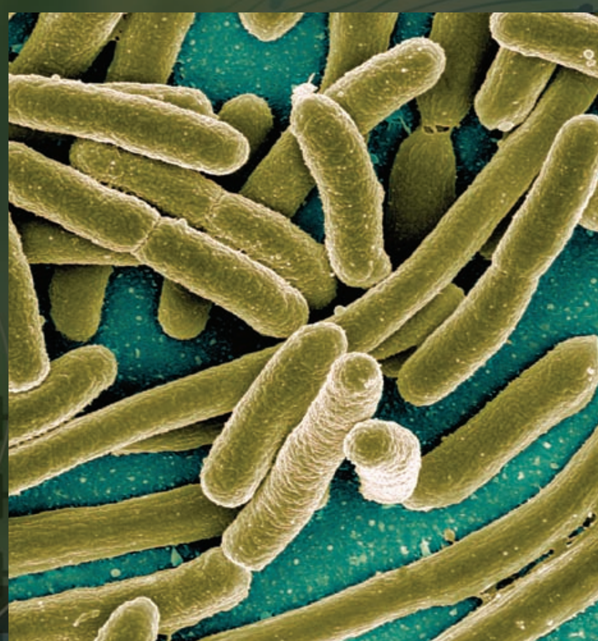
CHAPTER 11

Death: Meaning, Manner, Mechanism, Cause, and Time

MYSTERIOUS DEATH AT THE FAIR

The Washington County Fairgrounds in upstate New York was the site of the 1999 annual county fair. Well water, the source of drinking water for the event, became contaminated by runoff from a nearby cattle barn after a recent storm. The cattle and their manure carried a type of the bacteria called *Escherichia coli*. *E. coli* is a natural, and necessary, inhabitant of our digestive systems, but one strain carried by cattle produces a powerful toxin. The cattle that carry this strain of *E. coli* are unharmed, but humans can become very sick and die from an infection. Two of the 127 confirmed cases of *E. coli* poisoning from the fair died from the infection. As is often the case with *E. coli* poisoning, the deaths were from among the youngest and eldest of the group infected, a 79-year-old man and a 3-year-old girl. Manner of death—accidental; cause of death—food poisoning/water contamination; mechanism of death—kidney failure.

Escherichia coli is a leading cause of food-borne illness. Scientists estimate there are 73,000 cases of infection and 61 deaths in the United States each year. In addition to eating undercooked meat, people can become infected in a variety of ways. People have become ill from eating contaminated bean sprouts or fresh leafy vegetables, or through person-to-person contact in families and child care centers. Infection also can result from drinking raw milk or swimming in or drinking sewage-contaminated water.



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E. coli bacteria.

OBJECTIVES

By the end of this chapter you will be able to

- ✔ Discuss the definition of death.
- ✔ Distinguish between four manners of death: natural, accidental, suicidal, and homicidal.
- ✔ Distinguish between cause, manner, and mechanisms of death.
- ✔ Explain how the development of rigor, algor, and livor mortis occurs following death.
- ✔ Use evidence of rigor, algor, and livor mortis to calculate the approximate time of death.
- ✔ Describe the stages of decomposition of a corpse.
- ✔ Use evidence from the autopsy's report on stomach contents to estimate time of death.
- ✔ Explain how time of death can be estimated using insect evidence.
- ✔ Provide an example of the succession of different types of insects that are found on a body as it decomposes.
- ✔ Given insect evidence, livor, rigor, and algor mortis data, be able to estimate time of death.
- ✔ Describe how various environmental factors may influence the estimated time of death.

TOPICAL SCIENCES KEY

VOCABULARY

algor mortis the cooling of the body after death

autolysis the spontaneous breakdown of cells as they self-digest

cause of death the immediate reason for a person's death (such as heart attack, kidney failure)

death the cessation, or end, of life

decomposition the process of rotting and breaking down

forensic entomology the study of insects as they pertain to legal issues

instar one of the three larval stages of insect development

larva (plural **larvae**) immature form of an animal that undergoes metamorphosis (for example, a maggot)

livor mortis the pooling of the blood in tissues after death resulting in a reddish color to the skin

manner of death one of four means by which someone dies (i.e., natural, accidental, suicidal, or homicidal)

mechanism of death the specific body failure that leads to death

pupa (plural **pupae**) the stage in an insect's life cycle when the larva forms a capsule around itself and changes into its adult form

rigor mortis the stiffening of the skeletal muscles after death

INTRODUCTION

In the 17th century, before the stethoscope was invented, anyone in a coma or with a weak heartbeat was presumed dead and was buried. The fear of being buried alive led to the fad of placing a bell in the coffin. If someone was buried by mistake and awoke, he or she could ring the bell to get someone's attention. This is how the phrase "saved by the bell" might have originated.

Today, people no longer fear being buried alive. It is, however, sometimes difficult to tell if a person is dead or not. The outward signs of death, such as being cold to the touch and comatose, can be present even though a person is still alive. One definition of **death** is the cessation, or end, of life. To be more precise, death is sometimes defined as the "irreversible cessation of circulation of blood." In other words, the heart stops beating and cannot be restarted. Death might also be defined as the cessation of all brain activity. Even this definition is not perfect. Experts cannot agree on a single definition for death. Is a person with a heartbeat alive even if there is no brain activity? This is not an easy question to answer.

Did You Know?

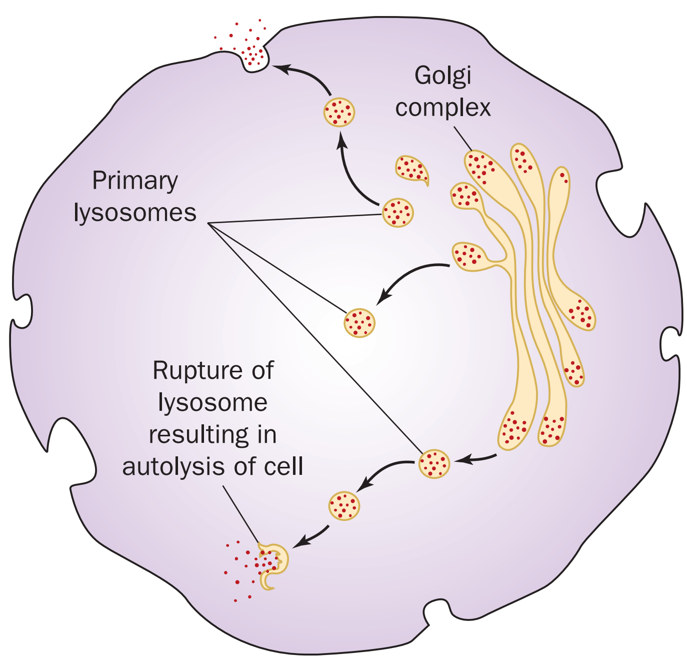
To avoid burying people before they were dead, "waiting mortuaries" were established in the 17th century. Those people thought to be dead were placed on cots and observed until the body began to rot. Only then was the person declared dead.

It remains difficult to precisely pinpoint the moment that someone dies. For one thing, death is a process rather than an instant event. The moment of death is usually considered the point of no return. According to physiologists, when the heart stops beating, the cells of the body begin to die because they no longer receive a fresh supply of oxygen. As oxygen levels drop, the basic processes of the body fail to occur. Nerves, muscles, organs, and the brain stop working. This is the first stage of death—stoppage.

When a cell dies, it breaks down. Once enough cells begin to break down, life cannot be restarted. Cell breakdown is called **autolysis** (Figure 11-1). When the cell membrane dissolves, enzymes and other cell contents spill out and digest surrounding tissues.

In cases of suspicious or unnatural deaths, a medical doctor called a forensic pathologist conducts an examination on the deceased. This examination is called an *autopsy*. The autopsy is conducted to determine the manner, cause, and mechanism of death, described in the following sections.

Figure 11-1. Autolysis occurs when cells break down.



THE MANNER OF DEATH

There are four ways a person can die, referred to in official terms as the **manner of death**: natural death, accidental death, suicidal death, and homicidal death. A fifth manner of death, undetermined, perhaps should be added because it is occasionally the official cause recorded on a death certificate. Natural death is caused by interruption and failure of body functions resulting from age or disease. This is the most common manner of death. Accidental death is caused by unplanned events, such as a car accident or falling from a ladder. Suicide occurs when a person purposefully kills oneself, whether by hanging, drug overdose, gunshot, or some other method. A homicide is the death of one person caused by another person.

Sometimes it is difficult to determine if the manner of death was a suicide or an accidental death. Did the person deliberately take an overdose of pills, or was it an accident? Did a person mean to shoot himself, or was it a mistake? In some cases, the coroner cannot make this determination and marks the manner of death as unknown on the death certificate.

Consider the following two examples. How would you categorize the manner of death?

- A man with a heart condition is attacked and dies from a heart attack during the assault. Is the manner of death accident or homicide?
- An elderly woman dies after being kept from receiving proper health care by her son. Is the manner of death natural or homicide?

In both cases, homicide would be the manner of death. Proving in court that the manner of death was a homicide, however, may be difficult.

CAUSE AND MECHANISM OF DEATH

Figure 11-2. *Cause of death describes the event that led to a person's death (e.g., hanging).*

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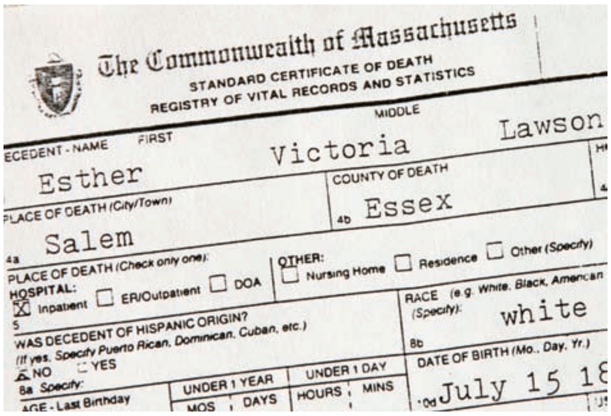
The reason someone dies is called the **cause of death** (Figure 11-2). Disease, physical injury, stroke, and heart attack can all cause death. Examples of causes of death by homicide include bludgeoning, shooting, burning, drowning, strangulation, hanging, and suffocation. Have you ever heard the term "proximate cause of death"? It refers to an underlying cause of death, as opposed to the final cause. If someone is exposed to large amounts of radiation and then develops cancer, the proximate cause of death is the radiation exposure.

Mechanism of death describes the specific change in the body that brought about the cessation of life. For example, if the cause of death is shooting, the mechanism of death might be loss of blood, exsanguination, or it might be the cessation of brain function. If the cause of death is a heart attack, the mechanism of death is the heart stopping to beat or pulmonary arrest.

Figure 11-3. *The official death certificate lists the cause and sometimes the mechanism of death.*


The Commonwealth of Massachusetts
STANDARD CERTIFICATE OF DEATH
REGISTRY OF VITAL RECORDS AND STATISTICS
DECEDENT - NAME FIRST MIDDLE
Esther Victoria Lawson
PLACE OF DEATH (City/Town) COUNTY OF DEATH
Salem Essex
PLACE OF DEATH (Check only one):
HOSPITAL: ☒ Inpatient ☐ ER/Outpatient ☐ DOA
OTHER: ☐ Nursing Home ☐ Residence ☐ Other (Specify)
WAS DECEDENT OF HISPANIC ORIGIN? (If yes, Specify Puerto Rican, Dominican, Cuban, etc.)
☒ NO ☐ YES
Specify:
RACE (e.g. White, Black, American (Specify): white
AGE - Last Birthday UNDER 1 YEAR MOS DAYS UNDER 1 DAY HOURS MINS
DATE OF BIRTH (Mo., Day, Yr.) July 15 18

©Susan Van Etten

A forensic pathologist's report may indicate the cause and mechanisms of death in a single statement (as do some death certificates, Figure 11-3). For example, someone killed in a car accident may be said to have died from "massive trauma to the body leading to pulmonary arrest." Trauma to the body is the cause of death; respiratory arrest is the mechanism of death.

TIME OF DEATH

During an autopsy, the forensic examiner wants to determine when the person died. By establishing the time of death, a suspect may be proved innocent simply because he or she was not in the same place as the victim at the time of death. On the other hand, the suspect may remain a person of interest if he or she was in the same area at the time a person died. Many factors are used to approximate the time of death. These factors are discussed in more detail in the following sections.

LIVOR MORTIS

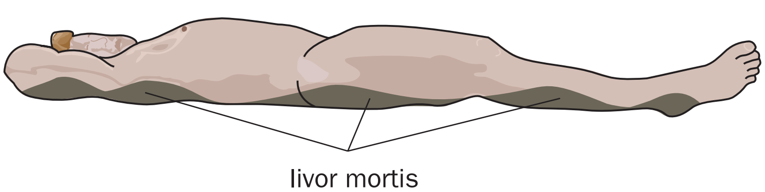
Livor mortis means, roughly, death color. As a body begins to decompose, blood seeps down through the tissues and settles into the lower parts of the body. The red blood cells begin to break down, spilling their contents. Hemoglobin, the substance in red blood cells that carries oxygen and gives blood its red color, turns purple when it spills out of the cells. This purplish color is visible on parts of the skin wherever the blood pools. The process of livor mortis takes time.

Pooling of blood in the body, known as *lividity*, provides a clue as to how long the person has been dead. Lividity first begins about two hours after death. The discoloration becomes permanent after eight hours. If death occurred between two and eight hours, lividity will be present, but if the skin is pressed, the color will disappear. After eight hours, if the skin is pressed, the lividity will remain. The ambient temperature at which a person dies impacts the time it takes for lividity in set in. If the corpse is left outside on a hot, summer day, livor mortis takes place at a faster rate. If the body is left in a cool room, livor mortis is slower. This is why it is so important to record the environmental conditions surrounding a dead body. The extent of livor mortis is also affected by anything impeding the flow of blood, such as tight wristwatches or belts.

Besides providing an approximate time of death, livor mortis can provide other important clues. Because gravity pulls the blood toward the ground, lividity can reveal the position of a corpse during the first eight hours (Figure 11-4). If the corpse were face down in a flat position, blood would pool along the face, chest, abdomen, and portions of the arms and legs close to the floor. If the corpse were positioned on its back, blood would pool along the back, the buttocks, head, and the parts of the arms and legs close to the floor. If the corpse were wedged in a standing position, the blood would collect in the lower legs and feet and the lower arms and hands.

Lividity also can reveal if a body has been moved. For example, if the person

Figure 11-4. *The location of livor mortis can reveal the position of the body during the first eight hours after death.*



died sitting in a chair, lividity would appear on the back of the thighs, buttocks, and the bottom of the feet. If the corpse were then moved so that the body was lying face down on the floor, lividity would also be found on the face, chest, abdomen, and front surface of the legs. Dual lividity could occur if the body was kept in one position two hours after death and then moved to a second position before the lividity became permanent. This is not uncommon if a murder victim is killed in one place and then transported somewhere else.

RIGOR MORTIS

BIOLOGY

Have you ever seen a dead animal in the road? Were all four of its legs stiff and sticking straight up in the air (Figure 11-5)? If the animal was still there a few days later, you may have noticed that the animal was no longer stiff. **Rigor mortis** means, roughly, death stiffness. It is temporary and can be very useful in determining the time of death.

Rigor mortis starts within two hours after death. The stiffness starts in the head and gradually works its way down to the legs. After 12 hours, the body is at its most rigid state. The stiffness gradually disappears after 36 hours. Sometimes, depending on body weight and temperature in the area, rigor may remain for 48 hours. If a body shows no visible rigor, it has probably been dead less than two hours or more than 48 hours. If a body is very rigid, then the body has been dead for about 12 hours. If the body exhibits rigor only in the face and neck, then rigor has just started, and the time of death is just over two hours. If there is some rigor throughout the body, but a lack of rigor in the face, then the body is likely to be losing rigor, and the death occurred more than 15 hours ago.

> **Did You Know?**
>
> If a body needs to be transported when rigor is at its peak, it might be necessary to break bones to change the position of the body.

Figure 11-5. *During the first 48 hours of death, the skeletal muscles are stiff—a condition known as rigor mortis.*

©AP Photo/Damian Dovarganes

The stiffness occurs because the skeletal muscles are unable to relax and remain contracted and hard. In life, the flexing and relaxing of muscles happens as the muscle fibers slide back and forth. Whenever muscles contract, they release calcium. In healthy, live muscles, the calcium molecules are removed from the cells. This requires energy, and for cells to get energy, they need oxygen. After death without circulation, oxygen flow to the cells ceases, and calcium accumulates in the muscle tissue. In the presence of the extra calcium, the muscle fibers remain in the contracted, rigid position (Figure 11-6). Because the muscles control the movement of bones, the joints appear to be rigid as do the muscles. The muscles eventually begin to relax as the cells and muscle fibers begin to dissolve by autolysis.

Many factors affect when rigor mortis sets in and how long it lasts. When trying to estimate the time of death, these factors need to be taken into account:

1. *Ambient temperature.* The cooler the body, the slower the onset of rigor. The warmer the body, the onset of rigor is faster because chemical reactions happen more quickly at higher temperatures.

Figure 11-6. *Live muscle fibers slide back and forth; in the first 48 hours of death, the muscle fibers become locked in a flexed position.*

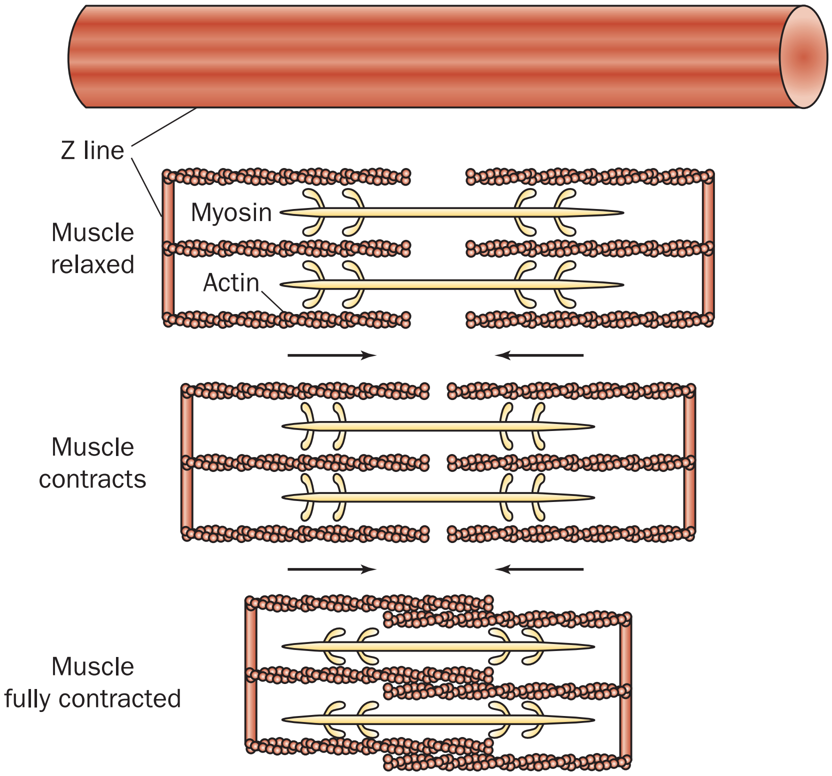


Figure 11-7. *Body weight and physical activity affect the timing of rigor mortis.*

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©Workbook Stock/Jupiter Images

2. *A person's weight.* Body fat stores extra oxygen and will slow down rigor mortis. A person with less oxygen stored in the body experiences rigor faster (Figure 11-7).
3. *The type of clothing.* Because clothing helps keep a body warm, the presence of clothes accelerates rigor mortis. A naked body cools faster, which slows down the onset of rigor mortis.
4. *Illness.* If a person dies with a fever, the body temperature will be higher, and rigor mortis will set in faster. If a person experiences hypothermia, the onset of rigor will be slower.
5. *Level of physical activity shortly before death.* If a person was exercising or struggling before death, then rigor will progress faster. This is true for several reasons, including the fact that exercise increases body temperature and decreases oxygen availability to the cells in the body and increases lactic acid levels.
6. *Sun exposure.* A body exposed to direct sunlight will be warmer, and rigor mortis would occur faster.

Because so many variables can affect how fast rigor mortis progresses, a precise time of death cannot be determined, it can only be estimated. However, when rigor mortis is combined with other factors, a more accurate time of death can be established (Figures 11-8 and 11-9).

Figure 11-8. *Progression of rigor mortis.*

Time After Death	Event	Appearance	Circumstances
2 to 6 hours	Rigor begins	Body becomes stiff and stiffness moves down body.	Stiffness begins with the eyelids and jaw muscles after about two hours, then center of body stiffens, then arms and legs.
12 hours	Rigor complete	Peak rigor is exhibited.	Entire body is rigid.
15 to 36 hours	Slow loss of rigor	Loss of rigor in small muscles first followed by larger muscles	Rigor lost first in head and neck and last in bigger leg muscles.
36 to 48 hours	Rigor totally disappears	Muscles become relaxed.	Many variables may extend rigor beyond the normal 36 hours.

Figure 11-9. *Factors Affecting Rigor Mortis.*

Factors Affecting Rigor	Event	Effect	Circumstances
Temperature	Cold temperature	Inhibits rigor	Slower onset and slower progression of rigor
	Warm temperature	Accelerates rigor	Faster onset and faster progression of rigor
Activity before death	Aerobic exercise	Accelerates rigor	Lack of oxygen to muscle, the build up of lactic acid, and higher body temperature accelerates rigor
	Sleep	Slows rigor	Muscles fully oxygenated will exhibit rigor more slowly
Body weight	Obese	Slows rigor	Fat stores oxygen
	Thin	Accelerates rigor	Body loses oxygen quickly and body heats faster

ALGOR MORTIS

Algor mortis means, roughly, death heat and describes the temperature loss in a corpse. When a person is alive, the body maintains a constant temperature. To keep our temperature within a normal range, many parts of our body work together, including the circulatory, respiratory, and nervous systems. In death, the body no longer generates heat and begins to cool down.

To take a corpse's temperature, forensic investigators insert a thermometer into the liver. Having a standard location for taking body temperature ensures that investigators can compare their results.

How fast a corpse loses heat has been measured, and investigators can determine how long ago death occurred by its temperature. Approximately one hour after death, the body cools at a rate of 0.78°C (1.4°F) per hour. After the first 12 hours, the body loses about 0.39°C (0.7°F) per hour until the body reaches the same temperature as the surroundings. This is just an estimate and will vary depending on surrounding temperature and conditions. In cooler environments, the body will lose heat faster than in hotter environments. If it is windy, heat loss will occur faster. The surrounding air temperature and other environmental factors are noted when a body is found, because the environment will affect the rate at which the body loses heat. The excess body fat and the presence of clothing will slow down heat loss. Time of death determined by body temperature calculations is always expressed as a range of time because it cannot be calculated exactly; however, a rule of thumb is to expect a heat loss of approximately 1 degree F per hour.

STOMACH AND INTESTINAL CONTENTS

Medical examiners help determine the time of death by studying the corpse's stomach contents. In general, it takes four to six hours for the stomach to empty its contents into the small intestine and another 12 hours for the food to leave the small intestine (Figure 11-10). It takes approximately 24 hours from when a meal was eaten until all undigested food is released from the large intestines. From this, it can be concluded that:

1. If undigested stomach contents are present, then death occurred zero to two hours after the last meal.

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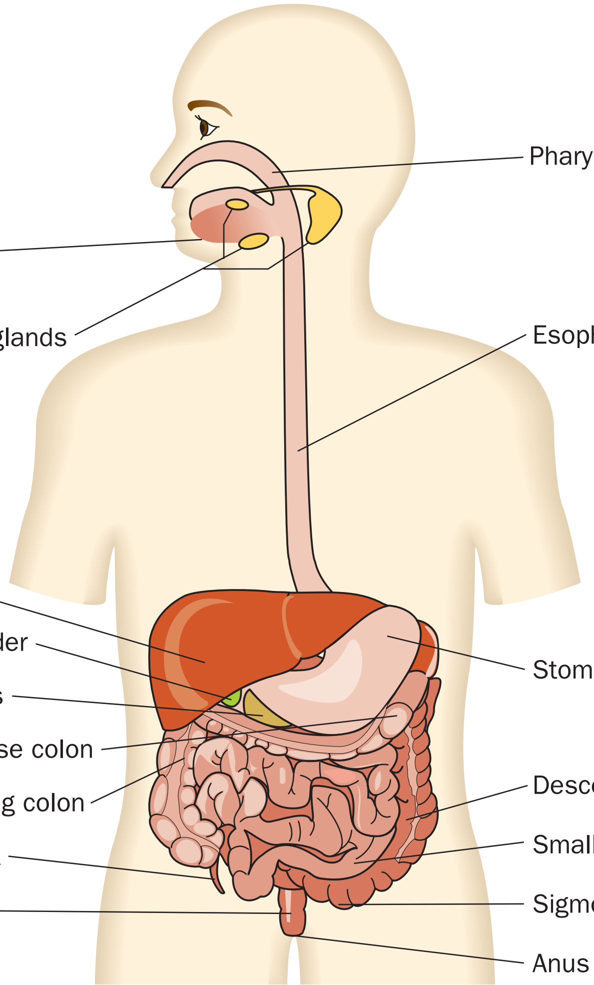
Figure 11-10. *The state of food digestion provides a clue to the time of death.*



2. If the stomach is empty but food is found in the small intestine, then death occurred at least four to six hours after a meal.
3. If the small intestine is empty and wastes are found in the large intestine, then death probably occurred 12 or more hours after a meal.

CHANGES OF THE EYE FOLLOWING DEATH

In life, the surface of the eye is kept moist by blinking. Following death, the surface of the eye dries out. A thin film is observed within two to three hours if the eyes were open at death and within 24 hours if the eyes were covered at death.

Following death, potassium accumulates inside the vitreous humor. Because decomposition progresses at a predictable rate, the buildup of potassium may be used to estimate the time of death. This method is still being refined and is not yet used as an accurate measure of time of death.

STAGES OF DECOMPOSITION

A corpse decomposes in predictable ways over time that can help examiners judge when death occurred:

1. Within two days after death:
   - Cell autolysis begins following death.
   - Green and purplish staining occurs from blood decomposition.
   - The skin takes on a marbled appearance.
   - The face becomes discolored.
2. After four days:
   - The skin blisters.
   - The abdomen swells with the gas carbon dioxide that is released by bacteria living in the intestines.
3. Within six to ten days:
   - The corpse bloats with carbon dioxide as bacteria continue to feed on tissues. Eventually, the gas causes the chest and abdominal cavities to burst and collapse.

- Fluids begin to leak from the body openings as cell membranes rupture.
- Eyeballs and other tissues liquefy.
- The skin sloughs off.

Figure 11-11 provides more information about the stages of decomposition.

Figure 11-11. *The stages of decomposition provide information about time of death.*

Stage	What Happens During Decomposition
Initial Decay	Corpse appears normal on the outside, but is starting to decompose from the actions of bacteria and autolysis.
Putrefaction	Odor of decaying flesh is present and the corpse appears swollen.
Black Putrefaction	Very strong odor. Parts of the flesh appear black. Gases escape and the corpse collapses.
Butyric Fermentation	Corpse is beginning to dry out. Most of the flesh is gone.
Dry Decay	Corpse is almost dry. Further decay is very slow from lack of moisture.

Ultimately, this leads to the **decomposition,** or rotting, of all tissues and organs. Bacteria and other microorganisms also help decompose a human body, just as they decompose plants and animals in the environment.

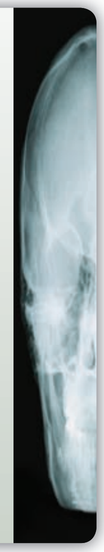
The speed of decomposition depends on the person's age, size of the body, and the nature of death. Sick individuals decompose faster than healthy people. The young decompose faster than the elderly. Overweight people with rich deposits of fat and body fluids break down faster than people of normal weight.

Just as environmental conditions affect rigor, they also influence decomposition. Naked bodies decompose faster than clothed bodies. Bodies decompose fastest in the 21–37°C (70–99°F) temperature range. Higher temperatures tend to dry out corpses, preserving them. Lower temperatures tend to prevent bacterial growth and slow down decomposition. Moist environments rich in oxygen speed up decomposition. Bodies decompose most quickly in air and slower in water or if buried.

Digging Deeper
with Forensic Science e-Collection

The science of forensics is always looking to improve its techniques or invent new ones to uncover the truth with greater accuracy. The article "A study of volatile organic compounds evolved from the decaying human body" explores a new technique for gathering information from a corpse. Search the Gale Forensic Sciences eCollection on school.cengage.com/forensicscience for the article. From what you have learned about the nature of tissue decomposition, evaluate this new technique and give a one-page argument about how this technique will be useful or not. Support your answer with information found in this textbook or other reputable sources.

Source: M. Statheropoulos, C. Spiliopoulou, and A. Agapiou, "A study of volatile organic compounds evolved from the decaying human body," *Forensic Science International* 153.2–3 (Oct 29, 2005): pp. 147(9). From *Forensic Science Journals*.



INSECTS

Insects can provide detailed information about time of death in several ways. In fact, insects are so useful in crime investigation that there is an entire field dedicated to this study and practice called **forensic entomology** (Figure 11-12). A forensic entomologist at a crime scene observes and records data

Figure 11-12. *Insects can provide information about time of death.*

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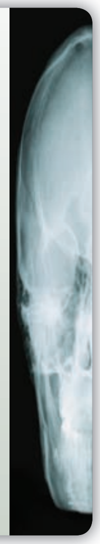
with Forensic Science e-Collection



Petechial hemorrhages are a common forensic tool that can provide evidence of time of death as well as some clues about the cause of death. Search the Gale Forensic Sciences eCollection on school .cengage.com/forensicscience for the article "Factors and circumstances influencing the development of hemorrhages in livor mortis." Read the article and then research the topic online. In 500 words or less, describe and characterize petechial hemorrhages: what they are, what they look like, what causes them, how forensic scientists use them, and how reliable they are as a tool for determining time of death.

Source: Britta Bockholdt, H. Maxeiner, and W. Hegenbarth, "Factors and circumstances influencing the development of hemorrhages in livor mortis," *Forensic Science International* 149.2–3 (May 10, 2005): pp. 133(5). From *Forensic Science Journals*.

To establish how different environmental conditions affect the appearance and rate of development of insects, University of Tennessee professor William Bass established the Body Farm in 1980. This has helped forensic experts interpret the evidence about the time of death much more accurately.

about the environmental conditions, including temperature, moisture, and wind, around the body as well as below it. The forensic entomologist collects insect evidence from on, above, and below the victim's body as well as insect evidence from the immediate area around the victim.

Within minutes of a death, certain insects arrive to lay their eggs on the warm body, attracted by the smell of the first stages of decomposition. The eggs will hatch and feed on the nutritious decomposing tissues. Blowflies are a common example. Blowflies are attracted to two gases of decomposition that have only recently been discovered by scientists, called putrescine and cadaverene. As a corpse progresses through the stages of decomposition, other kinds of insects will arrive. Tiny wasps come to lay their eggs on maggots already present on the body. Wasp **larvae** live as parasites inside the maggots, feeding on their flesh. The cheese skippers arrive once putrefaction is underway; they are attracted by the seepage of body fluids (Figure 11-13). The last groups of insects to arrive are those that favor drier conditions, such as the mites and beetles that feed on dry tissues and hair as shown in Figures 11-14, 11-15, and 11-16.

Blowflies are one of the first insects to arrive at a dead body and are very useful in determining the time of death. Like other insects, blowflies exhibit different stages as they develop from egg, larva stages (also known as **instars**), pupa, to adult. Refer to the blowfly life cycle table for more information (Figure 11-17).

Figure 11-13. *Cheese skipper.*

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Figure 11-14. *Rove beetles feeding on fly larva.*

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Because scientists know how long it takes for the various stages of development at given temperatures, forensic entomologists can determine when the blowflies arrive by studying the insects on the corpse. More importantly, it is quite easy to identify the stage of blowfly development by noting the change in size, color, mobility, presence or absence of a crop, and number of spiracle slits (Figure 11-18). The stages of blowfly larva can be determined by the number of spiracle slits at their posterior end.

Figure 11-15. *Adult dermestid beetle.*

©Cengage Learning

Figure 11-16. *Dermestid beetle larva.*

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Figure 11-17. *Blowfly Life Cycle (times are approximations).*

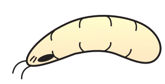
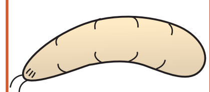
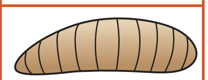
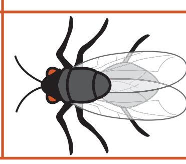
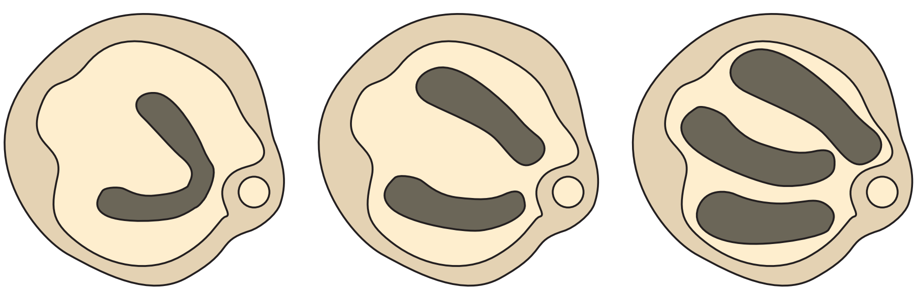
Stage	Size (mm)	Color	When first appears	Duration in phase	Characteristics	Sketch (not to scale)
Egg	2	white	Soon after death	8 hours	Found in moist, warm areas of body Mouth, eyes, ears, anus	
Larva 1 (instar 1)	5	white	1.8 days	20 hours	Black mouth hooks visible (anterior) Thin body One spiracle slit near anus	
Larva 2 (instar 2)	10	white	2.5 days	15–20 hours	Black mouth hooks (anterior) Dark crop seen on anterior dorsal side Actively feeding Two spiracle slits near anus	
Larva 3 (instar 3)	17	white	4–5 days	36–56 hours	Black mouth hooks Crop not visible, covered by fat deposits Fat body Three spiracle slits near anus	
Pre-Pupa	9		8–12 days	86–180 hours	Larva migrates away from body to a dry area	
Early and late Pupa	9	Light brown Changes to dark brown	18–24 days	6–12 days	Immobile, does not feed Changes to dark brown with age Filled air "balloon" to help split open pupa case prior to adult emerging	
Adult	Varies	Black or green	21–24 days	Several weeks	Incapable of flight for first few hours	

Figure 11-18. *Spiracle slits for larva stages Larva 1, Larva 2, Larva 3.*



Did You Know?

Maggots can help detect if a dead person had poison or drugs in the body at the time of death. When the maggots feed on tissues, any toxins or drugs they eat will be built into their own bodies. A "maggot milkshake" is prepared by a forensic entomologist, which is then analyzed for the presence of poisons or drugs.

First-stage larva has one V-shaped slit (1.8 days old); second-stage larva has two slits (2.5 days old); third-stage larva has three slits (4 to 5 days old). For example:

1. If a corpse contains blowfly eggs, then the approximate time of death would be 24 hours or less.
2. If a corpse contains third-stage larvae, then the time of death is approximately four to five days.
3. If a corpse contains pupae, then the time of death would be approximately 18 to 24 days.

Many factors affect insect development, including temperature, moisture, wind, time of day, season, exposure to the elements, and variations among individual insects. Because life cycles are affected by fluctuations in the daily environmental conditions, insects cannot provide an exact time of death, only a close estimate. Insects collected at the crime scene and then raised in the laboratory under the same environmental conditions as those found at the crime scene. This process can provide a more accurate estimate of time of death (Figure 11-19). The process is called Accumulated Degree Hours (ADH). Here is how this is done:

1. Immediately preserve some insects from the crime scene so you know exactly how old they are at the time of discovery of the body.
2. At the crime lab, raise some of the insects from the crime scene in the same conditions as those found at the crime scene.
3. Record the length of time for development under the specific conditions found at the crime scene.
4. Compare the insects raised at the crime lab to those found at the crime scene.

Figure 11-19. *Insects from the crime scene are raised in a laboratory to determine the time of their life cycle.*

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Forensic entomology includes more than an estimation of time of death. If insects from another region are found on a corpse, then it suggests that the corpse may have been moved.

Whatever the cause, mechanism, and time of death, reconstructing a detailed picture surrounding a fatality is critical to any forensic investigation.

SUMMARY

- There are several definitions of death, or the end of life, including the cessation of the heartbeat and the cessation of brain function. Upon death, cells break down and release their contents, resulting in decomposition.
- The manner of death refers to how the death occurs: by suicide, homicide, natural causes, or accident. If one of these four causes cannot be determined, the manner of death may be ruled undetermined.
- The cause of death refers to what led to the death and includes causes such as heart attack, gunshot wound, or cancer.
- The mechanism of death refers to the specific bodily function resulting in death. A heart attack might lead to the heart ceasing to beat, whereas a gunshot wound might lead to loss of blood or the ceasing of brain function that results in death.
- It is often important to determine the time of death in a forensic investigation. There are several means of doing this. Livor mortis, rigor mortis, and algor mortis are changes that happen to a body after it dies. Stomach contents and the condition of the eyes also provide clues. The states of decomposition of a corpse, as well as the insects on the body, provide further evidence of time of death.

CASE STUDIES

The Baby in the Box

In March 1944, the dead body of a newborn child was found wrapped in a blanket and newspaper in a cardboard box. The body had been placed in a pit dug in the forest floor and was covered with leaves. The forensic investigator who examined the body thought it had been abandoned for only a few hours because of the condition of the baby's body. The discovery of more than 20 beetles in the wrappings around the baby demonstrated that the time of death had to be much earlier than this. Recent cold weather had kept the body preserved and had disguised the real time of death.

Beetles on a Ski Mask Lead to the Conviction of a Rapist

A woman was attacked during the summer outside her apartment building in Chicago. The attacker, wearing a ski mask, leapt at her from the shrubs. He escaped. The police began to suspect a man in the building where the woman lived. A search warrant was obtained, and a ski mask was found in the suspect's apartment. The man claimed he had not used the ski mask since the previous winter.

The victim identified the man in a voice lineup, but this evidence was not sufficient for a conviction. On microscopic examination, fragments of a plant that matched a plant at the crime scene were found stuck to the ski mask. Live larvae of a beetle called a weevil were found in the bushes. The species of weevil survives the winter every year as adults, and larvae are found only during the summer months. The weevil larvae were also found on the ski mask. The presence of the weevil larvae on the ski mask proved the suspect was lying. The ski mask had been in contact with the plant at the crime scene that summer. The insect evidence was enough to convince the jury of the suspect's guilt.

When Insect Evidence Fails

In response to a 911 call by a relative, a family of three was found dead in a cabin. Their bodies were decomposing, and maggots were found on their flesh. A shocked relative, Mike Rubenstein, found the bodies. He stated he was the last person at the cabin in mid-November. The insect evidence placed the time of death well after this period, providing Mr. Rubenstein with an alibi, but police were suspicious when he quickly applied for the insurance money. A second look at the bodies by Bill Bass revealed that the stage of decomposition did not match that of the insect evidence. It appeared that the flies did not gain entry to the cabin until weeks after the family was killed. Decomposition evidence placed the time of death in mid-November, at the same time Mike Rubenstein says he was there. Eventually, he was convicted of the triple murder.

Think Critically **Review the Case Studies and the information on insect evidence in the chapter. Then state in your own words how insect evidence impacts a case.**

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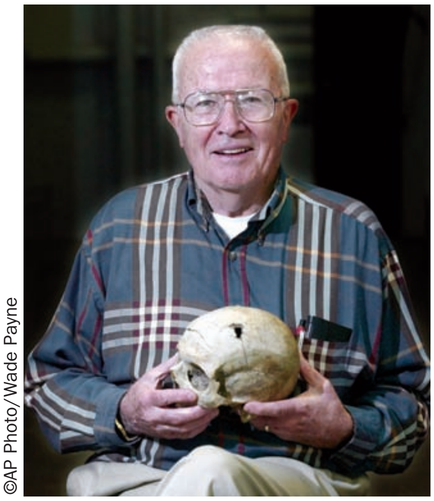
CAREERS IN FORENSICS

William Bass

William Bass was studying psychology. For fun, he enrolled in an elective anthropology course studying the behavior and culture of humans. His professor, a specialist in skeletal remains, was asked to come to the scene of a terrible accident. A collision on the highway resulted in a fire. Three people had died, and one body was burned so badly that identification was difficult and the professor was asked to help. The professor asked Bill for a ride to the crime scene and asked the young psychology student to join him. Bill decided right then and there to switch his studies and his career from psychology to anthropology. He learned all about the human body, skeletal remains, and what they can tell us about the life and death of a person.



©AP Photo/Wade Payne

William Bass at the Anthropology Research Facility.

While at the University of Tennessee, Bill spent many years examining bodies as a forensic expert assisting in solving crimes. In particular he specialized in digging up skeletal remains and learning their secrets, to answer a question of utmost importance in forensic cases, "How long ago did they die?" When Bill started, little information existed to link the physical characteristics of a rotting corpse to a specific time of death. Bill saw a need—and a solution—and in 1971 he approached his university to ask for a small piece of land to do research on decomposition of the human body. His request was granted, and his research on dead bodies has never stopped. Today it is one of the few facilities dedicated to human decomposition. At first, the questions Bill and his team asked were pretty simple, such as, "How long does it take for a limb to fall off of a corpse?" Since then the depth and breadth of the questions being explored has exploded.

At any given time, there are about 40 dead bodies on the three acres of the Anthropology Research Facility. They are rotting away in different circumstances, such as in water, in the shade, in the sun, in shallow burials, and in the trunks of cars. All changes in decomposition are carefully recorded over time. The researchers ask all types of specific questions about the chemical changes in different parts of the body during decomposition, as well as the details of insect growth and development under specific conditions. After the decomposition process is completed, the skeletons are catalogued. The collection of skeletons is, in fact, the largest of its kind in the world and is used to provide a vast array of information about a person from his or her remains. For example, from skeletal comparisons, it is possible to use the length of the thighbone to determine the person's gender, race, and height. The research facility is also used to train FBI personnel. Bodies are buried with evidence planted, and the FBI is sent in to find the body and recover the evidence.

In 1994, Patricia Cornwell, a mystery novel author, wrote a book based on the research facility. She called her book *The Body Farm*. The name has stuck. The bodies on the body farm are not grown, however. Most bodies are donated, either by families of the dead or given in a will. Hundreds of people have given their remains to the cause of improving forensic science.

Bill Bass, the body farmer, is now retired, but he is still involved in his facility and spends a lot of time communicating forensic science to the public. His work and the body farm are featured in documentaries and books, including *Death's Acre*, which Bass wrote.

Learn More About It

To learn more about the work of forensic entomologists, go to school.cengage.com/forensicscience.

CHAPTER 11 REVIEW

True or False

1. Many factors affect rigor mortis, such as the type of clothing the person was wearing.
2. Experts from different sciences agree that the definition of death is the end of life.
3. Blowflies are one of the first insects to arrive at a dead body and are very useful in determining the time of death.
4. Livor mortis refers to the color of a dead body.
5. The only two manners of death are natural death and homicidal death.
6. Mechanism of death describes what has occurred in the body to cause death.
7. The presence of drugs in a corpse cannot be determined by a chemical analysis of larvae found feeding on the body.
8. In the first 12 hours, a dead body cools about 1 degree F per hour.
9. Within minutes of a death, certain insects are attracted by the smell of the first stages of decomposition.
10. *The Body Farm* is a fictional account of the work of a country coroner.

Short Answer

1. Explain the similarities and differences of the following terms:

   a. manner of death and cause of death

   b. cause of death and mechanism of death

   c. larva and pupa

d. rigor mortis and livor mortis

e. autolysis and decomposition

2. As you drive along a roadside, you and your friend notice a dead deer that apparently was struck by a car. Your friend comments that she has never seen such a fat deer. "Did you see the size of its abdomen? It was huge!" As a student of forensics, how would you explain to your friend why the abdominal region of the dead deer was so large?

3. The forensic examiner tells the detective that he thinks the body was killed in the country before it was later found in an alley in New York City. What type of evidence could be present on the body to lead the forensic examiner to that conclusion?

4. A body is found with rigor mortis present in the face, neck, and upper torso. The young crime-scene investigator claims that the time of death must be at least 15 hours previous to the discovery of the body. The first-responding officer still at the crime scene asks what led her to that conclusion. The crime-scene investigator states that rigor mortis peaks at 12 hours and then gradually fades. Because there was no rigor in the legs, rigor mortis must be disappearing and is now only evident in the face, neck, and upper torso. Do you agree with this time estimation? Provide reasons for your answer.

5. Provide an example of the possible succession of insects that would be found on the body of a dead squirrel. Include in your answer: Which insect is usually the first to arrive on the dead body? Explain your reasoning. Which insects are usually the last to arrive on the dead body? Explain your reasoning.

ACTIVITY 11-1
CALCULATING TIME OF DEATH USING RIGOR MORTIS

Background:
In old detective movies, a dead body was often referred to as a "stiff." The term refers to the onset of rigor mortis that follows soon after death. In this activity, you will estimate the approximate time of death by analyzing the degree of rigor of the deceased body.

Objective:
By the end of this activity, you will be able to:
Estimate the time of death using rigor mortis evidence.

Materials:
paper
pen or pencil
calculator (optional)

Safety Precautions:
None

Procedure:
In pairs, answer the following questions dealing with approximating the time of death based on rigor mortis evidence. Refer to the Rigor Mortis Reference Table in your textbook (Figures 11-8 and 11-9).

Questions:
Part A
Estimate the approximate time of death for the following situations. Explain each of your answers:

1. A body was found with no evidence of rigor.
2. A body was found exhibiting rigor throughout the entire body.
3. A body was found exhibiting rigor in the chest, arms, face, and neck.
4. A body was discovered with rigor present in the legs, but no rigor in the upper torso.
5. A body was discovered with most muscles relaxed, except for the face.
6. A body was discovered in the weight room of a gym. A man had been doing " arm curls" with heavy weights. The only place rigor was present was in his arms.

Part B

Estimate the time of death based on the following information:

7. A frail, elderly woman's body was found in her apartment on a hot summer's evening. Her body exhibited advanced rigor in all places except her face and neck.
8. A body was discovered in the woods. The man had been missing for two days. The average temperature the past 48 hours was 50 degrees Fahrenheit. When the body was discovered, it was at peak rigor.
9. An obese man was discovered in his air-conditioned hotel room sitting in a chair in front of the television. The air conditioner was set for 65 degrees Fahrenheit. When the coroner arrived, the man's body exhibited rigor in his upper body only.
10. While jogging, a young woman was attacked and killed. The perpetrator hid the body in the trunk of a car and fled. When the woman's body was discovered, rigor was noticed in her thighs only.
11. The victim's body is not rigid. How long has she been dead? Explain your answer.
12. The body is completely stiff. How long has he been dead? Explain your answer.
13. The victim was found in a snowbank alongside a road. His body is rigid. How long has he been dead? Explain your answer, remembering the cold temperature.
14. The body of the runner was found in the park one early, hot summer morning. Her body shows rigor in her face, neck, arms, and torso. How long has she been dead? Explain your answer.

ACTIVITY 11-2
CALCULATING TIME OF DEATH USING ALGOR MORTIS

Objective:

By the end of this activity, you will be able to:
Estimate the time of death using algor mortis measurements.

Materials:

paper
pen or pencil
calculator
Rigor Algor Reference Table

Safety Precautions:

None

Procedure:

Working in pairs, answer the following questions using this information:

- For the first 12 hours, the body loses 0.78°C (1.4°F) per hour.
- After the first 12 hours, the body loses about 0.39°C (0.7°F) per hour.

Example 1: What is the temperature loss for someone who has been dead for 12 hours?
Temperature loss = (0.78°C/hour) x 12 hours = 9.36°C

Example 2: Calculate the time of death if a person has been dead for less than 12 hours.
If temperature loss is less than 12 hours (or less than 9.36°C), then you use the rate of 0.78°C per hour to estimate the time of death.
Temperature of dead body is 32.2°C (90°F).
Normal body temperature is 37°C. (98.6°F)
37°C – 32.2°C = 4.8°C lost since death.
How long did it take to lose 4.8°C ?
0.78 (°C/hour) x (unknown number of hours) = degrees lost
0.78 (°C/hour) x (unknown number of hours) = 4.8°C lost by body
Solve for the unknown number of hours since death occurred:
Number of hours = 4.8°C ÷ 0.78 (°C/hour)
Number of hours = 6.1 hours
Convert 0.1 hours into minutes:
0.1 hour (60 (min/hour) = 6 minutes
Hours since death = 6.1 hours or 6 hours and 6 minutes

Example 3: Is the time of death more than 12 hours or less than 12 hours?
Recall that if a body has been dead 12 hours or less, the body loses heat at the rate of 78°C per hour. If the body has been dead 12 hours, then 78°C/hour x 12 hours = 9.36°C.

If a body loses 9.36°C, then the person has been dead for 12 hours.

If a body loses more than 9.36°C, then the person has been dead for more than 12 hours.

If they lose less than 9.36°C, then the body has been dead for less than 12 hours.

For each of the following, state if the body had been dead for more than or less than 12 hours based on the number of degrees lost:

1. total loss of 7.9°C
2. total loss of 4.4°C
3. total loss of 11.7°C
4. total loss of 17.2°C
5. total loss of 10.6°C

Example 4: Calculate the time of death if the person was dead for more than 12 hours.

If the body has lost more than 9.36°C, then you know that the victim has been dead for more than 12 hours. Recall that after 12 hours, the body loses heat at a rate of 0.39°C per hour. You need to calculate how many hours beyond the 12 hours that someone died and add it to the 12 hours. Body temperature was given as 22.2°C (72°F).

1. How many total degrees were lost from the time of death until the body was found?

   37°C – 22.2°C = 14.8°C
2. Since 14.8°C is more than 9.36°C, you know that the body was dead longer than 12 hours. How much longer?

   37°C – 22.2°C = total loss of 14.8°C since death

   9.36°C were lost in the first 12 hours

   14.8°C lost since death – 9.36°C lost the first 12 hours = 5.44°C lost after the first 12 hours
3. Recall that the rate of heat lost after 12 hours is 0.39°C per hour.

   You need to determine how many hours it took to lose that 5.44°C.

   (0.39°C/ hour) x (unknown # of hours) = degrees lost after 12 hours

   (0.39°C/hours) x (unknown # of hours) = 5.44°C lost after the initial 12 hours

   Solve for unknown number of hours:

   unknown # of hours (x) = 5.44°C ÷ (0.39°C/hour)

   = 14.8 hours total time to lose 14.8°C or approximate time of death
4. First 12 hours there was a loss of 9.36 degrees C 9.36°C

   Next 14.8 hours there was an additional loss of 5.44˚ C= 5.44°C

   Therefore, the victim has been dead about 26.8 hours. (or approximately 27 hours)

   .8 hours x 60 min/hr = 48 minutes

Questions:

Part A

1. Determine the approximate time of death using evidence from algor mortis. Show your work. Approximately how long has the victim been dead if his body temperature was 33.1°C (91.6°F)?

2. A body found outside in the winter has a temperature of 33.1°C. Has the body been dead a longer or shorter time than in problem 1? Explain your answer.
3. Approximately how long has the victim been dead if his body temperature was 25.9°C (85.2°F)?
4. What is the approximate time of death if the body temperature was 15.6°C (60.8°F)?
5. What is the approximate time of death if the body temperature was 10°C (50°F)?
6. What is the approximate time of death if the body temperature was 29.4°C (84.9°F)?
7. What is the approximate time of death if the body temperature was 24°C (75°F)?

Part B

Describe the impact on time of death for each of the variables listed below. If you based your time of death estimates strictly on temperature loss to be 10 hours earlier, would you reduce your 10-hour estimate or increase your 10-hour estimate if the body had been:

1. Naked
2. Exposed to windy conditions
3. Suffering from an illness prior to death
4. Submerged in a lake

Further Study:

1. Investigate the procedures used by crime-scene investigators to take accurate body temperature readings.
2. What is the significance of determining the time of death? Why is it so important to crime-scene investigators to take the temperature of the deceased body if the person is already known to be dead?

ACTIVITY 11-3
INSECT STUDY

Objective:
By the end of this activity, you will be able to:
Study the behavior and life cycles of insects associated with decomposition.

Introduction:
The blowfly is often the first insect to reach a corpse and lay its eggs. Use Figures 11-17 and 11-18 as references in your study of blowfly development.

Materials:
Data Table: Insect Study
1 lb. cottage cheese or pudding containers
raw calf liver (1 lb.)
sharp knife
warm (or hot) day (but not windy or too hot!)
thermometer
plastic kitchen-sized garbage can with a flip top
plastic garbage bag liner
another cardboard box to cut up into smaller pieces
small cardboard box large enough to hold the plastic cottage cheese container and fit inside a garbage can
digital camera (optional)

Safety Precautions:
Wash your hands after handling the flies.

Procedure:
Part A: Setting up the Fly Incubator
1. Line a plastic kitchen-sized flip-top or swinging-lid garbage can with a plastic liner.
2. Cut up a cardboard box and fold the cardboard pieces in half so that the pieces of cardboard don't lie flat.
3. Add the folded cardboard to the bottom of the kitchen garbage bag so that the garbage bag is one-third full. This is important because, during the last stage, the larvae will migrate away from the food to a dry area. If you have ample cardboard pieces available, the larvae will have many areas to hide. (Depending on the size of your garbage can, you might want to add an empty box on top of the cardboard pieces to elevate your fly assembly so that you will have easier access to the fly dish shown on the next page.

Part B: Preparing Your Liver Dish
1. Add raw liver in a plastic cottage cheese container.
2. Cut some slices into the surface of the liver to make gashes within the liver to resemble an open wound.

Part C: Obtaining Flies

1. Leave your open liver container in an area where you want to collect flies. The odor of the liver should attract flies within minutes.
2. Collect flies on a warm day. If it is too cold or too windy, flies will not lay their eggs. Avoid taking fly collections on very windy days or very hot days.
3. Leave the liver container in the open area for at least one hour. Place the dish in an area that will not be disturbed by dogs or cats.
4. Look for very small, white clusters of fly eggs on top of the liver.

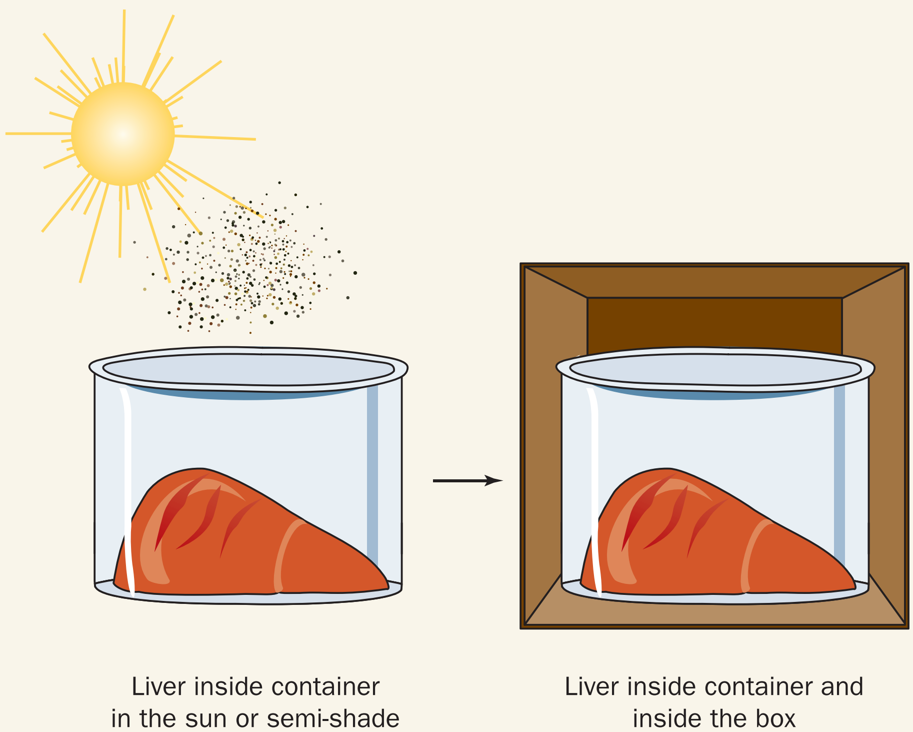
Part D: Incubation of Fly Eggs

1. Place the liver container and fly eggs into a small cardboard box. Be sure the cardboard box and the plastic liver dish will fit in the garbage can.
2. Allow the flip-top cover of the garbage can to close. This will still allow other insects to enter the dish while keeping some of the odor inside the garbage can.
3. Keep the garbage can in an area that is not in direct sunlight. Because some odor will be given off, place the garbage can in an area where the odor will not present a problem to others.

Part E: Observations and Data Collection

1. Make observations each day and record on your data table until adult flies have emerged.
2. Take a digital photo of the liver container and any organisms near or on the container. Note: Larvae tend to move away from light, so be ready to quickly take pictures when you view your liver dish.
3. Complete the data table as you make your daily observations. Record the date and time of your daily collections. Record the tempera-

Insect study setup.



ture inside the fly incubator (garbage can). Make other observations such as the color, size, and behavior of your insects.

Part F: Report

Option 1

1. Create a PowerPoint presentation of the insects collected on the liver. Include your digital photos taken of the different stages of the insects you observed. If you do not have a digital camera, obtain pictures of the insects from the Internet.
2. Include the name of all insects and correctly identify their stage of development. Indicate the preferred food source for each of the insects.
3. Do not place too many words on each frame.

Option 2

Write an autobiography from the viewpoint of the fly as it develops from an egg into adulthood. Include in your diary:

- Physical description of the insect at different stages of development
- Physical description of the insect's environment
- Descriptions of when the insect feeds or does not feed
- Description of the type of food it is eating
- Descriptions of any "travels" or migrations and movements of the insect
- Photos from your digital pictures taken during the study

Your information should be scientifically correct, but feel free to be creative in your insect diary!

Option 3

Prepare a scrapbook from the viewpoint of the insect as it progresses through its different stages. Use the photos from your study. Add notations indicating the:

- Physical descriptions of the insect at the different stages of development
- Physical descriptions of the insect's environment
- Descriptions or comments on the insect's source of food at different stages
- Descriptions of any "travels" or migrations of the insect

Your information should be scientifically correct, but feel free to be creative with this scrapbook!

ACTIVITY 11-4
ESTIMATING TIME OF DEATH USING INSECT, ALGOR, AND LIVOR MORTIS EVIDENCE

Objective:

By the end of this activity, you will be able to:
Estimate the time of death using insect, algor, and livor mortis evidence.

Materials:

paper
pen or pencil
calculator
Rigor Mortis Reference Table: Refer to the tables distributed by your teacher (Figures 11-8 and 11-9)
Insect Reference table: Refer to the table distributed by your teacher (Figure 11-7).

Safety Precautions:

None

Procedure:

Working in pairs, answer the following questions.

Questions

1. A naked, male corpse was found at 8 a.m. on Tuesday, July 9. The air temperature was already 26.7°C (81°F). The body exhibited some stiffness in the face and eyelids and had a body temperature of 34.4°C (93.9°F). Livor mortis was not evident.
   a. Approximately how long ago did the man die?
   b. Justify your answer.
   c. Would clothing on the body have made a difference in determining the actual time of death? Why or why not?
2. At noon, a female corpse was found partially submerged on the shore of a lake. The air temperature was 26.7°C (81°F), and the water temperature was about 15.6°C (61°F). Rigor mortis was not evident, and the body's temperature was 15.6°C. Livor mortis showed a noticeable reddening on the victim's back that did not disappear when pressed. Bacterial activity was not significantly increased, and the lungs were filled with water.
   a. Approximately how long ago did the woman die?
   b. Justify your answer.
3. The body felt cold to the touch. The thermometer gave a reading of 21.1°C (70°F) for the body temperature. No rigor mortis was evident, but livor mortis had set in with blood pooling along the back. There was no noticeable increase in bloating or bacterial activity in the digestive system and no putrefaction. The man had been dead for more than 48 hours. How is that possible?

4. The dead body contained evidence of blowfly infestation. The larvae were collected and reared in a lab in an environment similar to the conditions surrounding the dead body. Adult flies mated and laid eggs. Data was collected, noting the time required to progress from one stage to the other and recorded in the following Data Table.

Stage	Accumulated Time Since Egg Was Laid (Hours)	Accumulated Time Since Egg Was Laid (Days)
Egg	Egg laid minutes after death	0
Larva stage 1	24	1
Larva stage 2	60	2.5
Larva stage 3	96–120	4–5
Pupa	192–288	8–12
Adult	432–576	18–24

   a. Record the estimated time since death if the insects recovered from the dead body were in each of the stages below:
      egg, larva 1, larva 2, larva 3, pupa, adult.
   b. Record the estimated time since death if insects were in the following stages: Some eggs and some larva stage 1, some adults and some pupae, some larva found in stage 2 and stage 3.
5. A dead body of an elderly gentleman was discovered in an abandoned building. Blowfly pupae were found on the body. A missing person's report was filed for an elderly gentleman who had wandered away from home just two days before. The body found was similar in age, height, and weight to the missing person. Could this possibly be the same person as the person described in the missing person's report? Explain your answer.
6. The police received a report about a body found in the woods behind the local shopping center. The forensic investigator collected 5 different types of living insects on the man's body. It's important to stress that investigators found all 5 insects alive on the body at the same time. The insects were sent to the forensic entomology lab, where they were raised under similar conditions to those found around the dead body. The following chart describes the life cycles of each of the five different types of insects found on the dead body. How long has the man been dead? Justify your answer.

	Day									
Insect	1	2	3	4	5	6	7	8	9	10
Blowfly	1	1	1	1	1	1	1	1	1	0
Species A	0	0	0	0	1	1	1	1	1	1
Species B	0	0	0	0	0	0	1	1	1	0
Species C	0	0	0	0	0	0	0	0	1	1
Species D	0	0	0	0	0	1	1	1	1	1

0 = no evidence of fly species; 1 = evidence of egg, larva (maggot) or pupa

ACTIVITY 11-5
TOMMY THE TUB

Background:

Whether you are playing volleyball on a hot beach in August or snowboarding down a mountain on a cold, windy day in January, your body is constantly working to maintain a normal body temperature. Living organisms are equipped with mechanisms that maintain this balance (homeostasis). However, if a person becomes ill or dies, the mechanisms fail.

Objectives:

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

1. Observe and record the heat loss each hour of a simulated human body, "Tommy the Tub," over a 24-hour period.
2. Compare that heat loss to the projected heat loss of a human corpse.

In this activity, you will create a simulation of a human body and record the heat loss over a 24-hour time period. Because the body is mostly water, you will substitute a tub of approximately the same volume of water as a human body. You are to compare the heat loss of Tommy the Tub to the projected heat loss of 0.78°C (1.4°F) for the first 12 hours and 0.39°C (0.7°F) for the next 12 hours.

Materials:

Activity Sheet for Activity 11-5
66-L plastic tub (with drawing of body, optional)
probe ware interface and two temperature probes or two thermometers
computer or TI-83 calculator (or better)
cart for transporting the tub
graph paper

Safety Precautions:

None

Time Required to Complete Activity:

two consecutive days (30 minutes per day)

Procedure:

1. Fill a tub with approximately 66 liters of hot water, adjusting the temperature to about 37°C (98.6°F).
2. Connect two temperature probes to a computer or TI-83 calculator to record temperature readings over an extended period. One probe should record the ambient air temperature. The second probe should be submerged in the tub to record the "body temperature."
3. Set the probe to measure temperature at one-hour intervals for a 24-hour period.
4. Record tub temperatures on the data table.
5. From the probe ware data or your data table, determine the average air temperature over the 24-hour period.
   Average air temperature = ________°C

6. From the probe ware data or your data table, determine the average loss of tub water temperature for the first 12 hours _______°C, average loss of tub water temperature for hours 13 to 24 ________°C, and average loss of tub temperature for hours 1 to 24 ________°C.
7. Prepare a best-fit graph of Tommy's heat loss over a 24-hour period. Include in your graph:
   a. Title of graph
   b. Appropriate scale for *x* and *y* axis
   c. Labeled *x* and *y* axis
   d. Units on *x* and *y* scale
   e. Draw the best-fit line (This line is approximated. It will be a straight line that will pass through some of the points but not necessarily all of them. There will be some points on either side of the line and not on the line.)

Time (hrs.)	Tommy Tub Temp. (˚C)	Ambient Temp (˚C)	Time (hrs.)	Tommy Tub Temp. (˚C)	Ambient Temp (˚C)
0			13		
1			14		
2			15		
3			16		
4			17		
5			18		
6			19		
7			20		
8			21		
9			22		
10			23		
11			24		
12			Average loss per hour		

Questions:

1. How does Tommy the Tub's temperature loss over the first 12 hours compare with that of a real human corpse? Explain your answer. Include data from your graph or data table to support your answer.
2. How does Tommy the Tub's temperature loss over the next 12 hours (hours 13 to 24) compare with the expected heat loss of a real human corpse? Explain your answer. Include data from your graph or data table to support your answer.
3. Explain some of the limitations of using Tommy the Tub as an appropriate model for a human body.
4. How could you design a more realistic model of a human corpse to be used in this experiment?
5. Did the ambient temperature change over the 24-hour period? If the ambient temperature did change, describe its possible impact on the loss of temperature noted on Tommy the Tub.
6. List some variables affecting the rate of heat loss from a human corpse.