

Decomposition of Buried and Submerged Bodies

In death investigation, the forensic scientist will certainly encounter his or her share of cases involving a decomposed body or remains. A substantial number of these cases will involve buried bodies or those recovered from an aquatic environment. Such cases require careful consideration in determining the postmortem interval based on compositional change, as the rate of decomposition is slower than that which occurs in air. When not specified otherwise, case observations are those from the authors' case experience.

The reduced rate of decomposition of a buried corpse, which in general proceeds at a rate eight times slower than above ground, can be attributed to two major factors. The first factor is that of limitation of carrion insect and animal activity. Burial of a corpse either limits or totally prevents access to the body by carrion insects and animals; thus breakdown of the tissues is primarily the result of autolysis and bacterial putrefaction (Clark this volume). The degree of access is directly related to the burial depth and soil compactness. Studies and numerous field observations have shown that carrion depredation is primarily restricted to burial depths of a foot or less (Rodriguez and Bass 1985).

At burial depths less than a foot, decomposition odors given off by a corpse easily penetrate the soil, reaching above ground, thus attracting insects and other animals. Carrion-frequenting mammals, primarily carnivores, will dig up and expose portions of, or all of a corpse buried at depths less than a foot in order to feed on the soft tissues and bones. Carrion insects, such as adult blowflies, gain access to a shallow burial by migration through small cracks and crevices in the soil created by bloating of the body. Upon reaching the corpse, the adult females will oviposit on the tissues. It has also been observed that after a period of rain or in the presence of moist soil conditions and concentrated decomposition odors, adult females will oviposit on the soil surface (Rodriguez and Bass 1983). Upon emergence from the eggs, the fly larvae migrate down to the corpse to feed and develop. For treatments of forensic entomology see Catts and Haskell (1990), Smith (1986), and Haskell et al. this volume.

The second major factor responsible for reduced decomposition rates below ground is the soil environment. Soil provides an efficient barrier to solar radiation, and therefore both temperatures and temperature fluctuation decrease with soil depth. As temperature decreases with soil depth so does the rate of decomposition by cooling of the body. At depths of less than a foot or so, one can expect temperatures to be close to those above ground and to fluctuate daily (Rodriguez and Bass 1985).

Thermal stabilization in soil, in general occurs at depths greater than 2 feet, with no significant temperature fluctuations other than by season. Deep burials of approximately 4 feet or greater, by maintenance of cool temperatures and inhibition of depredation, provide an extremely reduced rate of decomposition. A corpse buried at such depths will remain virtually intact, with minimal tissue loss for a period of at least 1 year.

Two other aspects of the soil environment affecting the decompositional rate are moisture content and the presence of soil organisms, both plant and animal. The presence of ground water, or clay type soils which retain moisture, in most cases produces an environment conducive for adipocere formation. A body recovered from a burial site which contains significant amounts of clay soil typically exhibits advanced adipocere formation, whereas a body recovered from dry or well-drained soil lacks significant adipocere formation. Wet soil environments are commonly associated with deep burials, and therefore bodies recovered from such sites tend to exhibit adipocere formation over most of the body surface. At greater soil depth there is typically more moisture due to lesser degree of evaporation, due to the soil barrier, and resulting from being more approximate to the water table.

At shallow depths, a buried body is subjected to temperatures which approximate those above ground and undergoes increased degradation by plants and soil organisms. Plant roots grow towards a decaying corpse, seeking the rich organic nutrients produced by decomposition. The release of organic nutrients by decomposition results in increased and differential plant growth at the burial site (Rodriguez and Bass 1985). This observation may permit the rapid location of a buried body in large fields where changes in soil compaction may be difficult to spot. Once in contact with the body, the roots will begin to degrade the clothing, skin, and finally the skeletal remains during the later stage of decomposition. Many skeletal remains recovered from shallow burials exhibit obvious root damage. This damage appears as irregular multichanneled grooving of the outer bone cortex. In many instances, skeletal material will be recovered with adhering roots which have grown into the bone trabeculae or completely through the bone. Skeletal or clothing remains which have been penetrated by roots should be handled with care so as to not disturb the context of the roots. Root growth associated with remains can be useful in estimations of the postmortem interval, especially in cases involving remains approximately 1 year to a few years in age (Willey and Heilman 1987). Such material should be taken to an experienced botanist for identification of the plant species and time required for present stage of root growth.

Soil-dwelling insects and bacteria, like plant roots, are most prolific at shallow depths due to the enriched upper soil, and therefore contribute to the more rapid decompositional process associated with shallow burials. The criminal disposal of a corpse in a deep grave tends to produce a retardation of surface plant growth, as primary root structures are destroyed and there is surface redeposition of nonnutritive soil by the digging. A lack of, or disruption of plant growth at a burial site is one sign which fortunately provides evidence of a grave. Also it is fortunate that no matter how carefully a grave site is filled, resettling of the soil will occur, producing an outlined depression of the grave site which can be referred to as a "primary grave depression" (Morse 1983). With the passage of time, the depth of the depression will increase until the soil finally settles. As a general rule, the presence of a deep primary depression usually indicates a deep burial. A corpse buried during warm weather and at depths of 2 feet or less, in general, undergoes decomposition in which there is significant bloating of the chest and abdomen by decompositional gases. As bloating occurs, the soil covering the body is pushed upwards followed by resettling of the soil into the chest cavity as it collapses in the latter stage of decomposition. This filling in of the chest area by soil creates what can be referred to as a "secondary grave depression".

Mummification of a corpse is commonly encountered in cases involving a shallow burial during winter months, after which the body is recovered in the late spring or summer. The cold temperatures greatly retard or practically halt the decompositional process. As environmental temperatures slowly warm in the spring, the body begins to desiccate similar to the effect of freeze-drying, thus producing mummification of the corpse (Rodriguez and Bass 1985).

Experimental studies conducted on the decay rate of buried cadavers in Tennessee (Rodriguez and Bass 1983, 1985) and observations on cases in the Northeast have shown that in general, complete skeletonization of a buried corpse at depths of approximately 4 feet or

greater takes approximately 2 to 3 years. Complete skeletonization of a body buried at a shallow depth of approximately a foot takes approximately 6 months to a year or more. This is true for most latitudes in North America. The time required for complete degradation of buried skeletal and dental remains is extremely lengthy, with breakdown taking anywhere from several years to hundreds, as demonstrated by the survivability of archaeological specimens. The two most significant factors responsible for the degradation of skeletal remains are soil pH and moisture. Skeletal remains subjected to very wet burial environments can degrade rapidly and be destroyed within a few years. The same is true for skeletal remains if the soil pH is too alkaline or too acidic.

Decomposition of a body submerged in an aquatic environment occurs at a rate roughly half that of decomposition in air. The reduced rate of decomposition in water, like that of buried bodies, results primarily from cooler temperatures and inhibition of insect activity. As in the case of drowning, the victim will proceed to sink downward in the water as air escapes the lungs. The depth and rate at which the victim descends is quite variable and is dependent on a number of factors. With the expulsion of most of the air in the lungs, the decedent will sink to the bottom of the lake, river, or other aquatic body (Donoghue and Minnigerode 1977; Sorg et al. Section V this volume). Once reaching the bottom, the early changes associated with death occur, followed by active decomposition. With the accumulation of decompositional gases in the gastrointestinal tract and lungs, the body will begin to ascend to the surface. Once at the surface, the body will float with the head and limbs hanging down beneath the surface. This position in the water results in the head and limbs exhibiting more lividity than observed on the trunk. At the surface, the body continues to undergo decomposition and therefore attracts carrion insects such as the blowflies which feed and reproduce on the tissues exposed above the surface. Entomological analysis of developing fly larvae on a body which has resurfaced may prove useful in the determination of time at which the body resurfaced.

The time required for the body to resurface is primarily dependent on the water temperature, which typically decreases with depth. With fairly warm water temperatures, a body can be expected to surface within a few days, whereas with cold or near-freezing water temperatures, resurfacing of the body can be delayed for several weeks to several months (Cotton et al. 1987). Other factors which affect the rate of decomposition in water include bacterial content and salinity. A corpse submerged in a stagnant swamp, for example, or a water source polluted with organic wastes, will decompose much more rapidly than a corpse in a relatively clean lake that has a lower bacterial content. Decomposition of a body in the ocean or other salt water sources, undergoes a slower decomposition than would a corpse submerged in fresh water, due to the reduction of bacterial action by the salt concentration. The presence of aquatic animal life may also alter the rate of decomposition and surfacing time by tissue removal, thus providing additional portals of entry for bacteria, or reducing torso body weight.

Adipocere formation is typically observed in bodies submerged for lengthy periods of time. Advanced adipocere formation in submerged bodies will provide some preservation of tissues. There are many documented cases of bodies recovered in relatively good condition after being submerged for months to a few years. One case of particular note involved an elderly male who committed suicide by jumping off a high bridge into a river. The remains of the deceased were not recovered until some 3 years later in northern Louisiana, when they were spotted along the banks of the Red River, at a time when the water level of the river had dropped to a record low due to a drought.

Examination of the remains, which consisted of the lower torso, legs and feet, found them to have undergone advanced adipocere formation followed by complete desiccation. The subject made his fatal jump during cool weather, when his body became permanently entangled in the branches of a large and deeply submerged tree. At the time of recovery, the river level had dropped well below the tree, allowing the adipocere-engulfed remains to mummify, high in the branches of the tree. Positive identification of the decedent was accomplished by radiographic comparison of an antemortem pelvic film.

Anomalies of Decomposition and Artifactual Preservation

With the multitude of factors affecting the rate of decomposition, it seems only reasonable that anomalies exist, such as cases involving extended preservation or irregular decomposition. Recognition of variations in the decompositional sequence is of extreme importance to the forensic scientist and death investigator, as it may provide clues to circumstances at death.

The first anomaly can be termed "irregular or disproportional decomposition." Irregular decomposition can be defined as the premature or disproportional decomposition of tissues in an area or areas of a body. There are three mechanisms responsible for irregular decomposition (Rodriguez and Bass 1983).

1. Antemortem or postmortem injury in an area of the body which results in the exposure of blood and underlying tissues, thus providing a portal of entry for carrion insects and bacteria (Rodriguez and Bass 1983).
2. Exposure of a specific area of the body to physical or chemical agents such as heat or corrosive acids.
3. Prior local bacterial infection, such as an abscess or cellulitis (Willey and Heilman 1987).

Of these three, the first (antemortem or postmortem injury) is the one most commonly encountered. Cases involving irregular decomposition should be subjected to detailed investigation, as many of these cases are homicides. An excellent example involved the death of a young white adult female whose body was discovered approximately 12 days after her disappearance (Rodriguez and McCormick 1987a). The decedent was reported missing several hours after her failure to return from an evening walk in her neighborhood. Law enforcement officers along with local neighbors conducted extensive and numerous searches for the missing girl.

Twelve days later, her body was discovered in a partially wooded field near the interstate. At the scene, the body was found to be in a fairly advanced state of decomposition with extensive infestation of blowfly larvae. An autopsy was performed although no significant organ material was present. The findings of the autopsy and what little toxicology could be performed provided no answers as to cause or manner of death.

Approximately 2½ years later, the case was being reviewed by a police detective who questioned whether or not the decedent may have been abducted and held for some period of time and then later killed. A forensic anthropologist was consulted by the case detective concerning an estimate as to the time since death of the decedent. Upon review of scene photographs and environmental data, it was found that the time period for which the decedent had been missing appeared consistent with the state of decomposition. However, it was noted that there appeared to be "irregularities" of the decompositional state which indicated antemortem or postmortem injury to the body. The most notable irregularity observed in the photographs consisted of extensive tissue destruction in the chest and upper abdominal area along with heavy maggot infestation. Also noted was the comparatively large amount of remaining tissue on the skull and the decomposition and maggot infestation in the palms of both hands. Other areas of the decedent's body were noted to be in relatively fair condition. The markedly advanced state of decomposition appeared at first to be the result of carnivore activity. Closer inspection of the scene photos revealed the exposed ribs and costal cartilages to be intact; thus it was unlikely that carnivores were responsible. As for the palmar surfaces of the hands, large scavengers were also ruled out as most of the tendons were undamaged. It was concluded that a strong possibility existed that the decedent had been stabbed in the chest and had suffered defense cuts on the hands. The wounds to the chest and hands provided a portal of entry for bacteria and insects, resulting in areas of premature decomposition. At

this point, it was suggested that the body be exhumed. Approximately a year later, the body was exhumed and a detailed examination of skeletal elements in question was conducted. Each of the exposed skeletal elements was carefully removed by hand, as only minor dissection by scalpel was required due to the decomposed state of the surrounding tissues. The elements removed were then wrapped in burlap cloth and carefully cleaned of adhering soft tissue by boiling. Inspection of the cleaned bones revealed several cut marks consistent with knife wounds, on the manubrium and sternbrae, as well as on the palmar surfaces of a few of the metacarpals. Also discovered was a cut mark on the inferior edge of the right second rib. Dark staining was observed along the cut marks, suggesting the injuries to have occurred perimortem. In view of these findings, the cause and manner of death were changed from unknown to death resulting from multiple stab wounds to the chest, and manner of death — homicide.

Cases involving a badly decomposed corpse tend not to be thoroughly examined due to the lack of recognizable soft tissues, the presence of maggot masses, and offensive decompositional odors. Many injuries, such as the ones in the previously discussed case, may not be readily visible on direct visual or radiographic examination, as they are masked by the decompositional debris and repositioned skeletal structures. However, recognition of "irregular decomposition," along with a thorough and detailed examination of the remaining tissues and bones, will many times provide more answers than one might think.

The second decompositional anomaly to be discussed is that which is termed "artifactual preservation." Artifactual preservation refers to the preservation of a body or body tissues by chemical substances, or by destruction of decompositional bacteria. Artifactual preservation may provide a false impression of a relatively short postmortem interval. One example is the tanning of body tissues by tannic acids, such as found in the remarkably preserved bodies from the ancient peat bogs of Denmark. Similar cases of body and tissue preservation have been documented in the forensic literature as the result of the corpse being placed in contact with plant materials such as tree bark, pine needles, decomposing leaves, or leather containing preservative compounds. Naturally occurring tannins leach out from the plant material under moist conditions, and in sufficient concentrations, tan and preserve the body tissues. Leaching of preservative compounds from leather goods in close contact with the body after death, such as tight boots or a leather jacket, may produce preservation of the tissues (Zugibe et al. 1987).

Other examples of artifactual preservation include bodies that have been placed in environments that inhibit bacterial action. One noteworthy case involved a homicide victim whose body had been wrapped in several layers of carpet and plastic sheeting. The body had been hidden in a concrete rental garage and not discovered by authorities until some 3 years later. Unwrapping of the body revealed it to be in excellent preservation, with only moderate skin shrinkage and discoloration. Not only was there remarkable external preservation, but there was also good preservation of the internal organs including the lungs. Other forensic scientists have encountered similar cases in which there has been remarkable preservation of the body or portions thereof which have been tightly covered by plastic or finely woven synthetic fabric.

To better understand this phenomenon, an experiment was conducted which involved the wrapping of body portions in plastic bags (Rodriguez and Bass 1986). Two intact unembalmed cadavers used in this experiment were buried in shallow graves following wrapping. One of the subjects had his left foot wrapped tightly inside two plastic bags, the other subject had his head, lower right arm, and leg wrapped inside doubled plastic bags.

After a period of 9 months and 6 months, respectively, the cadavers were exhumed and examined for gross decomposition changes. It was observed that the tightly wrapped plastic produced marked preservation of the covered tissues in comparison to those areas which were uncovered. Other field and case observations led to the conclusion that the observed preservation resulted from the buildup of bacterial by-products in an enclosed system. Initially, the bacteria acting to degrade the tissues multiply rapidly; however, as their by-products such as

ammonia and alcohol increase, along with the pH within the closed system the bacterial action is suppressed. Additionally, oxygen depletion by aerobic bacteria may further retard bacterial life.

Another type of artifactual preservation by suppression of bacterial action is that which has been reported for the recovery of embalmed bodies (Berryman et al., this volume), in particular those buried in historic type caskets made of lead or iron (see Owsley, this volume). In cases involving historic remains, it is believed that in addition to the embalming compounds, the airtight sealing of these caskets by welding with the release of oxidized metals in the form of gases may produce a highly bacterio-static environment. A classic example of a case involving such preservation is that of a Civil War army Colonel (see Bass, this volume).

Injuries Due to Insect and Terrestrial or Aquatic Animal Life

An exposed body that is not immediately discovered at death becomes increasingly subject to animal depredation with the progression of the postmortem period. Depredation of the corpse by various animals produces a wide array of postmortem injuries that may be easily misinterpreted by the unfamiliar death investigator as being antemortem injuries resulting from human action (Rodriguez and McCormick 1987b). There are five primary animal groups that have been associated with the postmortem depredation of a human corpse. They are insects, birds, rodents, aquatic animals, and mammalian carnivores.

Insects commonly responsible for postmortem injuries include the blowflies, roaches, and ants (Rodriguez and Bass 1983; Spitz 1993:44-47). Blowflies are the first insects to arrive at the corpse. The blowfly larvae upon emerging from their eggs, begin their ravenous feeding on the tissues of the corpse, and in large numbers are capable of tremendous tissue damage. Damage by the larvae is exhibited as small cylindrical bore holes which range from one to several millimeters in size, and mimic wounds produced by an ice pick or a small caliber bullet. An antemortem injury, for example a knife or bullet wound, in many instances will be distorted, enlarged, or made unrecognizable by feeding of the larvae at the injury site. Roaches and ants, like flies, can be commonly found indoors as well as outdoors. Depredation by ants and roaches appears as small erosions on the skin that may give the impression of antemortem abrasions. Drying of these postmortem bites gives the impression of brush type abrasions. In most cases, one can distinguish ant bites from roach bites, as the feeding pattern of ants is less confined, with small linear trails bordering the primary erosion points.

A corpse exposed outdoors is subject to depredation by various types of birds, most commonly vultures and crows. Vultures and crows typically feed on the corpse in the latter stages of decomposition. Injuries to the tissue from crows appear as small triangular shaped punctures resulting from pecking with the beak. The pecking and tearing action used in feeding by buzzards and vultures produces small strips of adherent tissue which has a sinewy type appearance. Smaller birds such as the common sparrow or blackbird will remove head hair, once it has sloughed from the body, for use as building and insulation material for their nests. This may account for the lack of head hair at scenes involving a decomposing body. Locating and searching birds nests near the death scene may be useful in securing the deceased's hair.

Rodents are another group of animals responsible for postmortem depredation of human remains (Haglund et al. 1988, 1989, also this volume; Rossi et al. 1994; Sorg 1985). Bodies exposed indoors in substandard housing are subject to attack by rodents such as mice and rats. Mice and rats are known to feed on a body within the first days following death, producing injuries that resemble antemortem ulcerated skin lesions. The areas of the body typically attacked include the face, scalp, and finger tips. In cases involving skeletal remains, rodents such as mice, rats, squirrels, and rabbits, will gnaw on bones for their mineral content. Common sites for gnawing include along the foramen magnum, eye orbits, mandible, and

maxilla of the skull, as well as the long bones. Gnaw marks on bone closely resemble cutmarks by a knife or other sharp-bladed instrument, and may initially appear suspicious when observed on the cervical vertebrae of the neck. Rodent gnaw marks can be distinguished from cut marks by the double-channeled grooving produced by the rodent's incisor teeth. Field mice in particular are infamous for their removal of small bones of the hands and feet, as well as teeth and small jewelry items, which are taken to their burrows. In the case of missing small skeletal elements or teeth at a death scene, it may be well worth the time and trouble to locate nearby rodent burrows and check them for the missing remains.

In addition to destruction due to their gnawing, mice are known to construct burrows inside the mummified remains or skull of a corpse. Aquatic animals, which include sharks (Rathbun and Rathbun 1984, this volume), fish, turtles, and crabs are commonly responsible for postmortem injuries observed on corpses recovered from ponds, lakes, rivers, and oceans (Spitz 1993:44-47). Depredation by small fish is primarily observed on exposed fingers and toes and along the lips and ears, and appears as small erosions of the tissue. Turtles and crabs, on the other hand, produce significant tissue damage during their feeding on the corpse. Most tissue injury produced by turtles is exhibited as large scalloped pits on exposed areas of the body. The size of the pitting will vary with the size of the turtle. Large turtle species such as the alligator snapping turtle are capable of producing crushing injuries to facial bones. Crabs found in bodies of fresh- and saltwater feed on most exposed areas of the body. Crab depredation can in some instances be mistaken for cutting injuries due to the "clean edge" appearance around the denuded feeding site. Depending on the feeding area, one might see small slits in the tissue adjacent to the denuded area which result from the pinchers used to grasp and move along the feeding site.

With the exception of carrion insects, mammalian carnivores are responsible for most cases of postmortem injury by depredation. Small carnivores like raccoons, skunks, and opossums, typically frequent an exposed corpse during the early part of the postmortem period. Areas of the body most commonly attacked are the hands, feet, and upper chest. The injuries produced by their feeding is typical of most carnivores as exhibited by tearing of the tissues, with multiple puncture marks produced by the canines, and linear scratches and tears by the claws. A corpse exposed indoors is subject to depredation by pet cats and dogs. Such cases of pet depredation are commonly seen among the elderly who live alone. One case of particular interest involved an elderly woman who for the most part had been totally consumed by her five dogs. Positive identification of the woman was established through dental comparisons of teeth which were recovered from the fecal remains of the dogs. The presence of urine or fecal material on the deceased, such as in the case of an individual who died while defecating, is commonly responsible for injury specifically to the genitals or buttocks by pet canines.

Larger carnivores, primarily wolves, coyotes, and domestic dogs are known to attack the corpse throughout the postmortem period, including skeletonization. Postmortem injury by these larger carnivores in most cases is quite extensive. Canid carnivores are also responsible in large part for the scattering and removal of bones commonly encountered in cases involving skeletonized remains. Scattering and removal of skeletal elements by coyotes and wolves tend to be less than scattering by domestic dogs. Domestic dogs are known to scatter skeletal remains over quite a large area.

Recently a number of studies concerning canid depredation and scavenging of human remains have provided valuable information on the types of bone injury and dispersal patterns (Haglund et al. 1988, 1989; Rodriguez and McCormick 1987b). One study that was reported involved the injuries commonly observed along the eye orbits, maxilla, and occipital area of the skull. These postmortem injuries which appear as fracture and puncture marks, may be misinterpreted as the result of a sharp pointed instrument such as an ice pick. The specific

occurrence of these injuries to the facial area of the skull was found to be the result of the skull being transported in the jaws of the canid.

In conclusion, one cannot emphasize enough the importance of possessing a good understanding of postmortem changes. These changes do not merely represent physical alterations to the body, but serve as important clues to answering a number of crucial questions common to death investigation such as: the estimation of the postmortem interval, determination of environmental conditions at and after death, and identification of antemortem injury vs. postmortem artifact.

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