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## Time Since Death and Decomposition of the Human Body: Variables and Observations in Case and Experimental Field Studies

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**ABSTRACT:** Much of the difficulty in determining the time since death stems from the lack of systematic observation and research on the decomposition rate of the human body. Continuing studies conducted at the University of Tennessee, Knoxville, provide useful information on the impact of carrion insect activity, ambient temperature, rainfall, clothing, burial and depth, carnivores, bodily trauma, body weight, and the surface with which the body is in contact. This paper reports findings and observations accumulated during eight years of research and case studies that may clarify some of the questions concerning bodily decay.

**KEYWORDS:** physical anthropology, musculoskeletal system, postmortem interval, human skeleton, decay studies, time since death, human decomposition

There are few studies on the decomposition rate of the human body [1–4].<sup>3,4</sup> However, nonhuman studies have been conducted on such varied topics as the decay and putrefaction rates of frozen, thawed, and mechanically injured rats [5]; carrion insect activity of pigs [6–8]; and scattering and destruction of mammalian and human remains by carnivores [9–13]. Difficulty in obtaining bodies, lack of suitable areas for placement and study of the bodies, and negative public opinion all contribute to deter most human decay studies. However, it is crucial that forensic scientists have adequate knowledge to estimate accurately how long a person has been dead if they are to contribute to the resolution of the legal issues involved when a human body is recovered. The most common way to obtain such information is to conduct controlled studies on deceased individuals of known age, race, sex, weight, and cause/manner of death in natural, rather than laboratory, settings. In the natural setting, it is imperative that the exact time of death,

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the nature of terrain where the body is placed, and season of placement be known and daily temperatures, rainfall, humidity, insect activity, bodily changes, and stages of decay monitored.

Estimating how long someone has been dead is a topic fraught with variables that are inextricably interrelated. The variables affecting the decay rate of the human body cannot be isolated or controlled in experimental field studies precisely because they are so interrelated—to isolate one variable would, in reality, give us only a tiny piece of a biased puzzle. Rarely, in an actual forensic science case, could a time-since-death estimate be determined based on a single variable such as temperature. Therefore, to test the variability in the decay rate of the body is to observe the decay process in natural and uncontrolled environmental conditions.

Since 1980, students and faculty members at the University of Tennessee have conducted experimental studies of the natural decay process in adult males and females of the three major races. The studies were all conducted at the Anthropology Research Facility (ARF) in east Tennessee. At this isolated, heavily wooded site it was possible to study 150 bodies in various stages of decay, including homicide victims, bodies donated to science, and unidentified persons. Some bodies were studied with specific questions in mind, while others were observed while they were “held” until they could be positively identified or buried. For comparison, experimental animal decay studies were also performed.

This report is not suited to the standard Materials and Methods, Results, and so forth, format of most scientific journals because it is a compilation of observations based on experience and case studies. The authors, William Bass in particular, have given hundreds of seminars, informal talks, and college courses on the many aspects of the human body in a forensic science context. It has been in these presentations that many of the same questions regarding human decomposition have been raised time and again. It was decided, therefore, that to disseminate some of the observations noted over the years, a single “report of findings” based on many case studies and aimed at a wide readership would be best suited. This paper serves this purpose.

The findings (Table 1) will be presented in two sections dealing with environmental and other variables. These variables have been found to affect the rate of bodily decay. It should be stressed that the findings in this report are preliminary and do not include every variable or factor that may affect the rate of bodily decomposition in a particular instance.

TABLE 1—*Variables affecting decay rate of human body.*

Variable	Effect on Decay Rate <sup>a</sup>
Temperature	5
Access by insects	5
Burial and depth	5
Carnivores/rodents	4
Trauma (penetrating/crushing)	4
Humidity/aridity	4
Rainfall	3
Body size and weight	3
Embalming	3
Clothing	2
Surface placed on	1
Soil pH	unknown

<sup>a</sup>Subjective criteria rating based on a five-point scale, 5 being the most influential.

Information that deals with the pattern (how decomposition is manifest in the body) but not the rate of bodily decay is presented in the section of general observations. This section serves as a bulletin board of interesting findings gained through field studies and through years of forensic science investigation both in the field and the laboratory.

## **Variables**

### *1. Temperature*

Ambient temperature appears to have the greatest effect on the decay rate of the human body. During cold or freezing weather, the decay process is greatly reduced or ceases completely. Flies will continue to visit a carcass and lay eggs in cold weather down to about the mid 40s or 50s degrees F (about 5 to 13°C). Below 32°F (0°C), fly eggs will die. The maggots (larvae) will also die if they are exposed to cold temperatures outside the body. Those maggots within the body cavities such as the head, chest, abdomen, and vagina will continue to feed and develop even in freezing weather because they produce their own heat due to their large numbers. On cold days, steam vapors (“heat”) can be seen rising above the body when a maggot-infested area of the body is opened.

One stage in the metamorphosis of the fly is the migration and pupation of larvae in the ground [14]. Many of the maggots that migrated away from or beneath the body and burrowed a few inches into the ground to pupate, will “over winter” until the return of warm weather. They emerge from their puparia, dig to the surface of the ground, and begin a new cycle of reproducing, egg-laying (females), and dying over a period of weeks.

Under ideal conditions (warm to hot weather), it usually takes between two and four weeks for a body to become nearly or completely skeletonized. Cold weather, however, may prevent all decay other than discoloration of the skin from a natural color to orange or black or both, with patches of mold over much of the body. The most difficult time of the year to estimate how long someone has been dead (rate of bodily decay) is those months when the temperature fluctuates between warm and cold.

### *2. Humidity/Aridity*

Increased humidity also appears to be correlated with fly and maggot activity. Arid areas such as deserts result in desiccated (dried out) and mummified remains that may show very little destruction by insects. On a number of occasions, bodies that had become mummified under natural conditions (especially during the winter) retained much of the skin anywhere from two to six years after death.

*Example*—A middle-aged male, who was placed at the ARF while there was snow on the ground, thawed when warm weather returned and decomposed internally, yet most of the mummified outer skin remained intact. The condition of this body has changed little over a period of six years at the ARF.

### *3. Rainfall*

Rainfall, even during severe thunderstorms, seems to have little or no effect on maggot activity—most of the larvae will remain hidden within the body cavities and continue to feed. However, fly activity (and subsequent egg-laying) during moderate to heavy rainfall may be reduced or halted altogether. Hard, pelting rain was not found to contribute to sloughing of decomposed skin.

#### 4. *Soil pH*

Daily soil samples are being taken from around and beneath decomposing bodies to test for the effect of soil pH (alkaline versus acid) on the rate of bodily decomposition. Presently it is not known what effect pH has on bodily decomposition.

#### 5. *Trauma to the Body*

It has been noted that when two bodies are placed on the ground at the same time, the one with any penetrating wound(s) or gross trauma will decay much faster than the body without trauma. The flies are quickly attracted to the wounds, where much of the early egg-laying takes place. The effect of trauma might explain why one body has decayed much more quickly than another when both were placed at the scene at the same time.

*Example*—Two males were placed at the ARF during the fall. One male had been shot once in the chest with a pistol, while the other male had no penetrating wounds or external trauma. Flies were immediately attracted to the bullet wound, where the females began laying eggs. Although flies also laid eggs on the other male, the bullet wound was the first area to show extensive maggot activity (feeding and destruction of the tissue). The wounded male decomposed much more quickly than the other.

#### 6. *Access of the Body to Insects*

If a body is in an environment (such as a sealed refrigerator or sealed plastic bag) that prevents carrion insect infestation, the decay process will be reduced. The overwhelming majority of soft-tissue destruction is due to feeding by insect larvae.

#### 7. *Burial and Depth*

Bodies lying on the surface of the ground tend to decay much more rapidly than those buried. The depth of burial also plays an integral part in the decay rate—bodies buried to a depth of 1 or 2 ft (0.3 or 0.6 m) may skeletonize in a few months to a year or more. However, bodies buried at 3 or 4 ft (0.9 or 1.2 m) may take many years to decompose to the same degree as those at shallower depths. Bodies or body parts placed in plastic bags or wrapped in plastic take much longer to decay than those left exposed to the elements.

*Example*—A male who died of a heart attack was buried at a depth of two feet (ARF) and left loosely wrapped in plastic from the nursing home. He was exhumed after a year and a half and was approximately three quarters skeletonized. Although the entire body showed varying degrees of decomposition, the head was nearly skeletonized and was covered with long strands of mold resembling spider webs. Slight maggot activity was noted at the time of exhumation. The body will soon be exhumed again, marking four years burial.

#### 8. *Carnivore and Rodent Activity*

Carnivores will eat the soft tissues of the body (especially the face and hands) and much of the skeleton (resulting in increased decay rate), especially the spongy ends of the longbones, innominate (pelvis), and vertebrae of both fresh and decayed remains. When a body has been mutilated by carnivores, it is important to search the general area for bones that may have been scattered. Carnivores, particularly dogs, are notorious for carrying bones as far as a quarter of a mile ( $\frac{1}{2}$  km) from the body and will frequently carry a skull or other bone back to their owner or neighborhood.

Rodents can cause extensive destruction to the face, hands, feet, and abdomen. The smaller bones of the hands and feet may be carried away by mice and rats and can usually be found within a few feet of the body. In contrast, a female opossum and her litter were noted living alongside a nearly skeletonized cadaver (which was inside a wire cage) for a period of months without feeding on the desiccated tissue or causing any destruction to the bones.

If a body is found in a wooded area during warm or hot weather and doesn't show evidence of carnivore feeding, it is likely that the body was kept in an area not accessible to dogs (for example, in a warehouse) long enough to allow considerable soft tissue destruction without concomitant bony destruction, and then carried out and dumped in the woods. At any rate, if a badly decomposed body is found in an open area (for example, woods, field, garbage dump) and there is no evidence of carnivore feeding, other possibilities have to be considered. For example, the absence of carnivore feeding may alert you that the body has not been exposed to the out of doors for more than a few days.

*Example*—A few years ago, body parts belonging to a single individual were found in plastic bags scattered about in three counties in Tennessee. The nearly complete upper torso was found in a secluded area frequented by neighborhood dogs. Although the body was badly decomposed (putrefied) and maggot-infested, no evidence of carnivore activity was present. As the case unfolded it was found that the individual had been killed, dismembered in his apartment, and, days later, scattered about in the woods. This explained the advanced degree of bodily decay and insect activity yet lack of carnivore destruction.

### 9. *Size and Weight of the Body*

Logically, this should be a very important factor in the rate of decay. However, preliminary studies have not borne this to be true. Studies at ARF have shown that obese bodies quickly lose body mass due to liquefaction (“melting away”) of body fats. Most variables being equal, no differences in the rate of decay of one sex over the other have been noted.

*Example*—On two occasions, bodies weighing more than 250 lb (110 kg) have decayed more rapidly than bodies weighing approximately 150 lb (65 kg). In each study one large and one small body were placed on the ground on the same day and within 15 or 20 ft (4 or 6 m) of one another. In one case a female weighing 265 lb (119 kg) was nearly skeletonized in only two weeks (hot weather), while a smaller male lying nearby took twice as long.

### 10. *Surface the Body is Placed On*

At the decay facility, bodies have been placed on concrete and directly on the ground at the same time. The bodies lying on concrete usually (but not always) decayed slower and became mummified faster than those on the ground. Although one might like to make “common sense” judgments that more insects can get to a body on the ground and that the ground is a more “natural environment,” at the present time, no provable reason can be offered for this phenomenon.

### 11. *Clothing*

Clothing serves to protect the body from sunlight, which the maggots avoid, and aids in speeding up the decay process. When looking for maggots, search the creases of clothing such as in the armpits, crotch, collar, and so forth.

## 12. *Embalming*

Embalming does greatly slow the decay rate of the body. Further, the pattern of decay is different in an embalmed body from one that decays naturally. For example, unembalmed bodies usually show the first signs of decay in the face, whereas embalmed bodies first show decay in the buttocks and legs, perhaps as a result of insufficient penetration of the embalming fluid in these areas. If an embalmed body is suspected and there is only bone remaining, look for suture material suggesting an embalming scar (injection), a trocar button (usually a plastic screw-type button for insertion in the abdominal area after aspiration of the internal organs), metal wire used to secure the mouth closed, and plastic eye caps. You may or may not find these items.

*Example*—An elderly black male was commercially embalmed at a funeral home and prepared for burial. A turn of events resulted in the body being donated to science. Since no one had ever studied the decay rate of an embalmed body on a daily basis, we took advantage of this opportunity and placed him (undressed) on the ground in a shallow depression at the ARF. Over a period of months it was noted that the pattern of decay of this embalmed body was different from what we had seen in unembalmed bodies.

The first area to decay (be removed by maggots) in unembalmed bodies is the face; however, the face of this individual did not decay even after three months. In comparison, the first areas to decay in this male were his legs and feet (rodents had also eaten some of the soft tissues of the lower legs), followed by the groin and an area beneath his right arm that was lying across his lower abdomen. The chest, arms, and hands remained nearly intact, although shriveled due to dehydration.

It is certain that embalming slows, but does not cease, decomposition of the human body. The most interesting finding in studying the embalmed male was that the tissues of his head and face remained mostly intact for over six months.

### **General Observations**

1. *Skin color in blacks may lighten considerably during decomposition and may look Caucasoid.*

*Example*—The nude body of a middle-age black female who died of “natural causes” was placed on the ground at ARF during the late fall. After only three weeks of cool weather, she lost nearly all her dark pigmentation. Although some areas of her body retained dark pigmentation, others were light in color and had the typical appearance of Caucasoid skin. The elderly black male discussed previously in the embalmed study also showed loss of dark pigmentation in some areas, although not nearly as diffuse as this female.

2. *After a month or more, female breasts will become flattened and have the same appearance of a male chest.*

The large nipples and lower placement of the areola will help make the sex distinction.

*Example*—On two occasions, large-breasted females were observed to lose the underlying fatty tissue, causing the breasts to “deflate.” There were no resulting skin folds or gross evidence, other than areola and nipple size, to indicate a female torso. With time, even the areola becomes indistinct. This observation proved fruitful when vandals removed the torso of a 70-year-old female from a cemetery, bound her with a chain and large stone, and threw her in a river as a prank (the torso was found two weeks after Halloween). Because she had been embalmed and in a sealed mausoleum for years, the

body had mummified. However, her head hair and other indicators of gender such as the breasts were gone or distorted. Although her breasts were not easily recognizable, it was the low placement of the areola and large nipples that allowed a quick determination of sex at the scene. She subsequently was positively identified and reinterred.

3. *The quickest rate of decay documented in our studies was a young, white female who was strangled.*

After autopsy (organs were not returned to the body) she was placed at the research facility in a disaster bag that was left unzipped down to the level of her mid-thoracic region. She was completely skeletonized in seven days during hot weather and in the shade.

4. *Bodies floating in water will exhibit the typical indicators of decay including bloating, discoloration, loss of hair, and maggot infestation.*

*Example*—During the fall, three prisoners escaped from a penitentiary and tried, unsuccessfully, to swim across a wide river. Four days later they were found floating and were taken to the morgue for positive identification. The bodies were bloated and heavily infested with maggots (within all the major body cavities).

5. *In warm to hot weather it literally takes only a few seconds for the first flies (blow flies) to land on a dead body placed outside in a wooded area.*

This has been noted on many occasions when placing bodies for study.

6. *After only a few days in warm to hot weather, head hair will slough off and usually remain intact as a hair mass.*

When a skeleton has been scattered by carnivores, search the area for a mass of hair which will indicate where the body initially lay and decomposed. If the skeleton has been scattered on a mountainside or hill, search further up the hill because many of the bones, especially the round skull, will roll downhill when the soft tissues holding the bones together decay. In very cold weather both head and pubic hair may remain attached to the skin as a result of the lack of dehydration and to expansion of the hair follicles.

*Example*—A Jane Doe was held in a morgue cooler (approximately 40°F [4°C]) for a period of nearly five years pending police and forensic investigations. When the woman's identity could not be established, she was taken to the ARF for holding. After four months her head and pubic hair were still firmly held and could not be removed except with force.

7. *If a body part has been exposed to certain chemicals, insects will avoid it.*

*Example*—At the ARF, a badly damaged human hand was removed for fingerprinting at the police laboratory and placed in a jar of formalin. When the hand was put back

with the still decaying body, the maggots would not feed on it, even after months of exposure outdoors. If a body is decomposed and nearly skeletonized but shows no destruction of an expected body part (for example, face), chemical exposure (for example, acids, embalming fluids, etc.) should be considered.

8. *In our studies birds have never been seen feeding on the human body, although they have been seen feeding on the maggots and carrion beetles.*

9. *Dog studies.*

Three dog studies using two dogs of similar size and weight were conducted. In two of the studies, one dog was placed on concrete and another on the ground. The dogs lying on the ground decayed quicker than those on the concrete. In comparison with humans, the dogs decayed much more quickly. In one case, a 35-lb (15-kg) dog was bloated and partially skeletonized in two days (hot) in October. On Day 4 he was completely skeletonized, with only bones and a "ring" of fur remaining around the carcass.

Studies on the decay rate of dogs at the University of Tennessee have not been shown to be comparable or valid substitutes for human studies. This statement, however, is not intended to discredit or in any way invalidate insect studies on dogs or other animals for species comparison to humans. However, without further comparative decay studies it simply is not valid to compare the rate of decay of a 50- or 80-lb (20- or 40-kg) dog to a 150- or 180-lb (65- or 80-kg) human. The dogs decay too rapidly, and insects leave the skeleton much more quickly than what we have witnessed in human studies. It should be noted that a large mastiff weighing just over 100 lb (45 kg) was also studied at the ARF. The mastiff, however, was placed out during a time when the temperature fluctuated between very cold and warm. The one similarity in the dog studies with those of humans is that the face was usually the first area of the body to become skeletonized.

10. *Variability in the decay rate of the human body is the rule.*

### **Summary**

Studies conducted at the University of Tennessee have shown that the rate of bodily decay is quite variable. General observations suggest that the three variables that most influence the rate of human bodily decay are temperature, access by insects, and burial depth. Penetrating wounds also play an integral part in the decay process. Clearly, a body that has been repeatedly stabbed and placed in the woods during the summer will decay much faster than a body with no penetrating wounds which is put out in the middle of the winter. The effect of rainfall is a variable that should be considered during those periods when heavy rain would prevent fly, and, subsequently, maggot activity. Although there are a number of known variables that affect decomposition, many variables have yet to be defined.

It is hoped that this paper provides a clearer explanation of the great variability in the decay rate of the human body. All of the studies reported in this paper are based on observations made in a heavily wooded area in eastern Tennessee. However, because of the great variability in bodily decomposition, it is imperative that further research be conducted not only in Tennessee, but in many other states where temperatures and other environmental and ecological factors differ from those in east Tennessee. Only by having

comparative experimental data from a number of regions in the United States can time-since-death estimates reliably be applied to actual forensic science cases.

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