
Postmortem Changes in Soft Tissues

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Introduction

The processes that reduce a human body to a skeleton through the postmortem destruction of soft tissues are complex. As with other biologic phenomena, there will be much variation from person to person and it is impossible to assign absolute times for any of the processes. The following discussion of decomposition is limited to bodies which have not been embalmed, since this process retards and, in some cases, completely prevents decomposition.

Determination of Death and Early Postmortem Changes

In a hospital setting, determination of death usually involves the use of such instruments as the electrocardiograph and the electroencephalograph. The more traditional and time-honored methods of determination of cessation of vital function are simple and straightforward. The absence of a heartbeat over the left side of the chest or lack of an arterial pulse in the neck or the wrists means that the patient is dead. Listening for a heartbeat with an ear to the chest or with a stethoscope is the next level of sophistication. Cessation of breathing after death can be observed by noting the lack of chest movement as well as by listening to the airway with or without a stethoscope.

Changes which occur within the first 2 hours after death are referred to as early postmortem changes. These alterations are caused by lack of effective cardiac pumping of oxygenated blood resulting in a loss of the usual skin color. This "pallor" is first noticed in very light-skinned people as early as 15 to 30 minutes after death, but it may go unnoticed in dark-skinned persons. At the same time, the skeletal muscles of the body, including the sphincters, relax. It is during this period that fecal soiling may occur. In addition, if a body is moved during the period of muscular relaxation, regurgitation of gastric contents or "purging" may occur.

External and internal alterations of the eye occur during the early postmortem period. Externally, a dark band of dried corneal epithelium may be visualized across the front of the eyes since relaxation of the orbicularis oculi muscles of the eyelids exposes the corneas to air drying. This phenomenon is sometimes referred to as "tache noir sclerotique." By using an ophthalmoscope, sludging and intravascular coagulation of blood in the retinal vessels can be seen. This is sometimes called sausing or boxcarring.

Following death, the blood gradually becomes acidic due to the accumulation of carbon dioxide and other chemicals released as the result of tissue breakdown (Cotran et al. 1994). This causes the activation of the intrinsic coagulation mechanism resulting in blood clots in both arteries and veins throughout the body. This generalized coagulation of the blood usually

occurs at about the same time as the development of rigor mortis or stiffening of the muscles. As decomposition continues, the blood pH further decreases, and enzymes called intrinsic fibrinolysins are activated. These enzymes cause reliquification of the coagulated blood. This generally occurs at the same time as rigor mortis begins to dissipate.

Late Postmortem Changes

Rigor mortis, algor mortis, and livor mortis are referred to as late postmortem changes because they are first observed beginning at 2 to 4 hours after death. These processes are independent of one another, but usually occur simultaneously.

Rigor mortis, or the postmortem stiffening of the muscles, is a reversible chemical change of the muscles. It begins in all skeletal muscles shortly after death, but is first noticeable in the facial muscles as tightening of the jaw at 2 to 3 hours postmortem. After 24 hours, the entire body will be rigid to the extent that it may be capable of supporting its own weight (Spitz 1993:27). As chemicals in the muscles are consumed, they relax by about 48 hours. Since rigor mortis is a chemical process, it is accelerated by heat. This means that if an individual dies following exertion or with a fever, rigidity will develop faster than in an individual whose body temperature is normal at the time of death. Rigor mortis does not cause muscular contraction and, Hollywood movies to the contrary, dead bodies do not sit up, grasp objects, or walk about due to rigor.

Algor mortis is the normal cooling of a body which takes place as the body equilibrates with the environment after death. The normal metabolic processes of the body which maintain a core temperature of 98.6°F during life cease at death and the body temperature will tend to approach the ambient temperature. In most circumstances this means that bodies cool after death at an approximate rate of 1.5°F per hour. If death occurs in a very warm environment, body temperature will rise after death. Elevated body temperature during life or hyperthermia will obviously modify postmortem changes in body temperature.

Livor mortis (also called livor or lividity) refers to the gravitational pooling of blood in dependent parts which occurs after death. In other words, the blood pools on the down side of the body because it is no longer being circulated by the heart. Livor can be first recognized as soon as 15 minutes after death by trained observers, but it is ordinarily first evident at about 2 hours postmortem. The normal color of livor mortis changes from red to purple as oxygen gradually dissociates from the hemoglobin of the red blood cells. This produces a pigment in the red cells called deoxyhemoglobin which is purple. When it is initially seen, livor mortis is nonfixed. This means that when a blunt object, such as the back of a finger, is drawn across an area of lividity, the pressure will force blood from the engorged capillaries resulting in an area of blanching which quickly refills. As the body cools (i.e., algor mortis), the fat in the dermis which surrounds the capillaries solidifies and pinches them such that pressure will no longer force blood away from the area of lividity. This phenomenon is called fixation of lividity and it occurs at 4 to 6 hours after death or after rigor mortis is easily detected (Figure 1). It should be noted that in patients who are profoundly anemic or have lost large quantities of blood, lividity may not easily be seen.

Lividity typically varies from red to purple and becomes darker as the postmortem interval increases. Deviations from these normal colors can be of profound importance. Specifically, cherry red lividity is diagnostic of carbon monoxide poisoning until proven otherwise. Bodies that have been exposed to very cold temperatures soon after death will appear pink because the cold inhibits dissociation of oxygen from the hemoglobin. The least common cause of red lividity is cyanide poisoning, where the cyanide inhibits dissociation of oxygen by blocking the cytochrome oxidase enzymes. All of these changes look similar. To tell the difference, laboratory testing of the blood must be done and these results should be



Figure 1 This elderly lady with a history of heart disease, was last seen alive 24 hours prior to being found sitting upright in her bathroom on the toilet. Note fixed lividity with blanching in areas of pressure produced by the weight of the body.

compared with information from the scene of death. Finally, the death investigation and laboratory data must be the subject of interpretation by a forensic pathologist who then compares that information with the findings at autopsy.

Tissue Changes

Now that early and late postmortem changes have been considered, we will begin a discussion of the changes which occur in the tissues eventually leading to skeletonization of the remains. The entire process is referred to as decomposition, and this process is further subdivided into autolysis and putrefaction.

Autolysis is a process whereby hydrolytic enzymes that are present in cytoplasmic granules in all cells, called lysosomes, are released into the cytoplasm. Autolysis is thought to be triggered by the decrease in intracellular pH which occurs as a result of decreased oxygen levels which occur after death (Cormack 1987). The hydrolytic enzymes in the lysosomes digest carbohydrates and proteins, while fats are affected to a lesser degree. Because the cell membranes are also disrupted during autolysis, these molecules are released and are utilized as nutrients by microorganisms (see below). Following death of the organism, homeostasis is no longer operative and all cells undergo autolysis beginning shortly after death. The time at which autolysis begins in different cell types and organs is quite variable. As a general rule, autolysis begins much sooner after death in those cell types which contain large numbers of lysosomes (e.g., pancreas) than in those which contain few hydrolytic enzymes (e.g., muscle). The process of autolysis is temperature dependent, and refrigeration of a body soon after death will retard the enzymatic self digestion of cells. Autolysis will be accelerated by ante-mortem fever, exertion, or a high ambient temperature.

The changes produced by autolysis initially can be seen only by use of a microscope, but as the process progresses the features can be seen with the naked eye. These changes will first be observed at about 48 hours after death. Externally, a phenomenon called skin slippage will be seen. In skin slippage, the postmortem release of hydrolytic enzymes by cells at the dermal-epidermal junction of the skin results in a loosening of the epidermis from the

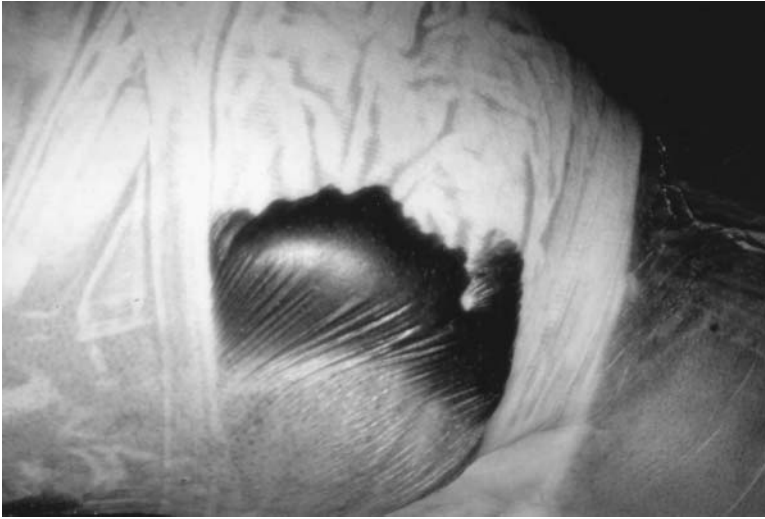


Figure 2 This individual died of a myocardial infarction but went undiscovered for some 72 hours. Note the large bulla at the dermal–epidermal junction

underlying dermis. As a result, the epidermis can be easily wiped off the dermis by the moving of a body. In addition, hair and nails become loose and, if not dislodged by moving the body, eventually fall off. It should be noted here that, horror fiction aside, hair and nails do not grow after death. If a body is found with head hair 3 feet in length and 3-in. long nails, these skin appendages were present at those measurements prior to death. Collections of fluid within the skin are called postmortem bullae (Figure 2). These accumulate at the dermal–epidermal junction in dependent portions of the body and are easily ruptured by moving the body.

Internally, autolysis will be noticed as a doughy consistency of the tissues as well as the staining of the intima of large blood vessels by postmortem hemolysis which is simply autolysis of the red blood cells. On the surface of the body, intravascular hemolysis will result in the outlining of superficial blood vessels by the blue color of deoxyhemoglobin, a process referred to as “marbling” (Figure 3).

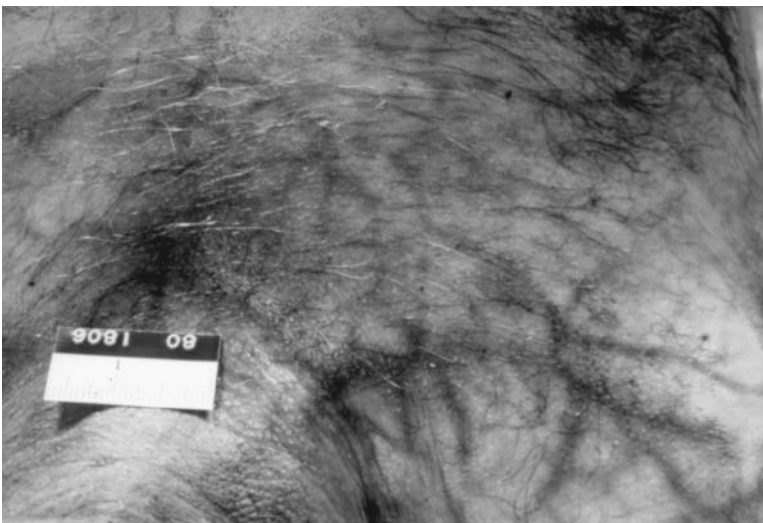


Figure 3 Note the prominent marbling caused by intravascular hemolysis in the skin of this man found approximately 48 hours after dying of natural causes.

During life, the normal homeostatic mechanisms of the body prevent bacterial overgrowth, but, when homeostasis ceases with somatic death, the uncontrolled growth of endogenous bacteria and fungi begins. This process is fueled by the copious quantities of carbohydrate, protein, and fat breakdown products which are released by autolysis. Many of the microorganisms produce large quantities of malodorous gases as well as pungent aromatic organic compounds. This is the stage at which decomposition is easily appreciated by the visual and olfactory senses. The rapid production and accumulation of gases causes both physical and chemical changes in the decomposing body which are superimposed on the autolytic processes described above. The physical changes of decomposition consist of alterations caused by accumulation of gases in the soft tissues as well as within the gastrointestinal and respiratory tracts. These changes are most prominent in the areas of the body which contain the most blood, since the red blood cells act as a food for the bacteria. Therefore, these putrefactive changes are more pronounced in areas of livor mortis. Ordinarily, the soft tissues of the face swell first and cause eversion of the lips (Figure 4). Then the abdomen becomes massively distended by gas and, in males, gas is forced from the peritoneal space down the inguinal canals and into the scrotum resulting in massive scrotal swelling. Extreme distortion of body contour occurs at this stage of decomposition which is commonly referred to as “bloating” (Figure 5).



Figure 4 This picture is of a homicide victim who died of a gunshot wound of the chest. He was discovered approximately 96 hours after death. Note the eversion of the lips, face swollen by tissue gases, purge fluid from the nose and mouth, and bulla of the eyelids.

The chemical composition of the gas is complex and may not be uniform from body to body. A large component of the gas is hydrogen sulfide (H_2S), which is a small molecule that readily diffuses through the tissues. It also reacts with hemoglobin to form a green pigment, sulfhemoglobin. This pigment initially outlines superficial blood vessels and, as decomposition proceeds, a generalized green hue may be seen in those portions of the body where livor mortis was most prominent.

The same processes which are visualized on the surface of the body also occur simultaneously in the internal organs. Autolysis and putrefaction lead to destruction of the tissues and gas formation. As a result, large gas bubbles may be seen grossly in the liver and other solid organs. Decomposition of the contents and lining of the gastrointestinal tract form a dark, malodorous fluid called “purge fluid” (Figure 4) which flows freely from the nose and mouth due to gas pressure within the gastrointestinal tract. This phenomenon is frequently confused with either antemortem gastrointestinal hemorrhage or injuries.



Figure 5 Extreme bloating of the abdomen accompanied by prominent marbling is demonstrated in this patient who died of heart disease.

Modifications of the Decomposition Process

Postmortem modification of soft tissue, when unchecked by some means of preservation, leads to partial or complete skeletonization. This loss or removal of soft tissue from bone is quite dependent on environmental circumstances. The autolytic and putrefactive processes are entirely capable of completely skeletonizing a body. The soft tissue component is merely lost to the environment. The progression from fresh state to skeletonization is frequently modified by vertebrate and invertebrate animal activity and by factors in the environment.

Animal activity on postmortem remains may elicit the image of large carnivorous predators such as bears or lions feeding on the dead. That scenario, while fascinating, is, of course, rare. More frequently, vertebrate animals which modify soft tissue are of the domestic variety. Dogs and cats which are confined in a structure when an owner dies have been found to feed on the remains as a means of survival (Figure 6). When an individual dies in an exposed environment, those remains are subject to scavenging by carnivorous animals in that environment, be they domestic pets, livestock, or wild animals. Additional scavengers are encountered in aquatic environments (Haglund 1993). Fish and turtles are able to remove flesh from bone quite effectively (Figure 7).

While vertebrate animal activity does occur, it is the invertebrates, mainly insects, which are exquisitely capable of modifying soft tissue to the point of exposing the skeleton. Insect activity on postmortem remains is dependent on environmental conditions which determine the species of insects living in a particular areas at different times of the year (Schoenly 1992). In a tightly closed building, there may be little or no insect activity, especially during cold weather (Emson 1991). In warmer exposed environments, insects begin to work before or very soon after death (Catts 1990). Flies are most frequently associated with the death scene. Their larvae (maggots) dramatically alter soft tissue by their voracious feeding (Figure 8). Goff and Catts (1990) list a plethora of invertebrates which feed on animal flesh or body fluids and therefore alter the remains. Schoenly et al. (1992) describe recognizable and predictable patterns of successional activity among certain flies and beetles. In aquatic environments, other populations of invertebrates including crustaceans have the opportunity to feed on the flesh and fluids of the dead. Environmental exposures, in addition to animal activity,

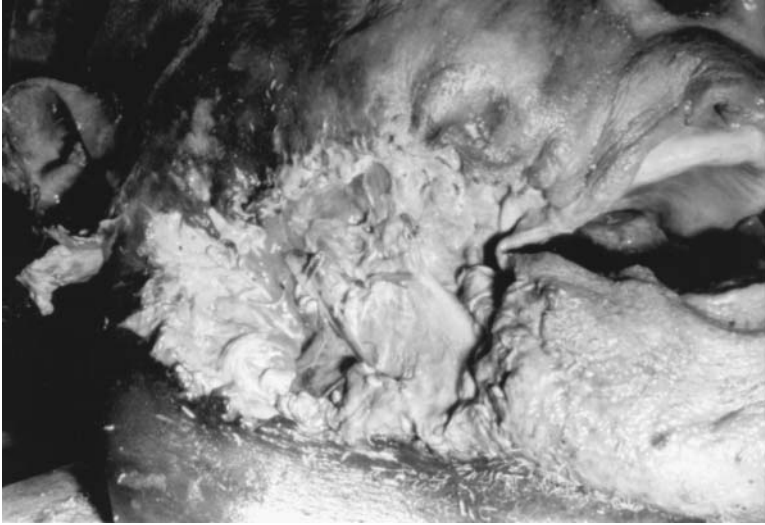


Figure 6 An elderly man died alone in his home of a massive heart attack. Note the area of missing tissue due to the activities of his dog which was trapped in the house with the victim for 3 days prior to discovery.

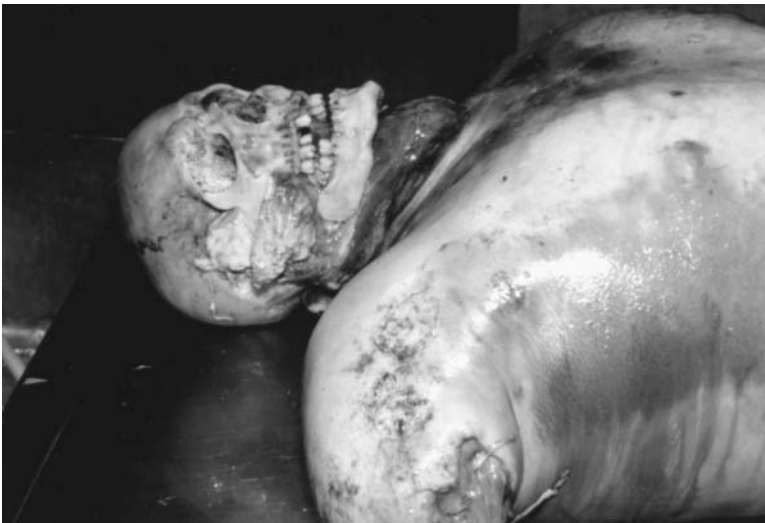


Figure 7 A 28-year-old male jumped off a ship at sea about 30 miles from shore, wearing heavy clothing covering everything except his head, hands, and legs. His body was recovered from salt water 3 weeks later. Partial skeletonization is due to marine animal activity.

are extremely important for determining the rate and degree of postmortem soft tissue modification.

Mummification of soft tissue occurs when the surrounding environment is very dry (Evans 1963). Mummies, such as have been encountered in Egypt, were prepared in ritualistic fashion using the hot, dry desert environment and often spices and herbs. Natural mummification takes place when death occurs and the body loses fluids to the environment via evaporation. Extremes of heat (Figure 9) or cold (Figure 10) can facilitate natural mummification.



Figure 8 This homicide victim was stabbed to death and left in a cornfield during the summer. The body was discovered 2 weeks after being reported missing. Note the large mass of maggots and partial skeletonization.



Figure 9 A 30-year-old woman was found dead on the roof of a building during a long summer drought. The woman had been dead for 3 to 4 weeks and exhibited total mummification with loss of hair, nails, and internal organs. Cause of death was undetermined.

Adipocere is a malodorous, cheesy, compound of fatty acids also referred to as grave wax (Evans 1963). Adipocere formation occurs most commonly when tissues are submerged in cool water where the oxygen content is very low (Figure 11). Over time, adipocere has been seen to become hard and brittle even in aquatic environments (Haglund 1993). Adipocere forms in both embalmed and unembalmed bodies via the hydrolysis and hydrogenation of fats to fatty acids. This process requires the presence of water either from an exogenous source or from the body itself. Areas covered by clothing appear to produce conditions which favor adipocere formation (Mellen et al. 1993). Dehydration and mummification may accompany adipocere formation in bodies where little or no exogenous water is available. As fats are



Figure 10 Mummification is apparent in the fingers of this 29 year old male who died in bed of a drug overdose. The conditions in the room included the air conditioning running at 60°F and an absence of insects.



Figure 11 This body was recovered from a shallow water-filled grave after being buried for 3 weeks. Note the large area of white adipocere formation on the right upper thigh.

converted to fatty acid, the pH drops which inhibits bacterial growth and thereby promotes preservation of soft tissues (Mant and Furbank 1957). In an emaciated person, adipocere formation is limited at best, due to the lack of a suitable substrate, i.e., fat.

Skeletonization

Skeletonization is the removal of soft tissue from bone. The process can be considered complete if all soft tissue is removed or partial if only portions of bone are exposed. A partially skeletonized body may proceed toward complete skeletonization with the appropriate circumstances. A buried

body in a warm environment may skeletonize as rapidly as an exposed body in a mild environment. Depth of burial is also a factor, as is soil type, in determining the rate at which skeletonization proceeds.

Skin, muscle, and internal organs may be lost to the environment well before a skeleton becomes disarticulated. The ligaments, and to some extent tendons, which hold bones in place, will all be lost in time. According to Rodriguez and Bass (1985) disarticulation generally proceeds from the head downward (with the mandible separating from the skull and head from vertebral column) and from central to peripheral (from vertebral column to limbs).

Bone is broken down over time by physical breaking, decalcification, and dissolution due to acidic soil or water. Motter (1898) describes bones exhumed from a buried coffin, after 71 years, as having their general shape and form, but “easily crushed between thumb and finger.” Bodies not in tombs or coffins therefore may in time disappear completely, or under appropriate conditions may become fossilized and preserved for millions of years.

Decomposition Staging Scale

When information concerning postmortem changes and decomposition is arranged in a logical sequence, it is possible to construct a series of stages of decomposition. These stages are in a temporal sequence, but because of varying environmental conditions as well as variations in body habitus and causes of death, it is not possible to assign an absolute “time since death” to any of these stages (Micozzi 1991). This systematic approach to the degree of decomposition is useful for descriptive and comparative purposes. The final stage of decomposition, skeletonization, has been reported to happen as early as 3 days after death in very hot humid areas where fly larva and beetle activity is high, or in the case of frozen bodies, it may take millennia. At normal conditions of standard 30% humidity and temperature of 70°F the first seven stages of decomposition will appear roughly at 24-hour intervals postmortem (Table 1). Mummification is likely to occur in dry areas after the series of putrefactive processes have run their course. If the body is in an extremely hot environment (>100°F) the rapidity of dehydration may reduce the usual swelling of the body. Likewise, if the temperatures are below freezing, putrefaction may not occur as the bacteria are destroyed or rendered inactive. Postmortem changes are summarized and compared with the decomposition staging scale in Table 2.

Autopsy of the Decomposed Body

An autopsy is an examination of a body performed after death: it includes both an external and an internal examination performed by a licensed physician specializing in pathology, or preferably, also certified in the subspeciality of forensic pathology. The objective of this medical procedure is to determine a cause of death and a manner of death as well as to collect any evidence which might be present either on or inside the body. An additional consideration in the case of decomposed bodies is that of identification. One of the classic mistakes in forensic pathology, as described in a definitive article by Alan Moritz (1956), is to regard the autopsy of a decomposed body as unrewarding. Although it may not be possible to determine a cause of death in some cases, many possible causes of death may be excluded by a careful autopsy performed on a badly decomposed body. As with any forensic autopsy, careful documentation in the form of photographs and written records is considered to be the standard of practice. In addition, a well-written report that can be easily understood by others is essential. In many cases, it is best to begin the autopsy by

Table 1 Decomposition Staging Scale

Category	Stage	Changes
Putrid	I	Early putrid odor
		Lividity fixed
		Rigor waning
		Tissues tacky
	II	Green discoloration of abdomen
		Hemolysis
		Intense livor
		No rigor
		Early skin slippage
III	Drying of nose, lips, and fingers	
	Tissue gas on X-rays	
	Prominent hemolysis	
	Tissues soft and slick	
	Skin slips easily	
Bloating	IV	Early body swelling
		Discoloration of head
		No discoloration of trunk
		Gas in heart
	V	Marbling
		Bullae
Destruction	VI	Moderate swelling
	VII	Discoloration of head and trunk
	VII	Maximal body swelling
	VII	Release of gases
n	VIII	Exhausted putrefied soft tissues
		Total destruction of blood
		Partially skeletonized
Skeleton	IX	Adipocere
		Mummification
		Skeleton with ligaments
	X	Skeleton with no soft tissues

taking a series of whole body X-rays with the clothing in place (Figures 12 and 13). This will help to locate objects such as keys which may play a pivotal role in the identification process. If dental fillings or appliances are in place, both an anteroposterior and lateral view of the skull should be taken to facilitate dental charting and identification. The frontal sinuses should also be included in the A/P view since frontal sinus X-ray patterns can be used for identification purposes (Marlin et al. 1991).

The collection of trace evidence is a critical part of the autopsy. The best rule of thumb to follow here is to think about what specimens may be needed at a future date, collect them, and preserve them in an appropriate fashion. In addition to saving body fluids (if available) for toxicology and serology studies, a sample of frozen skeletal muscle should also be saved for potential DNA analysis if appropriate. The temptation to wash off decomposed bodies with a fire-hose for 15 or 20 minutes before getting close enough to examine them should be avoided, since this procedure will result in the loss of valuable trace evidence.

Table 2 Postmortem Changes

Time after Death	Postmortem Changes	Modifiers	Category	Stage
0 minutes	Circulation and breathing stop Pallor Early lividity Muscular relaxation Sphincters may relax	Temperature Humidity Outdoor location Indoor location Submerged in water	See Table 1 Early changes	
2 hours	Vascular changes in eye Rigor mortis begins Algor mortis begins Lividity easily seen		Late changes	
4-5 hours	Coagulation of blood Fixation of lividity			
24 hours	Drying of cornea Re-liquefaction of blood		Putrid Tissue changes	I II
48 hours	Rigor disappears Intravascular hemolysis			III
72 hours	Loss of hair and nails			
96 hours	Skin slippage and bulla formation Bacterial overgrowth	Insect activity Animal activity	Bloated	IV V
Days-months	Green discoloration Bloating Release of gasses Release of liquified internal organs Gradual loss of soft tissues Partial skeletonization Complete skeletonization	Mummification Adipocere formation	Destruction Skeleton	VI VII VIII IX X

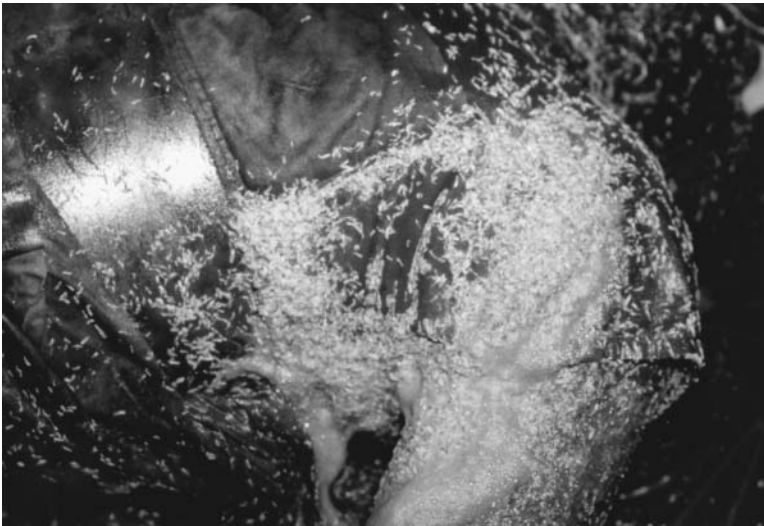


Figure 12 This body was recovered from a central Indiana cornfield in July. The victim had been dead for approximately 3 days. The clothing was in place prior to autopsy. Note the heavy maggot infestation.



Figure 13 This is an X-ray of the body in [Figure 12](#). Note the two projectiles present in the thorax and abdomen (arrows).

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