

Figure 1. A schematic diagram of the proper sequence for forensic evidence. First and foremost, evidence must be recognized at the crime scene. Secondly, but no less importantly, evidence must be well documented. Finally, collection and preservation must be maintained so as to preserve the integrity of the evidence.

which plant evidence was properly utilized are probably attributed to the general methodology of crime scene processing. Investigators are trying to establish linkages or associations between the victim, suspect, scene, and individual items as with any form of evidence (1) (Fig. 2).

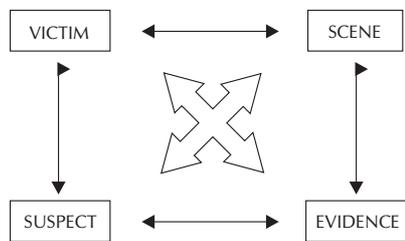


Figure 2. Botanical evidence may be used to link suspects, victims, and crime scenes using four-way linkage theory.

Thus, investigators would know the value of locating plant material on a suspect or victim, and then establishing the origin from which that plant came. On a macroscopic level, this may be a reasonable outcome. A large branch or clump of leaves found within a victim's palm will catch the curious eye of an investigator. In contrast, what about botanical evidence at the microscopic level, such as grains of pollen? Only if an investigator is aware of the potential existence of that evidence will any efforts be made to search for it. Finally, with limited or no training in botany, crime scene personnel will likely not know whether or not the plant material is indigenous to the area, relatively common, or rare. Thus, guidelines should dictate that, when in doubt, plant materials should be collected along with all necessary control samples.

Crime scene documentation is necessary to preserve the character and manner in which evidence was located and collected from a scene, and in showing the relationship of that evidence to the overall scene and other evidence. Proper scene documentation involves multiple formats, such as general note taking, photography, video taping, and sketches and diagrams. Each form of documentation is meant to complement the other. Further, documentation must be conducted throughout the entire scene process, and capture, as much as possible, the events leading up to recognition, as well as post collection. Whereas documentation is important for any type of evidence; documentation of transient or transfer types of evidence is very important since they may be subject to change over time. Most plant evidence, with the exception of pollen, may deteriorate, dry, mold, or be otherwise altered from the form in which it was first discovered. For example, a piece of vegetative material that was recovered from the scene, but neither documented nor properly preserved may degrade to the extent that examination and classification is limited. However, if sufficient quality documentation occurred it may provide additional information for a forensic botanist in classifying the plant species. Also, good documentation could be of assistance to a subsequent case reconstruction in regards to how that particular piece of plant material was transferred to the body of the victim. Was it clearly placed or created by direct contact, or could it merely have blown onto or otherwise relocated onto the victim in a manner that is irrelevant? Finally, thorough overall scene documentation may assist the botanist in determining if recovered plant material is potentially indigenous to an area, given the general topography and ecology.

Only after recognition and documentation should an attempt be made to seize and preserve plant material. However, it may be imperative to make the seizure as soon as possible to protect the sample from further degradation or contamination. Proper packaging will vary depending on the exact nature of the material, but in most cases botany specimens should be packaged in paper after drying to prevent bacterial growth or excessive moisture which would further degrade the material. Separate items should be packaged separately to avoid cross contamination. The precise location where each item was located should also

be recorded. Finally, since this evidence is indeed evidence in every sense, it must be collected and maintained in a manner in which a chain of custody is established. Simply, the evidence must be accounted for from the moment it was first seized until the completion of the case, and perhaps beyond in the example of cold case re-evaluations. Also, the location and flow of evidence transfers must be logged, and these transfers made only when necessary.

Another consideration is the need for control samples. Investigators must attempt to locate any potential sources of the material at the scene or in adjacent areas. This can be a great challenge if the evidentiary pieces of plant material are so small that it is difficult for investigators to associate it with a potential source based on visual characteristics. Further, if DNA typing is to be conducted on plant material, it will be necessary to obtain samples from numerous plants of the same species for the purposes of developing a meaningful data set for comparison and statistical analysis. All of this collection needs to be done contemporaneous with the original scene or time of transfer as plants are subject to change over a relatively short period of time. Whereas their genetic profiles will not vary over time, their physical attributes may vary greatly over different seasons.

Case Examples

Homicide or Suicide? Two cases in Taipei, Taiwan, show how plant material can be very simply used to establish whether an unidentified body was a result of homicide or suicide. In the first case, the body of a young woman was found lying in a gutter in an urban section of Taiwan. Before autopsy, due to lack of obvious bone fractures, it was thought that the victim died as a result of a hit and run accident. She was visible on a surveillance system tape, but after a truck passed by her, she was no longer visible on the surveillance tape. It was assumed that she was struck by the vehicle and her body moved to the gutter to hide the accident. Her body had already been relocated to the hospital by the time investigators reached the crime scene, so they decided to go to the hospital to examine the body. Some plant material (a tiny berry and stem) was found in the victim's hair that was unusual flora for the area, possibly from the genus *Solanaceae*, based on limited morphological characteristics (Fig. 3B). After searching the

crime scene for any plant belonging to the genus *Solanaceae*, part of a broken stem was found at the location where the body had been discovered. Investigators looked upwards and found some potted plants on the edge of a railing above the gutter (Fig. 3A). Those plants were identified as *Solanum nigrum* L., consistent with the botanical evidence from the victim's hair and there was a physical match between the stem on one plant and the stem fragment found in the gutter (Fig. 3C). Based on location and climate, wind force would not be

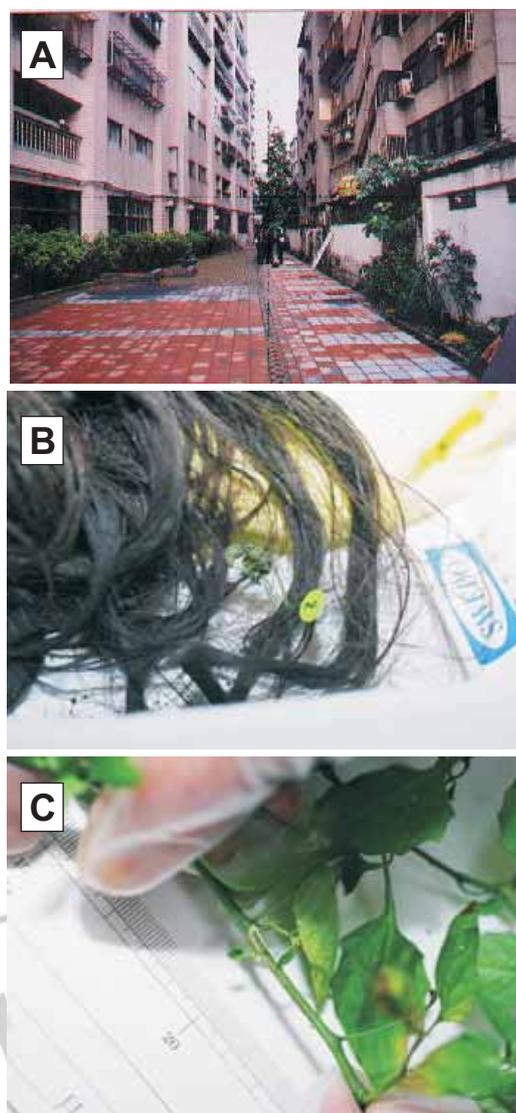


Figure 3. **A.** Photograph of the alley where the victim's body was found and the buildings from where the victim jumped. **B.** A tiny berry and stem fragment found in the young woman's hair. **C.** Physical match between the broken end of the stem from the plant on the railing and the broken stem from the gutter.

strong enough to break the stem, so investigators presumed the plant had received a strong impact from something heavy such as a body. Also, the height of the railing where the plants were found was 3.5 meters so they could not be reached by persons walking on the street. The likely scenario for this incident was that the female fell from the top of the building, her body made contact with the plants during the fall, and some of the plant was transferred to the gutter and the victim's hair. Several days later, autopsy results showed her death to be a result of her impact injuries and her relatives told the police that the young woman suffered from depression and had attempted suicide before. Another case from Taipei, Taiwan, used similar botanical evidence to aid in the determination of manner of death. A male's body was found hanging in a tree in a wooded area. It was clear that his death had resulted from asphyxiation due to hanging; however, the question was whether he had hung himself or if it was a result of foul play. The investigators at the scene noted that he had moss smeared on the insides of his wrists and when they examined the identical moss growing on the tree's branch, realized that he must have transferred the samples to his skin while tying the rope to an upper branch. His death was determined to be a suicide (Fig. 4).



Figure 4. The moss found on the victim's wrists was consistent with that on another location of the tree where the rope was tied, indicating he had himself tied the rope and then died.

Primary and Secondary Crime Scenes.

With any type of crime, plant evidence may be used to link a weapon or a body back to a primary crime scene. The following example shows how plant evidence can be used to identify the primary or secondary scene. The body of a young man was found in the gutter on the side of the road in Tai-

wan, with plant material grasped in his hand. Many injuries were evident including some contusions just below the knees. At autopsy, a fragment of bamboo was recovered from his stomach contents. In the gutter, where the body was found, no bamboo was growing. The bamboo evidence was used to locate the scene where the victim, injured, survived on water and bamboo before he crawled in the gutter for help, and eventually died (Fig. 5). The fact that he had grass in his closed hand indicated he was alive at the time he was in the gutter. Later information revealed that he had been a victim of a hit and run accident and was being taken to the hospital when the guilty persons changed their mind and left him for dead in the bamboo grove.



Figure 5. A bamboo leaf that was recovered from the victim's stomach contents after autopsy, indicating he spent some time in a nearby bamboo grove before crawling to the area where his body was ultimately discovered.

In an insurance fraud case, a young man, desperate for money, decided to use a cleaver to amputate his own hand and claim insurance money (Fig. 6). The insurance money would result from him claiming that he had been a victim of a robbery while driving his truck and the robbers



Figure 6. Grass recovered from inside the newspaper used to wrap the man's hand led the investigators to a nearby area where it became evident that he had severed his own hand in an attempt to gain insurance money.

had cut off his hand. His hope was that he would be compensated by the company for his permanent disability. Although there was a lot of blood at the scene where he had pulled his vehicle over to the side of the road, investigators were suspicious due to the angle of the cut that severed his hand. After further investigation of the vehicle, they found some grass fragments wrapped within a bloody newspaper. They searched the surrounding area and found the location where his hand had actually been severed; a low stone wall in a nearby wooded area. Here, the same grass species was growing as was found in the newspaper which he later confessed he had used to cover his arm while getting back into his vehicle to call for medical assistance. The grass samples linked the amputation to a different scene and refuted his alibi.

Another case example used algae to link a weapon used in a homicide to a nearby freshwater pond. In the Hoepplinger case, a young wife was murdered by her husband in the living room of their home (7). Her head had been struck by a blunt object, and plant material and abrasions were on her body and clothes. Initially, her husband insisted she was found on the sofa, but when the plant material matched to other vegetation in the driveway, he changed his story. Further investigation led to the identification of a brick in the pond behind the house with hair and tissue from the victim. How could the husband be linked to the weapon and the scene? The answer was in the stain on the T-shirt that he had been wearing when he said he found his wife's body (Fig. 7A). Microscopic analyses by botanists and forensic scientists identified the algal species on the shirt as being the same as those found in the pond, thereby establishing the link between the husband and the weapon (Fig. 7B).

Plant Succession and Clandestine Graves. Land that has been disturbed will follow a set pattern of plant re-colonization called plant succession. When an area has been cleared of plants, such as for a shallow grave site, then the primary colonizers are grass, followed by small shrubs and finally trees. Depending on the sunlight/shade and soil conditions, one can estimate the time of death at these sites based on the plant growth. A simple example of this is the postmortem dating of a skeleton located in a field by the age of a plant found growing through the eye socket of the skull (4). This type of evidence can be

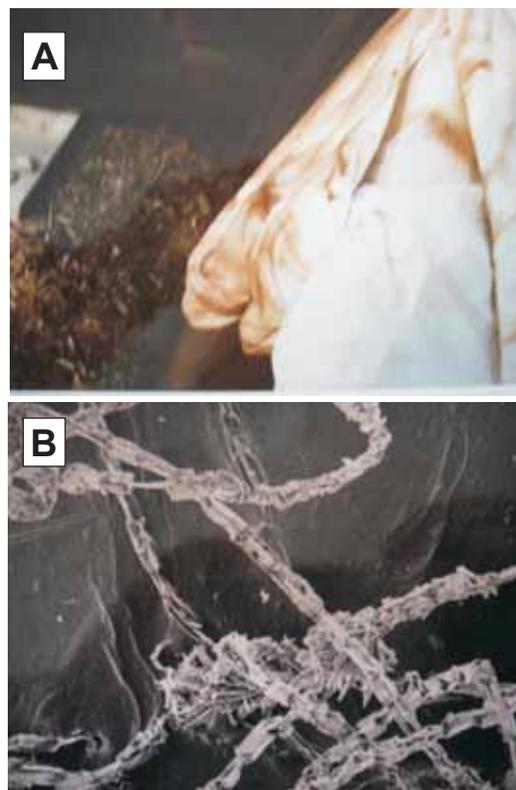


Figure 7. Algae to linking a weapon used in a homicide to a nearby freshwater pond. **A.** Stained T-shirt the husband was wearing at the time of the crime, hanging over the railing of his home. **B.** A photomicrograph of the algae present on the stained areas of the T-shirt that was the same as found in the pond.

used to give a minimum estimate of the time; however, not a maximum estimate, as there is no certain manner to determine precisely when the plant seed was initiated relative to the skeletal remains. In other words, the skeleton could have lain in the field for some time prior to when the plant sprouted.

In addition, scientists with experience in taxonomy and ecology can aid in missing persons cases. For example, a father and daughter were last seen together in Nevada, but a short while later, the father was found dead in his vehicle due to a self-inflicted gunshot wound (7). The only evidence of the daughter was her jacket with some leaf litter covered in blood on the seat of the vehicle. The leaf litter represented greenleaf manzanita, canyon live oak, interior live oak, ponderosa pine, black oak, and white fir. The growth requirements including sunlight, known geographic distributions, water, and elevation were used to

“profile” where this combination of tree and shrub species could be located, and five potential sites were selected to search for the missing girl. At the fifth site, at an area that was a few miles past where the vehicle was found, her body was located, hidden between two logs.

Time of Death. Many different tests can be performed to establish time of death, including the use of body temperature, forensic entomology, and forensic botany. After death occurs, the body will slowly cool to the surrounding temperature. Before the body reaches the equivalent ambient temperature, it is fairly straightforward to calculate time since death by extrapolating back from the original average body temperature. Both forensic botany and entomology may prove useful tools for estimating time of death. Entomology relies on predictable patterns of insect colonization of a corpse to estimate time of death (8). Forensic botany, however, can be used to establish time of death by pollen analysis (7,9) or analysis of stomach contents (7). A good example of pollen analysis and time of death estimates comes from a study of skeletons recovered from a mass grave in Magdeburg, Germany, in 1994 (5,7). Since 32 male skeletons were recovered, it was hypothesized that they died in a military interaction. Two possible hypotheses were considered: (a) the men were victims of the Gestapo at the end of World War II in the spring of 1945 or (b) they were Soviet soldiers killed by secret police after the German Democratic Republic revolt in summer of 1953. The remains were exhumed and the nasal cavities rinsed with a saline solution to recover any pollen that the men may have breathed in prior to their death. Appropriate control samples from the soil were also analyzed for pollen species composition. Seven of the tested skulls contained high amounts of plantain, rye, and lime tree pollen – all common for plants that flower in the summer months, thus supporting the second hypothesis.

The analysis of stomach contents can also be used to estimate time of death using simple microscopic methods (7). For example, a man in Colorado was suspected of being murdered in 1993 by his wife. He was the eighth husband of Jill Caroll and his body was found in his home. The victim was very habitual in that he always ate the same breakfast consisting of toast, hash brown potatoes and eggs at the same restaurant every morning. At autopsy, his stomach contents were mis-

identified as noodles, and then later correctly identified as potatoes. Knowing the estimated digestion time for this food, the victim must have died sometime between two and four hours after breakfast; a time frame that was not consistent with the wife’s alibi. She was later convicted of the crime.

Summary

The recognition, collection, and preservation of botanical evidence are crucial to the success of subsequent laboratory testing. Without the first steps of the process being performed properly, the legal acceptance of the evidence into court may be called into question. As with other forms of forensic evidence, plant material may be examined using simple microscopy or more sophisticated plant DNA testing to enhance the information gained from an investigation. Analogous to other forms of forensic testing, forensic botany first requires the identification of the plant species by morphological characteristics, microscopy, or molecular biology (2-6). After the species has been identified by its class characteristics, then an attempt to individualize the sample is made. The effectiveness of source attribution of plant material will depend on how unique the species is to the geographic area and its genetic history (7). If a plant is very rare, source attribution may not be difficult; however, many plants may require DNA testing to confirm that the evidentiary sample originated from a source plant, if generated by seed, or a source population if generated by clonal reproduction (7). Ultimately, the information from generating plant DNA databases can be used to correlate specific markers with known plant varieties; to establish forensic linkages, to make patent applications for new varieties, and to assess the degree of genetic variation found within a plant population. This article discussed several cases where botanical evidence was used to provide investigative leads or resolve cases and described the basic forensic principles of recognition, collection, and preservation of plants as evidence.

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