pollen types.
6. Design a method to collect pollen or diatoms.
7. Produce a digital database of local pollen, algae, or diatoms.
8. Explore the role of diatoms in toothpaste or various kinds of filters (such as water filters).
9. Design a procedure to determine the effectiveness of diatomaceous earth as an abrasive to polish dull pennies.
10. Search the Internet for cases in which the DNA of botanical evidence was used to link a suspect to a crime scene.

ACTIVITY 5-1

Pollen Examination: Matching a Suspect to a Crime Scene

Obj. 5.2, 5.4, 5.6, 5.8

Scenario:

A burglary had taken place at the Huxton’s home. Footprints were found throughout the recently watered flower garden and leading to the window of a bedroom located at the back of the expensive home. Just as the burglar was leaving the house, the owner returned home and caught a glimpse of a teenage boy dressed in a T-shirt and blue jeans running through the garden.

The police questioned four neighbor teens. All four were young firends who denied that they had been anywhere near the Huxton property and stated that they did not burglarize the home. After obtaining a warrant, the police searched the home of each of the four young men looking for blue jeans that could have been worn during the burglary. Four pairs of jeans were confiscated and taken in evidence bags to the crime lab to be examined for pollen evidence that could link the suspect to the Huxton garden.

Objectives:

By the end of this activity, you will be able to:

1. Prepare wet-mount slides of flower pollen.
2. View pollen under a compound microscope at 100× and 400× magnification.
3. View, observe, and analyze pollen grains.
4. Determine if pollen evidence from any of the suspects is consistent with pollen from the crime scene.

Time Required to Complete the Activity: 40 to 60 minutes

Materials:

Act 5 ± SH
Act 5 ± SH Student Design Ex
(for each group of two students)
1. microtube labeled “crime scene (CS)” containing pollen from the crime scene
4. evidence microtubes containing pollen from Suspect 1, Suspect 2, Suspect 3, Suspect 4
1. microtube or minitube sponge rack or small beaker to hold the tubes of pollen
1. compound microscope
5. microscope slides
5. flat wooden toothpicks
1. small beaker of tap water
2. dropper or pipette
5. coverslips
forceps
marker pen

Books and Journals


Internet Resources