### Chapter Overview

Forensic entomology plays an important role in solving crimes. Often overlooked, insect evidence can be used to establish postmortem intervals, identify the location of a crime scene, or link a suspect to a victim or crime scene. Using insect clues, it's possible to determine injury sites on the victim, if the body was moved, and whether or not the victim was under the influence of drugs or toxins. As the body decomposes, a predictable sequence of insects inhabits the body in a process known as insect succession. Common forensic insects include flies, beetles, wasps, and ants. A forensic entomologist identifies the insects at a crime scene and uses accumulated degree hours to estimate a postmortem interval. Proper evidence collection is required for insect evidence to be accepted in court. Forensic entomologists use scanning electron microscopes, gas chromatography, and mass spectrometry.

### The Big Ideas

Forensic entomology is an exciting field that uses insect evidence at a crime scene to help solve a crime. This chapter focuses primarily on flies and beetles and their roles in forensic entomology. Crime scene investigators must follow proper procedures for locating, documenting, and collecting insect evidence. Specimens are analyzed by forensic entomologists who identify species and stages of development and consider the local meteorological data to estimate a postmortem interval. Using accumulated degree hour studies, an entomologist can estimate how long it took for the insects collected at the crime scene to develop to their current state under local conditions. The pattern of insect succession that occurs on a body undergoing decomposition is predictable and provides evidence of first colonization of a body.

### SCENARIO

After students read the scenario, brainstorm answers to the following questions as a class.

1. The identity of a badly burned victim was established in this case by using maggots. Think of other types of situations where maggots could be used to identify a victim.
2. If the human tissue was ingested by the maggots, wouldn't the human tissue have been digested?
3. If the human DNA sample was obtained from only three maggots, how could there be enough DNA to run a DNA profile?
Teaching Tip
Before starting the unit on forensic entomology, conduct a carousel brainstorming activity (Ch 11 TN Pre-Assessment Carousel, on the OER, Chapter 11). This method serves as a good introduction to the topic of forensic entomology. Students should work in small collaborative groups and respond to eight different questions. This is a brainstorming activity, so responses are added to the sheet whether they are right or wrong. At the conclusion of the activity, a discussion will follow where each response is reviewed. This method makes it easier for reserved students to participate. It also is a good indication of what students know. Misconceptions can also be clarified using this method.

Engage
 Allow students to observe live maggots (fly larvae). Do not tell students what the organisms are. Ask:
• Are these alive? How can you tell?
• What structures do you observe? What functions do you expect these structures have?
• What is the role of these organisms in the ecosystem?
• How do these organisms relate to forensics?
• What are they? (Consider placing maggots in closed petri dishes or jars during the observation period.)

INTRODUCTION
Did you know that there are approximately a million species of insects? An insect has three body segments: a head, thorax, and abdomen (Figure 11-1). They have three pairs of jointed legs joined at the thorax, and their bodies are supported by an exoskeleton (an exterior skeletal structure). Most have wings. Most insects begin life as eggs, from which they hatch into larvae (singular larva). A larva is basically a wormlike eating machine. Most insects you will read about in this chapter undergo complete metamorphosis, which means the larva then turns into a pupa, or non-eating subadult, before it becomes an adult. Insects are the most abundant, diverse, strange, and beautiful group of animals on Earth, and new species are identified each day. You may think of insects as annoying creatures that bite, spoil your food, or destroy gardens and crops, but they serve many important roles in the environment. Without pollinating insects, there would be fewer flowers and fruits. Without the action of decomposing insects, dead bodies and animal remains would take longer to decompose. The air would be filled with foul odors, and the environment would be littered with slowly decomposing bodies, leading to disease. This chapter will reveal how insects can be a homicide detective’s friends.

The study of insects and other arthropods (spiders, crayfish) is called entomology. It has been estimated that insects have existed for more than 250 million years, whereas humans have been on Earth about 200,000 years. Forensic entomology is the interpretation of insect evidence used in civil or criminal investigations. Evidence may be in the form of a body, trousers (insect species that undergo incomplete metamorphosis), papers, larvae, eggs, or insect body parts collected from a body or crime scene (Figure 11-2). Insects removed from a car’s windshield or radiator can contribute vital information for solving crimes. The job of the forensic entomologist is to collect and identify insect evidence and interpret it in relation to the environmental conditions and other variables that exist at a crime scene. Forensic entomology provides an estimate of the minimum and maximum amounts of time that could have passed since colonization, the arrival of the first insects on a dead body. The forensic entomology report along with all the other evidence report from toxicology, botany, and the autopsy are then evaluated by the medical examiner or pathologist who estimates the postmortem interval (PMI), the time between death and discovery of the body. The primary focus of this chapter is forensic entomology— the study of how insects or their remains are used in the investigations of death, abuse, and neglect cases.

HOW IS FORENSIC ENTOMOLOGY USED? Obj. 11.1
Forensic entomology can be applied to estimate a postmortem interval (PMI). Recall that a postmortem interval is the time interval between a person’s death and the time the body was discovered. If a body is badly burned or if a body is found more than two to three days after death, it is difficult to estimate time of death using temperature, rigor mortis, or other common techniques. However, by using insect evidence and factoring in odonates, or environmental, variables such as location, temperature, humidity, and amount of rainfall and sunlight, it may be possible to provide a postmortem interval. This information may help to exclude or include a suspect.

Forensic entomology can also accomplish the following:
• Help reveal a body or remains by the presence of flies, their eggs or larva, or other insects (Figure 11-3).
• Determine if the body was moved. Were the insects found on the body normally found in that environment, or are they inhabitants of a different area?
• Identify a geographic range of the crime scene based on the types of insects found on a body that has been moved. Geographic ranges where specific insects can survive are limited.
• Link a suspect to a crime scene or to a victim by the presence of insect evidence or similar bites on both the suspect and victim.
• Indicate where the suspect had been traveling, based on insect evidence on the suspect’s vehicle and/or belongings.
• Trace the origin of drugs in drug trafficking based on insect evidence found in the drug packaging.

Limitations of Forensic Entomology
Insect data are less helpful in estimating a postmortem interval if the body was moved after death. A person might be murdered at home and then be hidden hours later in the woods. Insects found on a body in the woods...
can be used to estimate how long the body was in the woods, but not how long it was since the person died. However, the insect data could be helpful in constructing a case or a course against a suspect.

Forensic Entomologists
A forensic entomologist interprets insect evidence, applying environmental variables to help answer questions about a dead body. Entomologists estimate the particular species of insects attracted to bodies that have been exposed to certain conditions helps them answer many questions about a crime. (This is especially important when the body is severely decomposed or burned.)

- Where on the body are the injuries? Maggots (fly larvae) are attracted to open wounds; the presence of a maggot mass can indicate the site of an injury.
- Was the body moved after death? If the insects associated with the dead body differ from the insects found at the crime scene, it may indicate the body was moved.
- Was the victim restrained while alive? If so, weed and mural footprints would be on the body or were present, attracting homeflies rather than blowflies
- Was the body covered, buried, or submerged in snow? This would affect the onset of insect colonization and the type of insects that would be attracted to the body.
- Was the deceased exposed to any toxic chemical or under the influence of recreational drugs? Even if the body is too decomposed to analyze, the feeding larvae may have human tissue stored in their crops that can be analyzed for drugs and other chemicals.

Forensic entomologists work with other scientists using electron and scanning microscopes, DNA analysis, toxicology, gas chromatography, and mass spectrometry to analyze insect evidence from crime scenes. Improvements in technology have led to more reliable identification of larvae, a challenge, even for experts.

HISTORY OF FORENSIC ENTOMOLOGY 1961
One of the earliest cases to use insect evidence to solve a crime was described in the 1871 Chinese work by Song T'ou called The Washing Away of Wrongs. A bloody murder was discovered by a group of farmers returning home from their fields. All the workers were instructed to lay down their sickles. Soon flies identified the murderer by landing on the sickle blade containing microscopic remnants of flesh and blood.

Bergeret d'Arbois was a French entomologist. In 1850, he collected insect evidence during an autopsy of a suffocated body of a husband infant killed in the well of a house. Four different tenants were considered suspects. Bergeret had observed that insects colonize dead bodies in a predictable sequence known as insect succession. As a body decomposes, the predictable physical and chemical changes it undergoes make it attractive to different species of organisms. Bergeret applied the concept of insect succession to the case and estimated the baby died in 1849. The police used this information to link the murder to the couple who lived in the house in 1849.

Jean Pierre Megnin published further insect succession studies in 1894.

In the early part of the 20th century, U.S. cattle and sheep herds in Texas were devastated by screwworm flies. These flies fed on the carcasses and weakened them. American entomologist Dr. David G. Hall of the National Museum of Natural History was funded by the government to study the problem. His research helped reduce the damage and number of livestock deaths to flies. His book, Blowflies of North America laid the groundwork for future forensic entomologists.

Insect evidence slowly gained acceptance with investigators and the court system through the research and coursework of forensic entomologists Drs. Lee Goff, Paul Catts, Wayne Lord, and Gail Anderson. A concern was raised that much of the research was being done on pig carcasses. For evidence to meet the Daubert standard, it has to be generally accepted by the scientific community, but it also has to be tested under circumstances directly applicable to the case at trial. Dr. Neal Haskell's research comparing pig and human decomposition at the Body Farm at the University of Tennessee helped forensic entomologists meet the Daubert standard. Dr. Haskell found no difference between the developmental time of blowflies on humans and pigs. Reliability of insect evidence analysis continues to be challenged in the courts, however, because every living thing is unique, and explaining biology to juries can be a challenge.

INSECTS AND DECOMPOSITION
All organisms have specific requirements for survival. A habitat must be favorable or the organisms will not survive. The most important factors any organism needs for survival are suitable temperatures, the correct amount of moisture, a suitable food source, and oxygen. Factors affecting survival are the presence of other organisms competing for food and living space, predation, reproduction limitations (Figure 11-4), and toxic effects of poisons due to crowding.
**CHAPTER 11**

**Decomposition** Obj. 11.5, 11.8

In this chapter, you will study the primary insects of decomposition with an emphasis on flies and beetles. Decomposing bodies of animals provide a changing environment that serves as a source of nutrition for many different types of insects. The body undergoes a series of changes as organisms break it down and it decomposes. Different stages of decomposition make a body appropriate for different types of insects (and other organisms) as a food source. Insects that seek up liquids may get nourishment from moist parts of the body or during soft; earlier stages of decomposition. Insects with sharp mouthparts may get nourishment from a dry, decaying body in a later stage of decomposition.

Decomposition stages include the following:

- **Fresh:** a warm, newly dead body
- **Soon after death:** a corpse emitting odors of decaying flesh
- **Decay:** a body emitting gases of decay with strong odors, and showing signs of darkened tissues
- **Active (in advanced stages):** an organ starting to dry out; most flesh is gone
- **Dry, or desiccated:** mostly bones remain

These changes in a decomposing body follow a regular pattern and provide changing habitats. These different habitats support the predictable sequence of insect succession on a dead body.

**Blowflies (Bottle Flies)** Obj. 11.2, 11.3, 11.8

Within minutes of death, odors emitted from a dead body can be detected by blowflies from a mile away. The adult flies with their beautiful shiny metallic green, blue, or bronze bodies are among the first to arrive and can be very useful in determining the postmortem interval (Figure 11-3). As bacteria start to decompose tissue, two gases, putrescine and cadaverine, are released that attract the blowfly to a possible location to lay their eggs. The adult fly uses its siphon-like proboscis (mouthparts) (Figure 11-6) to suck up the protein-rich fluids from a decomposing body. Fortified with extra protein, the female flies deposit their eggs on clusters on the body, usually in natural openings such as the mouth, nose, ear, vagina, or anus. If there has been an injury to the skin, eggs will be laid there as well. The soft, moist tissue of the body will provide food for the larva, or maggot.

**GROWTH AND DEVELOPMENT**

Blowflies undergo complete metamorphosis, a change in body form, as they develop. As you see in Figures 11-7 and 11-8, the stages include egg, larva (plural larvae), pupa (plural pupae), and adult. If conditions are favorable, within a week after arriving on a dead body, the female will lay approximately 50 eggs in a cluster. If you look at Figure 11-2, you will see that the tiny eggs, about 1 millimeter long, look like miniature white rice grains.

Many environmental variables affect whether or not eggs are laid. If it’s too hot or too cold, too windy, too sunny, or too shady, different species will not lay eggs. Forensic entomologist Dr. Neal Haskell conducted many experiments that documented the fact that blowflies do not lay eggs at night. After blowfly eggs are laid, the rate of development varies depending primarily on temperature; the warmer the temperature, the faster the development.

Given a suitable environment, a female deposits eggs and releases a chemical (pheromone) that attracts other blowflies to lay eggs in the same area. Eggs hatch usually in less than 24 hours. After hatching, the blowfly progresses through three stages of larval, called instars. These stages are referred to as first, second, and third instar, with each stage larger than the one before. The pre-pupa stage follows with a decrease in size as the third instar stops feeding before it pupates (becomes a pupa).

**Figure 11-7 Blowfly life cycle: egg mass, first, second and third instars; pupa; and adult.**

**Figure 11-8 Blowfly life cycle (times are approximate).**

<table>
<thead>
<tr>
<th>Stage</th>
<th>(days)</th>
<th>Color</th>
<th>Appearance</th>
<th>Phase</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>2</td>
<td>White</td>
<td>Soon after death</td>
<td>8 hours</td>
<td>Found in moist, warm areas of body (mouth, eyes, ears, anus)</td>
</tr>
<tr>
<td>Larva 1</td>
<td>1</td>
<td>White</td>
<td>1-8 days</td>
<td>10 hours</td>
<td>Black mouth hooks visible (anterior) New body parts (instar 1)</td>
</tr>
<tr>
<td>Larva 2</td>
<td>3</td>
<td>White</td>
<td>2-3 days</td>
<td>10-20 hours</td>
<td>Black mouth hooks visible (anterior) Dark crop on anterior dorsal side</td>
</tr>
<tr>
<td>Larva 3</td>
<td>10</td>
<td>White</td>
<td>4-5 days</td>
<td>36-56 hours</td>
<td>Black mouth hooks Discolored, covered by fat deposits</td>
</tr>
<tr>
<td>Pupa</td>
<td>12</td>
<td>White</td>
<td>0-7 days</td>
<td>86-100 hours</td>
<td>Three spiracles slit near anus</td>
</tr>
<tr>
<td>Adult</td>
<td>17</td>
<td>White</td>
<td>4-5 days</td>
<td>3-4 weeks</td>
<td>Black mouth hooks Dark crop on anterior dorsal side</td>
</tr>
</tbody>
</table>

**DIFFERENTIATED LEARNING**

**At-Risk Students**

Explore how various insects obtain food. Research the special adaptations of insects that enable some to feed on a fresh body, while others are able to digest drier tissues found in the later stages of decomposition. Find images of the mouthparts of a fly sucking up liquids, the piercing, biting mouthparts of lace or flies, or the scraping mouthparts of hide beetles. Relate the structure of the mouthpart to the type of food ingested by the insect.
Teaching Tip

View live larvae under a stereomicroscope. Have students observe and describe how the larvae use the mouth hooks. Another option is to project images of the live larvae for the class.

Teaching Tip

Spiracle slits are visible under a stereomicroscope. They are most easily viewed in the third stage. Place larvae into alcohol to kill and temporarily store them. Poke a larva-diameter hole in a piece of plastic foam with a pin or dissecting needle. Place the larva in the hole posterior-side-up. View under a stereomicroscope. (You could place the larva in the hole anterior-side-up to view the mouth hooks.) Ask students to identify the stage based on the spiracle slits. Still, preserved larvae are easy to view than living larvae.

Figure 11-9 Note the hooks found at the thinner anterior (front) and of the blowfly larva (left). These are used to hold onto and scrape the food. The posterior end is more rounded. The darkened area is the crop where ingested food is stored (right).

Figure 11-10 Spiracles on the posterior end of blowfly larva are two circular regions that contain slits used for breathing. Spiracle slit configuration allows researchers to determine if a larva is first, second, or third instar. Illustrations, left to right: Spiracle slits in first instar, second instar, and third instar of blowfly. Photo, for right: This larva appears to be a third instar.

As food is ingested, it passes into the maggot's crop. Because no digestion occurs in the crop, ingested body tissue containing DNA can be removed and analyzed. Also, if the person was exposed to toxins or drugs, their presence could be detected by analyzing the contents of the crop. "Maggot millhikes," a blood of maggots recovered from a badly decomposed corpse, can be analyzed for the presence of drugs. In the second instar, it's possible to see a disintegrating crop on the dorsal (uppermost) anterior (front) end of the maggot. However, during the third instar, the crop is no longer visible. The addition of body fat required by the third instar stage obscures the crop.

The oval (omelet-shaped) of the larva does not grow with the maggot. The maggot sheds its cuticle (skin) in favor of a new, larger one. Toward the end of the third instar, the larva stops eating and pupates in its cell. It will move away from the decomposing flesh, sometimes crawling several feet in search of materials that are drying or rotten to pop. The thick skins of the third instar is not

deed; instead, it burrows into a pupal case. The maggot becomes smaller and more difficult to see as it turns into a white maggot and then a maggot in its pupal case. As a pupa, the maggot develops into an adult fly (Figure 11-11). An empty pupal case can provide evidence that a body has been in an area long enough for the blowfly to complete its full life cycle.

Figure 11-11 Blowfly pupa. Left: Head emerging from pupal case. Right: Empty pupal case; pupa formed at the same time will emerge at approximately the same time.

Houseflies, Flesh Flies, and Coffin Flies

Houseflies are smaller than blowflies. The housefly has a gray thorax with four dark longitudinal stripes (Figure 11-12). Food sources for the adults are sugar, sweat, blood, urine, and feces. Houseflies are common in normal houses but can also be indicative of abuse, due to their attraction to urine and feces. Flesh flies are medium-sized flies. They often come within minutes of death. The distinctive markings include black and gray longitudinal stripes on the thorax and a checkered pattern on their abdomen (Figure 11-13). Instead of laying eggs, flesh flies deposit living larvae onto the flesh. If a victim is concealed or wrapped in blankets or plastic, tiny coffin flies may be the only ones able to reach the body. Coffin flies are about the size of fruit flies (Figure 11-14). In the Casey Anthon murder trial, Dr. Haskell observed evidence of coffin flies, indicating that a dead body was in the car for several days.

Figure 11-12 You can identify a housefly by the four dark stripes on its thorax.

DIGGING DEEPER

The fluid-filled "balloon" that inflates and deflates to split open the pupa is called a pulvinum. Show the class the video at http://www.archive.org/house-fly/musca-domestica/videos.html of a house fly using its pulvinum to emerge from its pupa.
Teaching Tip
Using pinned collections of houseflies, blowflies, and flesh flies, ask students to observe the adults. Ask students to list distinguishing characteristics of the adults that could be used to help identify the species. Students should note: color, shiny or not shiny, stripes, number of stripes, checkerboard abdomen, eye color.

Beetles and Other Insects of Decomposition

Obj. 11-4, 11-5

Beetles are the most numerous of all insects. They have two sets of wings; the first is a hardened sheath or shell-like covering that protects the body and the other wings. The second set of wings is used for flying. Like flies, beetles undergo complete metamorphosis (Figure 11-15). Grubs (beetle larvae) are easy to distinguish from fly larvae because beetle larvae have three pairs of legs, whereas fly larvae have no legs (Figure 11-16). Beetles typically arrive after flies and will mate on the dead body. The female lays her eggs in the decomposing flesh. Like flies, beetles have diverse nutritional needs, and they follow the predictable path of insect succession on a decomposing body. The clown beetle, for example, feeds on fly eggs and on fly and beetle larvae, whereas the hide beetle prefers the dry remains of a corpse. Refer to Figure 11-17 for information on various species of beetles and the stage of decomposition at which they arrive.

Other insects also feed at decomposition sites. Ants, bees, and wasps feed on either the body or the eggs and larva of flies and beetles. The presence of any of these insect predators may delay the development of blowfly larvae and affect the postmortem interval estimate.

Figure 11-13 Flesh fly. Notice the checkerboard pattern on the flesh fly’s abdomen and the stripes on its thorax.

Figure 11-14 The coffin fly is about the size of a fruit fly.

Figure 11-17 Beetle Succession on a Decomposing Body.

<table>
<thead>
<tr>
<th>Beetle Species (in Order of Arrival on Body)</th>
<th>Preferred Food</th>
<th>Arrival on Corpse</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clown beetle</td>
<td>Fly eggs, maggots, beetle larva</td>
<td>Early</td>
<td>Adults 1/8 to 1/4 inch body mud, shiny metallic back or gray, found under body</td>
</tr>
<tr>
<td>Surinam carrion beetle</td>
<td>Maggots</td>
<td>Early</td>
<td>Distinctive beetle species on decomposing human bodies; adults 1/2 to 3/8 inch, orange marking on wings</td>
</tr>
<tr>
<td>American carrion beetle</td>
<td>Maggots</td>
<td>Early to advanced decomposition</td>
<td>Adults 3/8 to 1/2 inch, yellow patch behind head</td>
</tr>
<tr>
<td>Sexton beetle</td>
<td>Maggots</td>
<td>Fresh to advanced</td>
<td>Adults 1/4 to 1/2 inch; black with reddish orange markings; common in forested areas</td>
</tr>
<tr>
<td>Hairy rose beetle</td>
<td>Maggots</td>
<td>Fresh to advanced</td>
<td>Adults 1/4 to 1/2 inch; black with pale yellow bristles</td>
</tr>
<tr>
<td>Hide beetle</td>
<td>Dried remains</td>
<td>Advanced</td>
<td>Adults 1/4 to 1/2 inch; ridges and bumps on body</td>
</tr>
</tbody>
</table>

Figure 11-15 Beetle life cycle (left to right) first instar, second instar, pupa, adult.

Figure 11-16 Larvae from four families of beetles (left to right) scarab beetle, carrion beetle, row beetle, and skin beetle.

Teaching Tip
Refer to the article "New Insects Revealed in Entomological Decomposition" by the Entomological Society of America in The Forensic Magazine, January 22, 2015.
Insects and insect larvae found on or near a body can help forensic scientists estimate postmortem intervals. Different species will arrive in an area at different times of the year depending on environmental conditions. Because of insect succession, the presence of a particular species of insect can also provide important data for estimating postmortem interval. At crime scenes, live insects are collected and some are immediately preserved. The most developed larvae (alders) should be collected to provide the most accurate estimate of postmortem intervals. The live specimens are sent to a forensic entomologist who will raise them to adulthood in the laboratory. It is easier to identify species from adults than from larvae (Figure 11.18).

**Blowfly Importance** 11.2

Because blowflies arrive usually within minutes after death, blowflies are timekeepers for postmortem intervals. Knowing that insects follow a predictable succession, and knowing how long it takes for each species to reach their different stages of development, the estimate of postmortem interval can be calculated by going backward. For example, if only blowfly eggs are present and no blowfly larvae are present, the estimated postmortem interval is usually less than 30 hours because the eggs have not developed into larvae. If most of the insects are in the third instar stage, calculations are made to determine how long it took for those insects to develop to the third instar stage. Finding empty pupal cases at a crime scene is important because it indicates a minimum postmortem interval long enough for insects to develop to adulthood.

**Factors Affecting Development** 11.4, 11.6

Forensic entomologists must take into consideration many factors that affect insect development, such as local temperatures and environmental conditions. Outwelling (egg laying) will not occur at night, in the rain, or if temperatures and other environmental conditions are not suitable. Feeding maggots may have temperatures of 5°F to 20°F (C) to 1°C higher than the outdoors (surrounding) temperature, which can speed up development. This is why maggots mass temperatures are taken at the crime scene. Forensic entomologists must ask other questions when assessing insect development:

1. Was the body clothed?
2. Was the body wrapped, frozen, or inaccessible to insects, thus delaying insect colonization?
3. Was the body buried? If so, how deep? Was the burial medium permeable to insects? Could the medium release decomposition gases?
4. In what environment was the victim found: sandy beach, wooded area, desert, urban, rural?
5. Was the body exposed to sun, shade, or wind—factors that affect when eggs are laid?
6. Was the body found at night or during the daytime? (Insects don’t lay eggs at night.)

**Processing a Crime Scene for Insect Evidence** 11.9

Proper procedures for processing a crime scene should be followed as outlined in Chapter 2. The crime scene and evidence must be photographed and documented. Trained crime-scene investigators collect insect evidence.

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**Estimating Postmortem Interval** 11.2, 11.4, 11.6

**Steps:***

1. Estimate the maximum and minimum temperature in degrees Celsius for a 24-hour period and divide by 2 to get the average temperature for each day.
2. Subtract the lower-limit temperature, usually 10°C, from the average daily temperature to get the adjusted temperature.
3. Multiply the adjusted average temperature by the number of hours in the day to obtain the ADH for that day. (For example, if a body was found at 5:00 am, then the number of hours for that day would be 15 hours. If the body was found at 6:00 am, then the number of hours for that day would be 6 hours. Full days are 24 hours.) This product represents the degree min, or accumulated degree hours, for that day. Degree hours with a lower-limit of 20°C degrees Celsius are written as DH-20

A forensic entomologist who collected third instars from the crime scene would examine data from the controlled environment studies to determine the total number of ADH it would take to reach the third instar stage. Using reliable temperature records for that area (weather stations), the ADH for each day would be calculated starting with the day the body was found. The postmortem interval would be estimated by calculating how long it would take an insect to reach the third instar stage. That postmortem interval will only be an estimate; the forensic entomologist can only provide a range of times when insects could have colonized the body.

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**Degree Hours** 11.2, 11.4, 11.6

*(How is it possible to determine how long it takes insects to develop to each of the different stages when temperatures differ throughout the day?) To help answer this question, insects are raised at a constant temperature in a laboratory setting. The number of hours at an adjusted average temperature that it takes an insect species to reach a particular stage of development is expressed in accumulated degree hours (ADH) using degrees Celsius. When calculating degree hours for insects in an uncontrolled environment, such as the outdoors, it is necessary to factor in the insect’s lower-limit threshold. This is the temperature below which growth and development cease. For most insects, this is 1.8°C. To find the adjusted temperature, factoring in the lower-limit threshold, a forensic entomologist will do the following:

- Add the maximum and minimum temperature in degrees Celsius for a 24-hour period and divide by 2 to get the average temperature for each day.
- Subtract the lower-limit temperature, usually 10°C, from the average daily temperature to get the adjusted temperature.
- Multiply the adjusted average temperature by the number of hours in the day to obtain the ADH for that day. (For example, if a body was found at 5:00 am, then the number of hours for that day would be 15 hours. If the body was found at 6:00 am, then the number of hours for that day would be 6 hours. Full days are 24 hours.) This product represents the degree min, or accumulated degree hours, for that day. Degree hours with a lower-limit of 30°C degrees Celsius are written as DH-30

A forensic entomologist who collected third instars from the crime scene would examine data from the controlled environment studies to determine the total number of ADH it would take to reach the third instar stage. Using reliable temperature records for that area (weather stations), the ADH for each day would be calculated starting with the day the body was found. The postmortem interval would be estimated by calculating how long it would take an insect to reach the third instar stage. That postmortem interval will only be an estimate; the forensic entomologist can only provide a range of times when insects could have colonized the body.

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**Crime Scene: Understanding the Environment**

- Crime-scene investigators may mistake brownish flyspecks for blood spatters. Flies ingest blood and mix it with enzymes. The mixture is digested, and enzymes break down the food that will be later re-ingested. Wastes create more flyspecks. Unlike blood spatters, flyspecks are randomly distributed. Also, flyspecks have a depression in the center that is produced by the sucking action of the fly.

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**Teaching Tip**

Have students view maggots under a stereomicroscope and note the differences in the anterior and posterior ends. Find the hooks and crop. If they look very closely, they might be able to see hair-like structures called setae that help anchor the maggot as it moves.
Many of the eggs and first instars are very small, and third instars move away from the body before they pupate, so great care must be taken when looking for insect evidence. Too often, insect evidence is overlooked, not collected, or not photographed. If the evidence collection, documentation, and handling are not done correctly, the evidence cannot be used. The Website of forensic entomologist Dr. Jason Byrd (Figure 11-20) is the source of the following summarized procedures.

1. Death-Scene Observations
   - Location of crime scene, description of general habitat, weather conditions, locations of any open windows or doors near the body, whether the body is inside or outside.
   - Location of body in reference to vegetation, sun, shade.
   - Body condition: locations of any wounds or visible injuries, state of decomposition.
   - Insect observations: locations of insects on or around the body, types of insects, stages of development.

2. Collection of Meteorological Data
   - Ambient temperature at scene taken at chest level.
   - Maggot mass temperature taken from the center of the mass.
   - Ground surface temperature.
   - Interface between the body and ground.
   - Soil directly under the body.
   - Minimum and maximum daily temperatures from an accurate source.
   - Rainfall amount for a period from 1–2 weeks before the victim’s disappearance to 3–5 days after the body was discovered.

3. Two Collection Methods: Collect live insects, and collect and preserve other insects from the body at the crime scene (Figure 11-19).
   - Collect Adults First
     - Adults can be trapped with a net and placed in a killing jar containing cotton balls or plastic soaked with ethyl alcohol.
     - Jars should be labeled using a graphite pencil and paper placed both inside the jar and outside the jar.
     - Labels should include geographic location, date and hour of collection, case number, location on body where the insect was collected, and name of the collector.
   - Larvae and Eggs
     - If there is more than one maggot mass, treat each mass separately.
     - Collect about 50 maggots per mass, collecting the most-developed larvae.
     - Place larvae in killing jars with 75%–80% alcohol.
     - Living specimens should be placed in containers with tightly fitting lids and air holes, moist paper towels, and a moist source. Insert that container into a slightly larger container with ⅛ inch of soil or vermiculite to absorb any liquids and ship it overnight to an entomologist.

   - Collect insects from the area where the corpse was located and in the immediate vicinity. Keep some as live samples and preserve some of the insects. Label all specimens.
   - Collect and label soil and leaf litter samples from the area under the body and in the immediate location of the body (to a depth of 2 inches).

Evidence collectors and crime-scene investigators need training on how to recognize and collect forensic evidence. Forensic entomologists like Dr. Neil Haskell and Dr. Jason Byrd (Figure 11-20) are among many forensic entomologists who are involved in education as well as in their own casework. Future research involving advanced technologies and DNA profiling will help improve identification and refine estimates of post-mortem intervals to enhance forensic entomology.

**SUMMARY**

- Insects, the most numerous of all animals, provide valuable evidence in solving crimes.
- Forensic entomology is used to estimate postmortem intervals, identify the geographic location of the crime scene, link a suspect to a victim or crime scene, determine if a body was moved, locate injury sites, determine exposure to drugs or toxins, and provide evidence of neglect or abuse.
- The five stages of decomposition include fresh, bloated, active decay, advanced decay, and dry decay; stages of decomposition cause predictable changes in the chemical and physical environment of a body and the area surrounding it.
- Forensic insects include flies, beetles, wasps, ants, and more. Insects follow a predictable sequence of inhabiting a dead body, known as insect succession.
- Blowflies, usually the first to inhabit a dead body, undergo four stages of complete metamorphic egg, larva (first instar, second instar, third instar), pupa, and adult.
- Larvae use mouth hooks to help ingest food and move, a crop to store food, and spiracle slits to breathe.

**Teaching Tip**

Only eggs and no larvae are found on a corpse. Have students discuss reasons for the absence of larvae other than that the body was not in the location long enough.

**Explore**

Have students research aquatic forensic insects. What is the pattern of insect succession on a body submerged in water? Ask volunteers to report their findings to the class.

**Teaching Tip**

Bring an insect collection net to class. Demonstrate how to collect flying insects by quickly moving the net back and forth over the corpse. The net should be twisted at the end of each sweep. The final sweep should include several twists as the adults can't climb or fly out of the net. Insert the twisted net over a collection jar containing cotton balls soaked in alcohol to kill the insects.
Beetles usually arrive after flies and may consume the dead body or consume eggs and larvae found on the body.

Variables affecting the rate of insect growth include temperature, sun, shade, wind, moisture, injuries to the deceased, and a body that is closed or wrapped. All must be considered when a forensic entomologist interprets insect evidence.

The postmortem interval is an estimate of the interval of time between when the body was found and death.

Accumulated degree hours (ADH) are the number of hours at an adjusted average temperature it takes for an insect species to develop to a given developmental stage. ADH are used to estimate postmortem intervals.

Evidence collection includes crime-scene observations, collection of the insects and eggs, preserving insects, and collection of meteorological data.

**CASE STUDIES**

**Where's the Body?**

When authorities received a tip that a dead body was hidden in an old well somewhere in Illinois, they embarked on a mission of trying to find one well among many wells. After several hours of searching, the investigators received a second tip, this time from flies. Apparently, the suspect covered the well with flies, hoping to disguise the fact that there was a body at the bottom. When investigators arrived, they found a dark cloud of flies buzzing over the top of the well.

"You are what you eat." When maggots feed on the body tissues of a drug user, the maggots also become drug users. In October 1988, in Spokane, Washington, forensic entomologist Paul Catt was confused. The body of a woman was found lying face down. Large maggots of 11-18 millimeters were feeding in the victim's nose. However, on other sites on her body, only small maggots measuring just 2-9 millimeters were found. To reach a size of 11-18 millimeters for the two species of flies found on the body, it would have taken three weeks in that environment. To grow 2-9 millimeters, it would have taken only seven days.

Other forensic evidence indicated that a three-week postmortem interval was possible. The victim was last seen alive 10 days earlier. How could the larger maggots be accounted for? Forensic tests showed that maggots collected from her nose contained cocaine. To determine if cocaine could affect maggot growth rate, tissues containing cocaine were provided to maggots in the lab. The results showed that under the influence of cocaine (a stimulant), maggots could grow to 11-18 millimeters in only one week. Paul Catt's postmortem interval estimate of approximately one week was consistent with the other forensic evidence.

**Paul Catt's Case of the Massive Maggots: Effect of Cocaine on Maggots**

**Chigger Bites Link to a Crime Scene**

The body of a 24-year-old woman was discovered under a large eucalyptus tree in California. The sheriff's department investigated the scene from 10 a.m. until 2 a.m. Twenty of the twenty-three members of the investigation team complained of itchy red bites on their ankles, waist, and buttocks, which were identified as chigger bites. (Chiggers are mite larvae.) The same types of bites in similar locations were found on one of the suspects, Dr. James Webb, an entomologist, was consulted and confirmed the presence of chiggers at the crime scene. The suspect claimed to have fleasites he received at his sister's home. However, when investigators went to his sister's home, they found no evidence of fleas or chiggers. Because of the pattern and type of bite marks and the limited distribution of chiggers in that area, the jury convicted him of murder.
CHAPTER 11 REVIEW

True or False

1. Adult flies are attracted to dead bodies because of the odors.
   OBJ. 11.5, 11.6

2. Wasp stings after the blowflies because they feed on blowfly larvae and eggs.
   OBJ. 11.6

3. Insect evidence is the most accurate method to estimate a postmortem interval if the victim has been dead less than 24 hours.
   OBJ. 11.7

4. A well-trained forensic entomologist can always determine PMI using insect evidence only.
   OBJ. 11.7

5. When estimating a postmortem interval, it's important to factor into the interval the fact that flies and beetles don't lay eggs at night.
   OBJ. 11.2

6. Which is the correct sequence of developmental stages for blowflies?
   OBJ. 11.2
   a) egg, larva, pupa, adult
   b) egg, second instar, third instar, pupa, adult
   c) egg, pupa, maggot, adult
   d) first instar, second instar, third instar, pupa, adult

   1. Most insects are only active at night.
   2. Insect evidence is only found during active decay.
   3. Investigators are often not properly trained to find and collect insects.
   4. Insects can't be found if the body is buried or covered.

   11.3

7. What is one reason why insect evidence at crime scenes is often not collected?
   OBJ. 11.9
   a) They are found only on the first instar.
   b) They are useful in estimating the age of a blowfly larva.
   c) They are used for release of uninfested food.
   d) Both a and b are correct.

8. Which is true regarding spiral slits of a blowfly larva?
   OBJ. 11.3
   a) They are found only on the first instar.
   b) They are useful in estimating the age of a blowfly larva.
   c) They are used for release of uninfested food.
   d) Both a and b are correct.

Multiple Choice

9. a)

10. Second instar and third instar of the blowfly.
    OBJ. 11.2, 11.3
    a) Fresh, active decay, dry decay, blotted, advanced decay
    b) Blotted, advanced decay, active decay, dry decay, fresh
    c) Fresh, dry decay, blotted, active decay, advanced decay
    d) Fresh, blotted, active decay, advanced decay, dry decay

   11. Which is true regarding spiral slits of a blowfly larva?
   OBJ. 11.3
   a) They are found only on the first instar.
   b) They are useful in estimating the age of a blowfly larva.
   c) They are used for release of uninfested food.
   d) Both a and b are correct.

   11.5

11. The preferred food source for blowfly larvae is carrion beetle larvae.
    OBJ. 11.6

12. The anterior end of a blowfly and the posterior end of a blowfly.
    OBJ. 11.3
13. For each of the following, describe how insects can be useful in solving a crime. Obj. 11.2
a. Indicating where a body is hidden (Fig. 11.12, 11.3, 11.6)

b. Determining the primary crime scene: rural road, vacant lot, desert, woods, open field, etc. Obj. 11.4

c. Determining that the body was buried shortly after death (Fig. 11.2, 11.4, 11.5, 11.6, 11.7)

d. Determining if the deceased was under the influence of drugs (Fig. 11.8, 11.4)

14. At crime scenes, investigators need to record information about the habitat and the environmental conditions. Relate the importance of habitat and environmental conditions to the forensic entomologist's interpretation of the insect evidence. Obj. 11.3, 11.6

15. Why is it necessary to collect larvae from a forensic scene, not just on the body? Obj. 11.2, 11.4, 11.6

16. What value is there in collecting empty pupal cases from a crime scene where no live insects are evident? Obj. 11.2, 11.4

17. If there are various stages of larvae on the corpse, why should you collect the largest samples? Obj. 11.2, 11.4

18. If live adult beetles are collected using a net, is it necessary to place them in individual jars when shipping them to a forensic entomologist? Obj. 11.5, 11.5

19. What is the significance of sending live larvae to a forensic lab? Why not send just preserved specimens? Obj. 11.3, 11.7, 11.9

20. Refer to the case studies described above:

a. In the Casey Anthony murder trial, what was the basis for Dr. Haskell's opinion that a dead body had been in the car for 5 days? Obj. 11.3, 11.6, 11.6

b. In the chigger bite case study, what evidence did the forensic scientist cite that supported his claim that the bites on the ankles of both the investigators and suspect were chigger bites and not from another insect? Obj. 11.3, 11.9

c. Refer to Paul Catts's Case of the Massive Maggots. Obj. 11.2, 11.4, 11.8

i. What is the significance of the phrase "massive maggots"?

ii. Since maggots of the same fly species but of two very different sizes were collected from the corpse, how did Dr. Catts determine that both sizes of maggots were on the body for seven days?

21. Investigate the different types of forensically useful insects that can be found in your region. Research the times of your different insects are found, and describe their food source.


3. Design an experiment to collect data to answer one of the following questions:

a. How does temperature affect the developmental rate of blowflies?

b. How far will larvae migrate when looking for areas to pupate?

c. What is the temperature difference between a maggot mass and the ambient temperature?

d. Which of the factors below seems to have the greatest effect on when egg-laying occurs?

i. direct sunlight versus shade

ii. strong wind versus no breeze

iii. clothed versus unclothed body

Bibliography


Internet Resources

http://www.kingscollege.ac.uk/forensics/May2012/forensics-entomologyfordocumentary.html

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http://www.usu.edu/biology/usu2012/evolution/roost.html

http://www.macs.psu.edu/heritagecenter/forensic-science/creation/

http://en.wikipedia.org/wiki/Death's_door


http://www.forensicentomology.co.uk/forensics/whatdoesamaggottlooklike.jpg

http://www.forensicentomology.co.uk/forensics/forensic-maggot-identification.jpg

http://www.biol.uoguelph.ca/forensicentomology/flies.html


http://www.forensicentomology.org


Tutorials

Search the Internet for "NCMECDiMental" and "Postmortem Interval," Parts I through 5

https://www.anatrace.com/ncmes/252604/ForensicsInteractiveActivityonPostmortemIntervals

c. Some maggots of the same species were more than twice as large as others on the body.

d. Paul Catts conducted an experiment in the lab where he fed larvae cacoon to see if it was possible for insects to grow to lengths of 16–17 mm in just seven days. His experiment provided evidence that supported his claim that larvae of two different sizes could have been on the body for only seven days.