The Rest of the Story: A Study of Death, Decomposition and Metamorphosis

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This curriculum unit is recommended for:
High school forensics students or as an extension in a biology course

Keywords: forensic science, forensic entomology, decomposition, metamorphosis

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: The use of insects to determine post mortem interval dates back to the 13th century. It was not until the 1990's that forensic entomology began being used in death and criminal investigation as a way to determine estimated time of death or connect a suspect to a crime scene. By knowing and understanding the metamorphic cycle of the common blowfly (blue or green bottle fly), a forensic entomologist can use weather data and life cycle stages to determine an approximate post mortem interval. This unit introduces the learner to the processes of death and decomposition and connects them with the metamorphic cycle of the blowfly. Through research and field studies, students will engage in the work of a forensic entomologist as well as a crime scene investigator.

I plan to teach this unit during the coming year in to 130 students in Honors forensic science.

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Introduction

Myers Park High School, located in an affluent neighborhood in Charlotte, N.C.is the largest high school in Charlotte Mecklenburg Schools. Enrollment this year is 2717 students.[1] The student body represents over 25 different nationalities, many of whom are English language learners. Students can choose standard level, honors level, International Baccalaureate and Advanced Placement courses. We also have a substantial population of students with special needs. I currently teach 4 honors forensic science courses and 2 physical science courses. Class size ranges from 35 to 38 students. My professional background involves both medical laboratory science and teaching middle school and high school science. While working in the hospital laboratory, I became interested in the work of the medical examiner on our staff. As I transitioned to teaching, this interest became buried and almost forgotten. Two years ago, my science department chair was seeking to add some elective courses in science to our course offerings for students. I suggested a forensic science course and he basically said "go for it". I resurrected the ideas and interest and began to research and develop a base set of standards for a course in forensics. I polled students to see if there would be interest and the response was excellent. Along with the ideas of several other teachers in the county, a set of standards was created and training was conducted the following summer.

The Honors forensic science course is in its second year and has grown from 2 sections to 4 sections. The structure of the course is such that I can use a variety of strategies and integrate multiple areas of science such as physics, chemistry, biology, earth and environmental science. Literacy and writing fits well into the curriculum because there are many books about the subject. Integrating the arts through mock trials, crime scene sketching and facial reconstruction helps me address multiple learning styles and modalities. The students in my current class are my inspiration for this curriculum unit. They are enthusiastic, curious, and willing to go where the science leads them.

For my curriculum unit, I have chosen to address changes that occur to the body at death and during decomposition and how insect metamorphosis can aid in the determination of time of death or post mortem interval. The two major insect orders that are of particular interest to the forensic entomologist are *Diptera* (flies) and *Coleoptera* (beetles). Through understanding of the various stages of life cycle development, behaviors, and environmental factors, one can discover clues that can be used in the determination of post mortem interval and in some cases details such as drugs or toxins present.

Rationale

Literature has lured its readers into the world of mystery, crimes and criminals, and solving the mystery of “who did it” for many years. Sir Conan Doyle penned Sherlock Holmes who along with Watson engaged in finding the clues and solving the case. Kathy Reichs introduced us to Temperance Brennan (nicknamed “Bones”) which has transcended the pages of text to television. Patricia Cornwall gave us “The Body Farm” with its somewhat morbid but interesting look at forensic anthropology and studies of the dead. Merely perusing the television line up for any week and one can find a plethora of forensics based shows to watch and be entertained. Some shows such as “Forensic Files” on the HLN channel even address real crimes and how forensic science helped catch the perpetrator, get justice and close the case. It is evident that forensic science has a following of fans and is more popular than in the past. CSI: Crime Scene Investigation (the original series) was one of the first shows to rise in popularity. One of the main characters, Gill Grissom, was a crime scene investigator who had an interest in insects. Gill would often educate the other CSI’s about various species and how they linked to a particular crime scene. The basis of this unit involves the metamorphosis of the blowfly and how this life cycle can be used to determine an approximate interval from death to discovery known as the post mortem interval or PMI.

Many of my students are taking the class because they have watched various crime shows on television. The cameras of Hollywood often portray the work of the forensics team and the crime lab as a glamorous, exciting job where they always solve the crime. That is not always the case. Some cases become cold cases and are never solved. Some cases come together more quickly because the deceased are easily identified and the evidence is easier to process and test. Badly decomposed bodies, victims left in obscure places, buried in shallow graves or discovered after years of being missing require a different expertise such as that of a forensic entomologist who studies insects or a forensic anthropologist who studies bones.

This unit is designed for an honors forensics class but could be taught as an extension unit or enrichment topic in a biology class. It is designed to be used as a traditionally taught unit or as a “flipped classroom” unit. In the “flipped model” students would complete the notes, viewing the presentations and some videos outside of class. Class time would be used to conduct lab investigations and assessments. Because the investigations involve a series of observations of decomposition, the unit activities may take up to a week initially and then once per week data collection for the duration of the semester. As part of this unit, students will read excerpts from Patricia Cornwell’s Body Farm and research the actual body farm at the University of Tennessee. Class discussions will focus on the reading and research work as well as discussions of the video clips that students will be analyzing.

Content Objectives

The content objectives for this unit are based on the standards developed at the local level for the honors forensic science course. Upon completion of their study, students will be able to (1) define death and (2) differentiate between the four manners of death. Clinical death is defined as the absence of heartbeat and the point where all body functions cease. Manners of death include natural death, homicide, suicide and accidental. Students will be able to distinguish cause, manner and mechanism of death. (3) Students will use evidence such as livor mortis, rigor mortis and algor mortis to estimate the approximate time of death. These signs begin to develop within 30 minutes of death and can extend up to three days. (4) Students will describe the stages of decomposition of a corpse: initial, putrefaction, black putrefaction, butyric fermentation and dry decay. (5) Students will explain how the time of death can be estimated using insect evidence and calculate a post mortem interval.

Background Information

Some of the background material that I teach or review with the students is presented in the following sections. The information is shared with the students in Google Drive via a slide presentation or short video clips. Students can download the student guided notes to complete while reviewing the material. Through the research for this unit, I have been able to extend the depth of the material from the previous material that I used in the beginning of the course. I guess you can say that the course (after only 2 semesters) is undergoing its own metamorphosis.

Metamorphosis

Metamorphosis is a term that brings to mind several definitions depending on whether one takes a biological point of view or a literary point of view. According to Merriam-Webster's online dictionary, metamorphosis is (a) a striking alteration in appearance, character or circumstances, or (b) a major change in the form or structure of some animals or insects that happens as it becomes an adult. In literature, Kafka's *Metamorphosis*, tells the story of Gregor Samsa, a travelling salesman, who awakens one morning to find that he has been transformed into a large insect. In biological science, the most familiar organisms to undergo these types of changes are the butterfly and grasshopper of the phylum *Insecta*. Insects are one of the largest groups with more than a million species.[3] Metamorphosis is prevalent in many other organisms such as the jellyfish, anemones, and corals which make up a portion of the phylum *Cnidaria* which boasts over 9000 species throughout the world.[4] The metamorphic cycle has several main stages: egg, larva, pupa, and adult. The female will produce large numbers of eggs and depending upon species, there may be multiple larval forms. Each stage is preceded by a molt in which the organism sheds its outer "skin" and the new form emerges. In the blowfly (focal insect for this unit) there are three larval stages called Instars.[5] The first and second Instar stages are mainly growing stages in which the larva feeds and gets larger. The third Instar stage is divided into two periods, a feeding stage and a migrating stage. During the feeding stage the Instar is storing energy to undergo the final metamorphosis. After feeding, the Instar migrates from the food source and burrows in the ground nearby to pupate. The energy stored during feeding will be used as the larva transforms into the adult fly. According to a study done by Arnott and Turner, the dispersal time of the post-feeding larvae may be short if the larva stay close to the food source like *Chrysomya albiceps* or may take several days to find a suitable site like the *Calliphora* species.[6]

This unit will provide information about the various biological processes as students study the metamorphic cycle of the blowfly and how it provides valuable information about the metamorphosis that takes place after one dies. This information will be integrated into legal investigation processes demonstrating how these kinds of studies help forensic scientists to determine how long a corpse has been deceased from the time it was discovered, known as the post mortem interval or PMI.

Defining Death: Manner, Mechanism, Cause

Death occurs when all body functions stop: heartbeat, breathing, and brain activity. This is referred to as physiological death and there may not always be a definite time of death because there may not have been a witness present to document it. In cases of unattended death where a decedent's body may not have been discovered for a period of time, cases of suspicious death, or in the case of criminal activity where a murder has occurred and the perpetrator has disposed of the body it is often difficult to determine an exact time of death. Medical examiners may perform an autopsy in order to get additional information regarding the manner of death, the cause of death and the mechanism of death because sometimes these are not obvious. Cause of death is the immediate reason such as blunt force trauma to the head or heart attack. Manners of death are natural, homicide, suicide and accidental. Mechanism of death is the specific body failure that resulted in death such as internal bleeding caused by an aneurysm.[7]

For cases where the decedent has been dead for less than 50 hours, the medical examiner can use some visual signs to determine an approximate time of death. Rigor mortis is a stiffening of the muscles that begins in the smaller muscles within a couple hours of death and progresses to the larger muscles. This rigidity of the muscles lasts for about 36 hours and then the muscles begin to relax.[8] Livor mortis or lividity begins at death as the blood cells in the tissues begin to settle due to gravity. This gives the corpse a mottled purple discoloration in the tissues at the lowest point. After six hours, lividity becomes fixed and movement of the corpse will not alter its pattern.[9] Prior to six hours if the corpse is moved then the lividity will be redistributed. This is one of the indicators that medical examiners use to determine if the person died in the location where it was found or if it had been moved. When a person dies, the body begins to cool, a process known as algor mortis. The core temperature drops about 1.5 degrees Celsius per hour.[10] The medical examiner can take the core temperature using a rectal thermometer or via a temperature probe that resembles a meat thermometer inserted into the liver. If the decedent was febrile prior to death, the core temperature would be above the normal 37 degrees Celsius and this can affect the estimation of the time of death. Likewise, if the body was left in a cold location, the time of death can be overestimated.

Death investigation is not always an easy task especially if the corpse is badly decomposed, disfigured, or dismembered. It is estimated that about 4,000 unidentified deceased persons are discovered each year and of that number, about 3000 are identified by law enforcement.[11] For unattended deaths (where no one is present at the time the person dies) or for deceased that have been dead for a period of time, the expertise of a forensic entomologist can help to determine the approximate time of death or post mortem interval (PMI). Insects present in the area or on the corpse can provide links to primary or secondary crime scenes as well as clues about when the deceased died. From this information, investigators can begin building a case and develop a possible scenario as to what happened to the victim.

The Decomposition Process

To understand how the metamorphosis of insects can contribute to the determination of post mortem interval, it is helpful to study the stages of decomposition which is a transformation in itself. Stages of human decomposition were first described by Jean Pierre Megnin in 1894 when he described eight stages and narrowed to six in the 1960’s by Jerry Payne.[12] In this unit, I will focus on five stages of decomposition which change the body of an animal or human over time to a form that has a minimum resemblance to its former self. At the moment of death, the heart stops pumping oxygen rich blood to cells and tissues of the body. Within 4-6 minutes after death, the brain cells begin irreversible changes due to the lack of oxygen. The chemical changes that begin to take place create a chemically toxic environment that can no longer support living cells and the tissues begin to decompose. During the first stage of decomposition, initial decay, the changes are mainly internal and the corpse appears normal on the outside except for a pale tint to the skin.[13] The second stage, putrefaction, is marked by continuing internal chemical changes that produce gases. The corpse begins to exude a “death smell” and begins to swell as the gases are trapped inside.[14] As decomposition continues, the odor becomes very strong and the corpse begins to turn black. The gases that have built up inside the body escape and cause the corpse to collapse. This stage is black putrefaction.[15] The fourth stage, butyric fermentation, is marked by drying and loss of the flesh. The final stage is dry decay which is slower than the other stages due to lack of moisture.[16]

The corpse is almost completely dry. The length of the stages of decomposition may be affected by high humidity, hot or cold temperatures, lack of moisture, and whether the body is exposed, dumped in water, or buried in soil. Decomposition is slower when temperatures are cold and humidity is low. Corpses left on top of soil will decompose faster than those buried beneath because there is less exposure to the environmental elements. Soil temperature, moisture and pH level can also influence decomposition. Moist, acidic soil will accelerate the rate.[17] Exposure to animals especially insects can affect the rate. Eventually, if enough time passes, the remaining skeleton may return to the earth.

The decomposition process is the focus of study at the University of Tennessee's forensic research facility, known by its nickname the “body farm.”.[18] The facility is home to cadavers in various stages of decomposition and in various "burial" conditions. The research being performed here provides valuable data and information about the processes that happen during decay under real conditions. Some corpses are buried in shallow graves, closed in cars, or exposed to the environment. Researchers study the bodies and record data about the decomposition process so that they can better understand the factors that affect the rates of decomposition. They also study conditions such as how the body responds when burned or submerged in water. Once the remains reach dry decay, the bones of some skeletons are studied to determine markings and mechanism of death. The facility also is used as a training facility for forensic investigators and cadaver canines. New technologies in forensic anthropology are under development using the research data provided from this facility as well as the four other body farms around the United States. The newest facility in southwestern Pennsylvania will allow scientists to study decomposition in a very different climate than in the southeast and south west.[19] Information gathered about decomposition in colder climates will be a welcome addition to the body of knowledge in an area deficient of research.

Insects and Decomposition

The use of insect evidence in criminal investigation dates back to the early 13th century. A travelling Chinese judge, Sung Tz'u, wrote about cases in which flies attracted to the fresh blood on a scythe helped link the suspect to the victim.[20] In 1668 Francesco Redi discovered that maggots arise from eggs and not abiogenesis.[21] In Switzerland in 1855, Dr. Berguret d'Arbois used fly evidence to solve a 5 year old murder case in which the body of an infant was hidden in the walls of a house. Upon examining the eggs present and calculating the post mortem interval, the doctor was able to link the crime to the previous owners of the house.[22] It was not until 1984 that forensic entomology was recognized as a profession and finally in 1996 began to be used in legal investigations.[23]

A forensic entomologist studies the species succession and life cycles of insects that may be present on the decaying corpse. Some insects feed on the fresh corpse while others prefer to feed on one that has been deceased for several days to two weeks.

Carrion insects will spend their entire life feeding on dead flesh and produce multiple generations in the process.[24] Other insects present may be predators of the insects feeding on the corpse. There are two major orders of insects that are of particular interest in forensic investigation: *Diptera* (flies) and *Coleoptera* (beetles). Blow flies of the family Calliphoridae are viewed by some as the most important ones on the corpse as they are the first responders. These flies look like common house flies but they have a metallic green, blue, or copper body with feathery hair on the terminal antennal segment. [25] Some entomologists say that blow flies can smell death up to a mile away and immediately seek out the corpse and lay eggs in the eyes, nose, ears and mouth.

The blowfly undergoes a complete metamorphic cycle with 6 major stages before adulthood: (Figure 1): egg, larva (3 Instars), and pupa. The adult female lays the white, sausage-shaped eggs in clumps in areas where mucous membranes are exposed to air.[26] Eggs can also be found in wounds and areas where the skin is broken. Once the eggs hatch, the larval stage begins. The time interval from egg to larva is 23 hours at 25 degrees Celsius. These small white tubular larvae feed on the decaying corpse.[27]The first Instar and second Instar larval stages are feeding stages. The interval from first to second Instar is 27 hours and from second to third Instar is 22 hours.[28] The third Instar is a migrating larva which leaves the body to pupate in the soil. The length of this migration as observed in laboratory experiments is short but in natural conditions may take hours or days as the larvae must find a suitable site to pupate.[29] The time interval for transformation from third Instar to pupa is 130 hours at 25 degrees Celsius. The final stage of the cycle in which the pupa emerges into an adult fly takes 143 hours. The total life cycle at 25 degrees Celsius takes only 14.375 days or 345 hours[30]

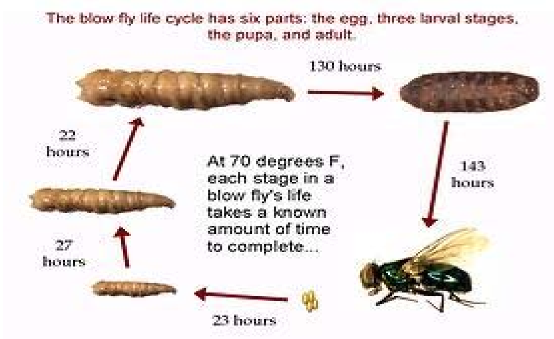

Figure 1. Life cycle of the blowfly
www.nlm.nih.gov (Cleveland Museum of Natural History)[31]

Beetles are one of the largest groups on Earth but only two species of beetle are of interest to the forensic entomologist in North America: the sexton beetle or *Nicrophorus orbicollis* and the American carrion beetle, *Necrophila Americana.* Once blow flies have left the corpse to pupate, the beetles will arrive.[32] Both beetle species are nocturnal insects however in daylight, the sexton beetle can be found in the soil or under the body while the American carrion beetle can be found on the upper surfaces of the body. Beetles undergo a complete metamorphic cycle from larvae to pupa to adult. The larvae of beetles can be differentiated from the maggots (larvae) of flies due to the present of 3 pairs of legs in beetle larva. Fly maggots do not have legs. The bodies of beetle larvae can appear hairless, white, chubby, or slim, dark brown, and hairy. Unlike fly maggots where each species looks like another, each beetle species produces distinct larvae that aids in differentiation between the two species of beetle.[33]

There are a number of factors that can affect the forensic entomologist's ability to determine an approximate post mortem interval or PMI. It is important to know what species of insect is present as well as the climate conditions of the area both past and present. Forensic entomologists examine the death scene and determine whether the environment is natural or artificial and the whether the lighting is natural or artificial.[34] Because insects are poikilotherms, larval development is of all species is affected by temperature. At low temperatures, development takes longer. Weather can also impact development rates or colonization. Rain and storms affect the laying of eggs especially for blow flies. These flies are typically not active in stormy weather or at night. The size of the larval mass affects the decomposition process as well. Large masses of larvae (known as larval crowding) speed up the decomposition of the corpse because there are many feeders at work and this generates heat that hastens the breakdown of tissue in addition to the feeding.[35]

Entomotoxicology

A new area of insect study has emerged in recent years and it shows promise in the area of death investigation. Entomotoxicology is the study of insects and detection of drugs and toxins. The forensic entomologist collects and analyzes the larvae and empty pupa cases for drugs and toxins that they may have ingested while feeding on the tissues of the corpse. The premise is that as the larvae ingest and metabolize the drugs which build up in their own bodies much like humans ingesting mercury tainted fish. The preferred species are the *Diptera* and *Coleoptera* since they are the first flies to colonize the corpse after death.[36] While the absorption, metabolism and elimination of drugs in insects are not fully understood, it is believed that the presence of drugs in the tissues of the corpse could have an effect on the larval development.[37] This could in turn affect the post mortem interval estimate.

Teaching Strategies

Teaching and learning strategies that will be used in this unit are focused on research, data collection and analysis, writing and reflection. Students who take the class have experience in writing a variety of essay types such as argumentative and expository but lack experience in the technical type of writing that science requires. As a part of developing this skill, students will keep a combination lab notebook and writing journal. Resources available through The Writing Center of the University of North Carolina at Chapel Hill (writingcenter.unc.edu) will be used to help students review writing styles. The site contains reproducible handouts for scientific writing that can be used to guide students in the development of scientific writing including scientific report writing. As students read various types of writing including scientific journal articles, excerpts from fictional novels and nonfictional texts, they will create comparison charts in their journals noting the voice, tone, and choice of vocabulary. Vocabulary development will be stressed as many terms will be new to students because of the nature of the content. Technology including computers, podcasts and an online classroom learning module will be used to deliver instruction including several video documentaries. To help students focus and strengthen their viewing comprehension skills they will be taking viewing notes and developing questions to accompany the notes in a modified Cornell note taking style. Students will strengthen laboratory and inquiry skills through the field study in which they will actively collect data, analyze data and formulate conclusions. During the unit, students will use Google classroom to post and share data with their groups and the class. A discussion forum will be established in which students will post responses to various learning experiences in the unit and comments to their peers. The questions will be generated from the field study as well as current event articles. The expected outcome is for students to engage in discussion both in and out of class. Students will be assessed during the unit using quizzes, video viewing responses, journal responses, field study data collection and analysis and a culminating test.

Classroom Activities

Decomposition Field Study

At the high school level, many students may be unfamiliar with the processes that occur during decomposition of a corpse or their experience may be limited to seeing and smelling dead animals lying on the side of the road. During the lecture portion of this unit, students will learn about the signs and significance of decomposition. Students will view and discuss the documentary "The Body Farm" produced by National Geographic Channel. This documentary gives the viewer a tour of the University of Tennessee's Forensic Anthropology Research facility created by Dr. Bass and discusses the research and training that is conducted there.

Using the documentary as background knowledge, students will create a body farm using chicken drumsticks as their research subjects. Students will decide what type of burial method or body disposal method they want to study: shallow burial, surface disposition, hanging, in a container representing a car trunk or trash can, wrapped in plastic or submerged in water. Prior to burial, students will record observations such as mass, length, color, and temperature of the chicken drumstick. At the time of burial, students will record the time of burial, air temperature, weather conditions, soil temperature (if burying in soil), and water temperature (if disposing in water). This information should be recorded in their notebooks in a data table. A sketch of the chicken drumstick with any markings should be done and a description of the burial method recorded as well.

Each day, students should examine their corpse and record time of day, temperature, weather conditions and observe and create a sketch of what they observe. Students should look for signs of rigor mortis, algor mortis, and livor mortis and note presence or absence. Using a magnifying lens they must closely examine the specimen for eggs indicating that blow flies have been present. Oviposition is affected by weather conditions and temperature. If the air temperature is cooler than 25° Celsius or the weather is stormy, the laying of eggs may be delayed. This was a problem in the study conducted by my classes as the first week of our study; the weather was unseasonably cooler and rainy. We observed each day and it took about a week for students to see signs of eggs and larvae and this was only after the air temperature rose to 23°Celsius. Once temperatures returned to a favorable temperature for fly activity, students were able to observe the life cycle stages of the blow flies that were present. Students should continue to collect data for at least 14 to 16 days to observe all life cycle stages. Once all life stages have been documented, the specimens may be observed two or three times a week until students are able to document the dry decay stage. Depending on climatic conditions, insect and predator activity, this may take several weeks or more.

Weather Research

Weather conditions are very critical in the determination of post mortem interval using insect data. Forensic entomologists rely on this information to determine the time the flies laid eggs on the corpse. As a part of their field study outlined above, students will be recording the air temperature and weather conditions and using the information to verify through calculation the date that they buried their specimen and the approximate day the flies laid the eggs. In a real forensic case, the entomologist would have to research this information therefore students will be researching the weather data for the Charlotte region using the Internet to acquire information about the weather patterns prior to their observations. This information can be found using local weather forecasting records as well as the National Oceanic and Atmospheric Association's website, www.noaa.gov. Students will create a data chart of the weather using Microsoft Excel for the month in which they conducted the field study.

Examination of Preserved Blowfly Specimens

Since students might have limited experience with recognizing life stages of blow flies, this activity will introduce them to "known" specimens representing each stage. I am currently using two species of flies provided by Crosscutting concepts in their kit: The Mystery of Lyle and Louise: Forensic Entomology. The kit also contains two unknown specimens for the students to examine and determine what stages and species are present. Preserved fly specimens can be obtained from most biology supply companies.

In this activity, students will observe each of the known life stages macroscopically and microscopically. Length and color are important characteristics to note as this can be helpful in distinguishing stages. Morphological features and structural characteristics should be noted to enhance differentiation between stages since some larval forms are similar in size depending on age. Since the specimens are fixed in alcohol and each one has been selected to represent each life stage, it is important that students understand that differentiation may be difficult in the field. Each specimen should be carefully removed from the vial and examined under the microscope for any details that are not easily visualized without magnification. Information should be recorded in detail. I stress the importance of detail since the larval stages look similar to the naked eye. I assess students using a "practical" in which they must identify the stage using their notes.

Calculation of Post Mortem Interval Using Blowfly Life Cycle

Students will determine the post mortem interval using blowfly life cycle information, weather data, and environmental conditions. The first step is to calculate the degree hours (DH) and accumulated degree hours (ADH) for the fly species. For example, at 25° Celsius the time interval from egg to first Instar stage is 23 hours. The degree hours for this stage would be calculated as follows

Temperature x hours for development = degree hours

Once the degree- hour for each stage is calculated, this information can be used to determine the accumulated degree hour. This is done by adding the degree hours for each stage to determine the total.

The degree hours and cumulative degree hours for each day in the climate data chart is calculated. Degree hours are determined by multiplying the average temperature for that day by 24 hours. The hours are adjusted for the days that the fly specimens are collected. For example, if the corpse is found on day 5 and specimens are collected at 1300 hours, then the degree hour calculation is adjusted since the interval was only 1300 hours that day and not a full 24 hours. Another approach to calculating degree hours would be to perform hourly degree hour determinations over a 24 hour period and compare the results using summation of hourly degree hours to the data using average degree hours.

After calculating the degree hours and accumulated degree hours from the weather data and identifying all species of flies collected from the corpse, students will identify the oldest stage collected for each species. Using the accumulated degree hour information for that life stage, students will check the climate chart and find the accumulated degree hour interval that corresponds to the oldest life stage. This would be the day that the fly laid eggs. This is done for all species found.

To determine the post mortem interval, the earliest day that any species laid eggs is used. The number of hours between when the eggs were laid and the specimen was collect is calculated. This is the post mortem interval. It important to note that post mortem interval is an estimate of the interval between actual death and discovery of the corpse. Climatic conditions can affect this estimate as adult flies are less active at night and during stormy weather. If the weather conditions are not favorable such as severe storms in the area, the flies may lay eggs on a later day.

Alternative Activity

In some educational settings, the field study many not be feasible due to availability of an outside space. I am fortunate that my school has a large campus with woods and a stream. A study of fly growth and development can be done using commercially prepared live specimens purchased through a biological supply company. The flies can be cultivated using commercial media or beef liver. Students can observe the living organism as opposed to the fixed specimens.

Appendix 1: Implementing Teaching Standards

Implementing District Standards

Essential Standard: HS-FS-FPa-1
Students will evaluate the role of Forensics as it pertains to Medico-legal Death Investigation
Students will define the role of forensics including evidence collection and testing and evaluate its value in investigating death

Substandard HS-FS-FPa-1a
Students will describe how and why the dead body of a victim contains an abundance of evidence that can be used to identify the mechanism of death
Students will use text, Internet and lab based resources to define death and distinguish between cause, mechanism and manner of death Students will use field investigations to examine specimens for the signs of death and the stages of decomposition Students will view documentary videos addressing the procedures performed during an autopsy and the study of decomposition at the body farm research facility

Substandard HS-FS-FPa-1b
Students will assess how Entomological evidence can be used to determine time of death
Students will implement a research project to study decomposition and the succession of insects, primarily the blowfly Students will use blowfly life cycle information to determine post mortem interval and estimated time of death

Appendix 2: Essential Vocabulary for Students

Clinical death
Natural death
Homicide
Suicide:
Accidental death
Cause of death
Mechanism of death
Post-mortem interval (PMI)
Rigor mortis
Algor mortis
Livor mortis
Degree-hour
Accumulated degree-hour
Succession
Metamorphosis
Egg
larva (Instar)
Pupa

Appendix 3

Decomposition Study

Purpose: To observe and document the stages of decomposition: initial decay, putrefaction, black putrefaction, butyric fermentation, and dry decay; to observe and document the stages in the life cycle of the blowfly; to document factors that affect the decomposition process and the appearance of life stages of the blowfly.

Materials

Chicken drumstick (one per group)
"Burial" containers: boxes, plastic bags or containers, wood boxes, metal boxes
String or rope
Enclosure for protecting specimens from predator animals (wire cage or similar)
Gloves
Celsius thermometer
Collection vials
Tweezers
Microscope
Microscope slides
Lab notebook
Metric ruler

Safety notes: Students should wear gloves when handling raw chicken. Any surface where chicken has touched should be disinfected immediately using 50% bleach or other disinfectant that will kill *Salmonella sp.* Students should wash hands after removing gloves.

Procedures

Determine the width and length of the chicken drumstick. Record the information in the data table.
Mass the chicken drumstick using a balance. Be sure to use plastic wrap or aluminum foil to cover the balance. Be sure to subtract the mass of the foil. Record the mass in the data table.
Record the temperature of the chicken drumstick.
Select a "burial" method for the chicken drumstick. Suggestions: shallow grave, hanging, in a container, "clothed or naked.
Record the air temperature and any weather conditions present at the time of burial.
Observe daily for about two weeks. Record the presence of insect forms, temperature, and weather conditions. Take photographs to use in the classroom. Note: data may need to be collected for longer than two weeks depending upon weather conditions.

As fly larvae appear, collect several specimens using tweezers. Using a metric ruler, measure the length of the larva in millimeters and record in the data table. Observe and record observations with the unaided eye (macroscopic) and using a microscope.

Developmental Stage	Air Temperature (° Celsius)	Length	Color	Distinguishing Markings (Macroscopic)	Microscopic Observation	Weather Conditions
Egg						
1st Instar						
2nd Instar						
3rd Instar (Feeding)						
3rd Instar (migrating)						
Pupa						

Appendix 4

Weather Data Table

Research the climate data for the month that the fly specimens were collected from the corpse. You can find information using local weather statistics from the weather service or from the National Oceanic and Atmospheric Association website. Once you have completed the temperature and weather information, you will be able to calculate the degree-hour and accumulated degree-hour information. Students can use Microsoft Excel and create formulas to calculate the degree-hour and accumulated degree-hour.

Degree-hour (DH) = average temperature x hours /day
Accumulated degree-hours (ADH) = total of all degree hours (a running total)

Month: Day	ºC (High)	ºC (Low)	ºC (Average)	Weather Conditions	Degree-hrs.	Acc. Degree-hrs
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
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Appendix 5

Fly Life Stage Data and Calculating Post Mortem Interval

For each fly life stage, the degree-hour and accumulated degree-hour must be calculated

Stage	Egg	1st Instar	2nd Instar	3rd Instar	Pupa
Hours to develop at 25ºC	23	27	22	130	143
Degree-hours					
Accumulated Degree-hours					

Determining when Oviposition occurred:

After completing the chart for each species of fly collected from the corpse, one must examine the specimens and determine the day that each female fly laid eggs. This is determined by selecting the oldest stage represented and comparing the accumulated degree hours for that stage with the accumulated degree hours in the climate chart. The day that the fly laid eggs will be the day that is closest to the accumulated degree hours for the oldest stage. This is done for all species of flies collected.

Determining post-mortem interval

After determining the days on which oviposition occurred, determine the earliest date that any fly species laid eggs. Calculate the number of hours (or days) from that day until the day/hour that the specimens were collected. If the day of collection was not a 24 hour day, this must be taken into account in the total. This is the post-mortem interval.

Appendix 6

Forensic Pathology and Forensic Entomology Quiz

1. The following is partial climate data for May 1-5 A decomposing body was discovered early in the morning of May 5 Samples were collected at 6:00 pm. and sent to the lab for analysis. Complete the missing information in the data table. **One point awarded for each correct table entry.**

Day	Max.Temp.(C)	MinTemp (C)	Average temp (C0	weather	Average degree-hrs	Cumulative Degree-hrs.
1	25	10	20	sunny		
2.	27	15	20	sunny		
3.	30	20	25	partly cloudy		
4	35	25	27	sunny		
5	35	20	25	sunny		

2. The following information is for the first species identified from the specimens: **Species A.** Complete the table with the missing information. **One point per correct table entry.**

Temp(C)	Egg	1st Instar	2nd Instar	3rd Instar (feeding)	3rd Instar (migrating)	Pupae
13	10	15	20	25	30	35
Degree hours						
Cumulative degree hours						

3. Examination of the samples revealed that the oldest life stage present was the 3rd migrating instar. From the information above, determine the approximate day that the female fly laid eggs.

4. A second species was also identified in the specimens: **Species B.** Complete the missing information in the data table for Species B.

Temperature (C)	Egg	1st Instar	2nd Instar	3rd Instar feeding	3rd Instar migrating	Pupae
13	15	26	36	45	60	70
Degree hours						
Accumulated Degree Hours						

5. The oldest life stage of species B present was the second instar. Calculate the approximate day the female fly laid the eggs.

6. Using the data from questions 1-5, calculate the post mortem interval (PMI) for the decedent.

7. What is oviposition?

8. Match the description on the right with the correct life stage on the left

Column A	Column B
___9. Egg	a. the Instar drops off the corpse to burrow
___10. Pupa	b. very small, white (less than 1mm)
___11. 1st Instar	c. forms a hard casing to metamorphose
___12. 3rd Migrating Instar	d. larval form that hatches from the egg

13. What is succession?

14. Describe the effects of temperature on decomposition

15. How can the present of maggots affect the decomposition rate?

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Figure Legend

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