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Forensics, a Summative Laboratory Experience

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This forensics exercise is used at the end of the fall semester to reacquaint students with the equipment that they were exposed to and the types of data they generated during the semester. The exercise is also designed to promote critical thinking. Students are given additional types of data, e.g., plant fragments, phone records, shoe prints, and tire tracks, and they are challenged to explain the potential cause of death of an individual found suspended from a tree stand. In groups, students prepare a presentation and defend their findings to the class. There is no correct answer to this exercise.

Keywords: forensics, critical thinking, laboratory equipment, laboratory techniques, presentation

Link to Supplemental Materials
http://www/ableweb.org/volumes/vol-36/buikema/supplement.htm

Introduction

During a semester of introductory biology laboratories, students often do one experiment using specific equipment or techniques, and then they move onto another exercise using different equipment and techniques to generate different types of data. It is rare that students repeat using equipment or similar techniques in an introductory class. We asked, "What terminal laboratory exercise can we devise so students will revisit what they have learned during a fall semester laboratory course?" This was important because about 15% of our students no longer take a second semester of laboratory and this number is increasing every year. We also wanted to further promote critical thinking skills and have students present their findings while having fun at the same time.

To address our concerns, we designed a 3-week forensic exercise that met five objectives while presenting students with new critical thinking challenges. Students were required to

1) reuse laboratory techniques (e.g., pH measurement, microscope, balances, etc.),

2) revisit the types of data generated previously from earlier experiments (e.g., pH and DNA),

3) analyze and integrate large and diverse types of data sets,

4) collaborate on team work, and

5) develop professional presentation skills.

It took about six weeks to develop this exercise and collect or manufacture the various data sets and reference guides for students to use. Once completed, the exercise is relatively easy to set up. For two weeks, students needed access to microscopes to investigate hair samples, pH meters to determine soil acidity, balances to weigh out soil samples, possibly centrifuges to spin soil samples out of the water column, and copies of the various data. Students were asked to bring their own laptops to the laboratory so they could research various information. This assignment is conducted by about 1400 students in 60 laboratory sections; each laboratory section had no more than 24 students.

The landscape for this exercise is southwestern Virginia, and students are asked to determine the cause of the death of a young pregnant woman who went hunting and was found suspended from a deer (tree) stand. There are five suspects and 14 sets of data including plant DNA, suspect DNA, decayed leaf samples, human and animal hair samples, fingerprints, tire tracks, soil samples, blood type data, entomological data, boot prints, phone records, suspects' statements, weather data, and a medical examiner's report. The students are asked to determine potential cause of death and to defend their conclusions in a presentation to their classmates. The student challenge is that there is no correct answer for this assignment.

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Students work on this assignment for 3 weeks: a) Week 1 – introduction to and analysis of the data; b) Week 2 – continue evaluating the data and discussing their findings with group members; and c) Week 3 - present their results to the class. To facilitate division of labor among group members, students are given guidance as to which data sets will take the longest to analyze. Students must spend some time out of class to work on the data and develop their presentation. Initially, data are available in files on each laboratory desk during the first two weeks. Beginning with Week 2, all the data are also available online, and each data set can be downloaded as a PDF file. We did not make the data available online prior to Week 2 because we wanted to make sure that the students understood the data and to provide them with assistance if needed.

Students are given guidance on how to structure their presentation, and each student is expected to participate in the classroom presentation. Rubrics for grading are given to each student to grade not only their own work, but also the members of their group and the presentations of other groups in the class.

One issue we have had with the forensics exercise is that some graduate teaching assistants and students get frustrated. Graduate teaching assistants can get frustrated when students demand a correct answer, but this frustration varies with how much teaching experience each assistant has had. Some students believe that science provides answers to questions, and they get stressed because there is no single correct answer to this exercise. All in all, frustration has been a relatively minor problem. The second issue is that students need guidance when working through the data sets; some data sets take longer to process than others. We tell the students that the analyses of fingerprints, human and hair DNA patterns, plant fragments, and the death certificate will take the longest to process. Some students will go to great lengths to process all of the fingerprints even though this is usually not necessary. The following data take the least amount of time to process: leaf fragment DNA, tire tracks, shoe prints, and blood typing. The remaining data only take a moderate amount of time to process. Last, some students think that they must get through all the data in the first laboratory period; they need to be reminded that this often is not possible and that the data sets will also be available in class and online in the second week.

Workshop Presentation

This exercise is relatively easy to set up and most of the laboratory time is devoted to data analyses and group discussion. We will provide copies of all of the data and most supplies needed for a class of 24 students. Most of the data are also online for students to access outside of the laboratory. Attendees to this workshop will work in small groups and be given copies of the exercise and access to the data sets. They will be asked to divide the evidence for analyses. Guidance will be given as to which data sets will take the longest to analyze. After examining the data for about 90 minutes, each group will be asked to determine a cause of death. They will then be given the presentation and grading rubrics and asked to make a short group presentation of their findings to the other attendees. At the end of the exercise, attendees will be given copies of the setup sheets and answers to the unknown data.

Evaluation

Each week we meet with our ~25 GTAs to evaluate the material given the students and assess not only their reactions as instructors, but those of their students as well. This is the second iteration of this exercise and to date most students have had fun doing the work. A few student groups expected a definitive answer and were frustrated when there was none. This attitude was expected because of how their favorite TV shows solve cases accurately and in a very short period of time. It is an important lesson for students to learn that there are no easy or quick answers in science. Lastly, it was encouraging to see students dressed professionally for their presentations.

The initial collection of information used in this exercise took about three weeks simply because it was regionally specific. Once the information was assembled, laboratory setup each semester is relatively easy. Because this exercise is the last during the semester, the technicians appreciate the break from the normal chaos at the end of the semester.

Student Outline

Introduction

This is a mystery that deals with the demise of a young woman who was hunting in fall 2011. Your assignment is to speculate on how the victim died and if any of the suspects could be charged with her death.

This 3-week exercise will test your ability to think critically and apply several techniques you learned earlier this semester such as using the pH meter and microscope. In addition, you will need to incorporate what you learned during your DNA studies as well. You will need to bring your computer to class so you can look up information on the evidence.

The first 2 weeks you will work through the evidence and begin preparation for an in-class group presentation the third week. For the group presentation during the third week, your group will need to prepare a presentation with an additional time for questions from the class and the instructor. Your group will need to defend their decision. Each member of the group will be expected to present a portion of the case to the class and be professional when doing so. You can download a group grading rubric from the website so you can grade yourself and your teammates on individual contributions to this project.

Scenario Overview

The main characters in this case:

- Abby, the victim. She was in a relationship with Joe but broke up with him two months earlier and is now in a relationship with Ezra.
- Joe, Abby's former boyfriend
- Sally, Abby's sister, former girlfriend of Ezra
- Ezra, current boyfriend of Abby, former boyfriend of Sally
- Harold, Abby's landlord
- Robert, TV/Internet repairman
- Dr. Kerr, medical examiner

Very early on the morning of October 18, after a night of partying with friends and family, Abby left a note stating that she went hunting, but she did not say where she was going. She had taken her rifle and cell phone but left her backpack at home. When she did not return by noon, a rescue party went searching for her. Two days later, on October 20 at 2:00 p.m., she was found suspended two feet above the ground wearing a recommended full-body or parachute harness that kept her upright if she fell from a tree stand. Abby may have fallen from a metal ladder tree stand that was located 16 feet above the ground. When her body was discovered, several ammunition casings and her rifle were found on the ground, but Abby had not been shot. Not all of the rifle casings were from Abby's rifle. There was a blunt puncture wound in her abdomen and she had several bruises and scratches on her face, neck, torso, arms, and legs. In addition, there was a dead male deer found 50 yards away and it was shot with Abby's rifle. There was dried blood on one tip of an antler tine.

Dr. Kerr, the medical examiner, performed an autopsy. He noted the bruises and scratches on her body and verified that the abdominal puncture wound was due to a blunt instrument. He reported that Abby had been drinking, and based on examination of the vitreous humor of the eye he predicted that her blood alcohol level was greater than 0.16 when she died. Abby was under the care of a psychiatrist and was prescribed Zoloft at 200 mg per day. Blood analysis indicated that she was not abusing this drug. Dr. Kerr also noted that there were no illegal drugs in her system at the time of her death; the concentrations of illegal drugs that were reported on the medical examiner's certificate were at or below the level of detection. In addition, the medical examiner noted that Abby was 3 months pregnant. The medical examiner filed an extensive report, but his findings were inconclusive.

A forensic team studied the area around the tree stand taking photographs, noting the types of plants, taking soil samples, casts of shoe prints and tire tracks, etc. Based on a request of one of the police investigators, leaf samples found on the suspects and from the site were sent to an independent laboratory for verification. The crime scene investigator noticed that there were mature and immature insects on Abby's and the deer's bodies, and he sent these to a forensic entomologist to be identified and to estimate the time of death. The forensic entomologist also noted that the weather was very mild during this time period, and the temperatures ranged from the mid-40s at night to the mid-70s during the day. Additional evidence included phone call records which were subpoenaed from the telephone company and DNA data provided by an independent laboratory.

Data to Examine

Your assignment is to speculate on how the victim died and if any of the suspects could be charged with her death. Further, you might ask yourself, was this deer hunt legal? You are encouraged to research information about the data from the internet. During the laboratory session, you will be able to examine these data:

- DNA analysis of all parties of interest
- Human and animal hair samples

- DNA data for plant leaves
- Leaf fragments
- Fingerprints
- Tire tracks
- Shoe prints
- Blood types of suspects
- Insects found on the deer
- Weather data
- Soil samples
- Phone records
- Death certificate
- Suspects' statements

Additional Useful Information

To facilitate your forensic study, please read the information that follows prior to coming to class. In class you will be provided with more information on how to study the data from the crime scene.

A. Hair Identification

Please refer to the appendix on microscopes in the back of this manual as you complete this exercise.

Human hair is a frequently found piece of physical evidence located at a scene of a crime. Finding evidence can link a criminal to their act. Hair does not decompose as rapidly as most other human tissues or body fluids. Therefore, it remains intact long after other types of personal evidence have become useless. However, head hair samples obtained years after a crime are generally not suitable for meaningful comparison purposes since hair can be affected by a number of environmental and chemical conditions. Environmental alterations can result from exposure to excessive sunlight, wind, humidity, and other conditions. Chemicals alter the natural appearance of hair by using hair dyes, rinses, permanents, etc. Therefore, it is recommended that hair samples be obtained as soon as possible from suspects and victims of a crime even though it lasts longer than other body samples.

The core or the center of the hair shaft is the medulla (Figure 1). This structure is very useful in making species identification. The medulla's appearance can be classified as fragmental, interrupted, or continuous. Surrounding the medulla is the cortex. Within the cortex are other structures of interest to forensic scientists. Pigment granules (melanin) are found in both the cortex and the medulla, but they are absent from the cuticle. Pigments tend to be distributed toward the outer edges of the cortex and they help give hair its color. Melanin appears as small, dark objects. The location and distribution of these structures can be used for some species identification. Human females are more likely to have lighter colored hair than males, whereas males are more likely to have black or dark hair. Red and blond hair are relatively more common in women than in men. Cortical fusi are air spaces within the cortex, which are a contributory factor to light-colored or blond hair. They are usually found near the root end of the hair shaft. Changes in hair color typically occur naturally as people age, eventually turning to gray then white.

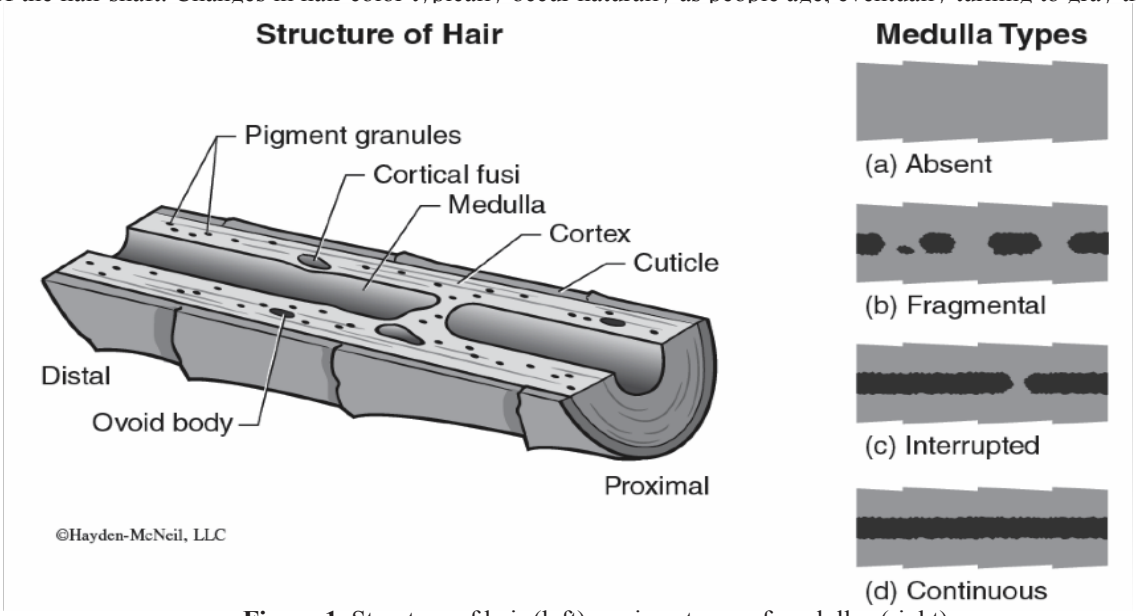

Figure 1. Structure of hair (left): various types of medullas (right).

This is called achromotrichia. The age at which graying begins seems almost entirely due to genetics. Some people are born with gray hair because they inherit the trait.

Hair analysis for comparison should be conducted simultaneously under the microscope. Identifying characteristic features of the hair in question is most easily done by viewing the hair in question with the hair from the known origin. The first step to the examination involves verifying whether the hair in question is that of a human or an animal (Table 1).

Table 1. Medulla patterns.

Uniserial—small blocks in a row (rabbit)	
Multiserial—several rows of blocks across (rabbit)	
Vacuolated—uneven pattern (dog, fox)	
Lattice—circular pattern (deer)	
Amorphous—without a specific pattern (human)	

The value of hair evidence is related to the variability of hair characteristics between individuals in the population. The criminologist is particularly interested in matching the color, length, and diameter. Hair approximately grows 5 mm per day or 1/2 inch per month. Forensic examiners differentiate between hairs of Caucasoid (European ancestry), Mongoloid (Asian ancestry), and Negroid (African ancestry) (Table 2). All of these types exhibit microscopic characteristics that distinguish one racial group from another. Hairs from individuals of mixed racial ancestry may possess microscopic characteristics attributed to more than one racial group.

Table 2. Hair characteristics from various racial ancestries.

Race	**Includes**	**Diameter**	**Cross Section**	**Pigmentation**	**Cuticle**	**Undulation**
Caucasoid	American, European, Mexican, Middle Eastern	70–100 µm	Oval	Evenly distributed	Medium	Uncommon
Mongoloid	Asian and Native American	90–120 µm	Round	Dense auburn	Thick	Never
Negroid	African	60–90 µm	Flat	Dense and clumped	---------	Prevalent

B. Fingerprinting

Fingerprints are a very common form of physical evidence. It requires considerable expertise in the area of fingerprinting to be able to accurately classify prints and match prints with each other. If a suspect's fingerprints match those found at a crime scene, this is highly conclusive proof of a link between the two.

There are a number of basic fingerprint patterns; arches, loops, and whorls are shown in Figure 2. The fingers on a person's hand may contain a number of patterns. You should make yourself familiar with the characteristic appearance of each of the patterns, as you will be making comparisons with these patterns later in this exercise.

One must look not only at the general patterns, but must also look closely for the fine structures of the ridges, and then you will see why it is that no two fingerprints have ever been found that are identical. The tips of a person's fingers have small friction ridges on them. Along these ridges are small pores that secrete salt (NaCl), water, and proteins. It is those substances, along with oil that may be picked up by touching one's hair or face, which will be deposited on objects that come in contact with the surface of our fingers.

It takes considerable time to dust and lift prints. An experienced person is required for this task, as a very good print may be ruined by a poor dusting technique. There are a variety of fingerprint dusting powders. The choice of powder color depends on the object being investigated for prints. Gray is for dark-colored objects and black is for light-colored objects. The transparent tape is basically a wide, clear adhesive tape. When pressed against the powder, the print is transferred to the adhesive surface of the tape. The tape is now placed on a paper whose color will provide a suitable contrast with the print. The transparent tape also provides an immediate positive print.

After lifting the fingerprint, it is mounted on a piece of plywood and held in place by a piece of masking tape over the top. This method of transport to the laboratory allows one to handle the object without adding additional prints. The tape over the top touches very little of the object.

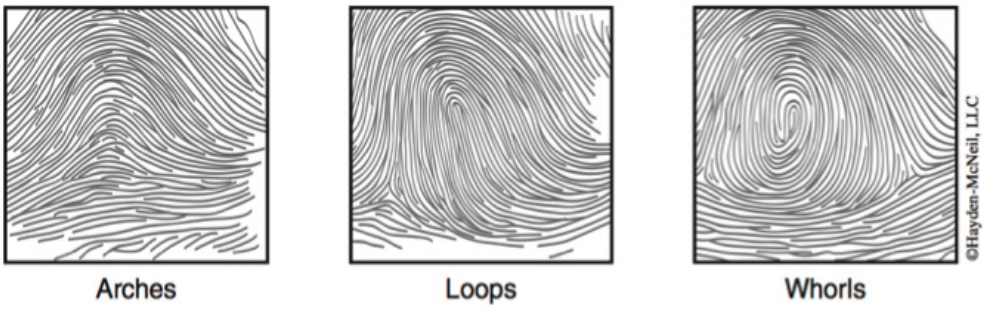

Figure 2. Arches, loops, and whorls, respectively.

C. Footprints

Footprints are another form of evidence and can be very useful in scenarios such as this one, which takes place outside where footprints were left by persons who might have been at the crime scene. Footprints are usually collected by photography or by making plaster casts.

D. Blood Typing

A common form of physical evidence found at a scene is that of blood. The first analysis performed on this evidence is the determination of whether or not the stains are blood, and if so, whether they are of human origin. If the stains are of human origin, the analysis is then extended to determine of what blood group and other blood factors that can associate the blood with a particular person. Not all blood types can mix freely with each other (Table 3). There are four main blood types: O, A, B, and AB. These types correspond to different carbohydrate molecules found on the red blood cell. Type A and Type B carbohydrate molecules are called antigens because they can stimulate an immune response. Type O blood was once called the universal donor and it was given to virtually everyone. With the advancement of research and a better understanding of the immune response to incompatible blood, O is not always seen as a suitable donor in every case. Research now shows that a transfusion with the exact type is best. If donated blood is incompatible with the recipient's blood, the blood can agglutinate, or clump together, blocking blood vessels or cause the donated red blood cells (RBC) to burst.

Table 3. General Summary of Incompatibility Relationships of the Blood Groups.

Blood Groups	Antigen on RBC	Antibodies in Serum	Can Receive Blood From	Can Give Blood To
A	A	Anti-B	A and O	A and AB
B	B	Anti-A	B and O	B and AB
AB	A and B	Neither anti-A nor anti-B	A, B, AB, and O	AB
O	Neither A nor B	Anti-A and anti-B	O	A, B, AB, and O

Everyone has two copies of the gene for blood type, so there are six possible combinations of alleles. Alleles are different forms of the same gene. In this case, the possible alleles are IA, IB, and i, and each individual will have two alleles, whether both are the same or different. The combination of alleles determines blood type and are listed below. Each combination of alleles is referred to as the genotype.

I^AI^A and I^Ai – each resulting in Type A blood
I^BI^B and I^Bi – each resulting in Type B blood
I^AI^B – resulting in Type AB blood
ii – resulting in Type O blood

Each biological parent gives one of their two alleles to their child. For example, a mother who is blood type O has genotype ii and can only give an i allele to her son or daughter. A father who is blood type AB could give either an IA or an IB allele to his son or daughter. This couple could have children of either blood type A (i from mother and IA from father) or blood type B (i from mother and IB from father).

E. DNA Fingerprinting

The first step in forensic DNA fingerprinting is the collection of blood or tissue samples from the crime scene or victim. A blood sample, often present as a stain, is treated with detergent to rupture cell membranes and obtain DNA for further analysis.

Most human DNA is the same; only about 0.1% of DNA differs among individuals. It is this portion of DNA that is used to identify individuals and can often be used to solve crimes. Restriction enzymes are used to cut out these regions; each type of restriction enzyme is specific to a specific sequence of nucleotides, the building blocks of DNA. Because these regions of DNA vary from individual to individual, the fragment lengths and numbers for one individual will differ from that of another individual. By examining several regions of DNA, a profile can be obtained that is unique to each individual (except for identical twins).

F. Forensic Entomology

Forensic entomology is the study of insects that feed on tissue during the postmortem period. Different types of insects feed on the bodies of dead vertebrates, as well as different species of insects at different stages of postmortem. If an insect is found on or in the body, its life stage can be used to calculate the amount of time that has passed since the time of the victim's death. This calculation is also referred to as the postmortem interval (PMI) and must also take into account certain environmental conditions including temperature, the time of day the death occurred, the time of year the death occurred, and whether the corpse is exposed or immersed in soil or water.

After death, the body begins to decay. The odors attract insects to the dead body. The first insects to arrive on the body are usually the flies. Flies develop by complete metamorphosis, passing through four distinct stages: egg, larva (maggot), pupa, and adult (Figure 3). In many cases, these insects arrive within minutes or up to a couple hours after death. Depending on the species of flies, some may deposit eggs in exposed natural openings of the body, such as the mouth, nose, ears, and genitalia, and others deposit larvae instead of eggs. Natural body openings provide moist, humid environments that enhance egg and larval survival. The changes that take place in a body immediately following death are often more rapid than those occurring later in the decomposition process. Decomposition is a continuous process that begins at the point of death and ends when the body has been reduced to a skeleton.

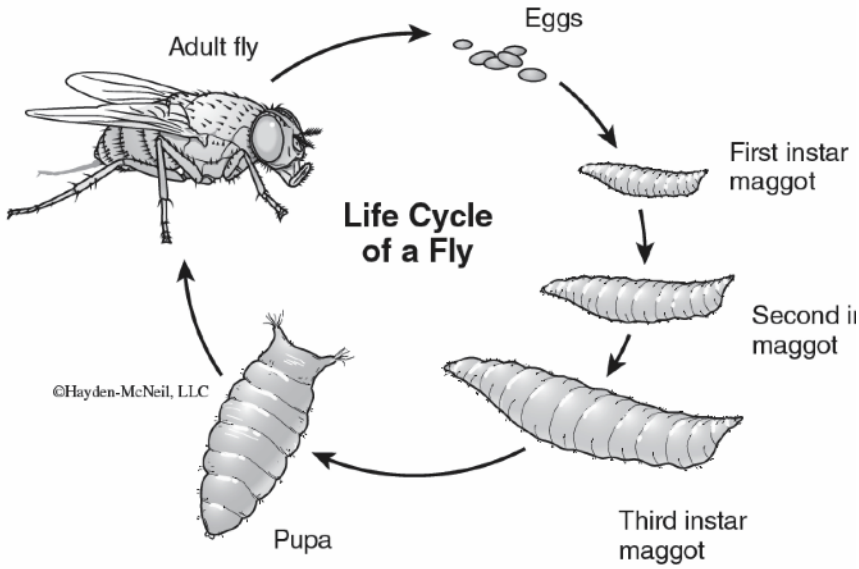

Figure 3. Stages of fly development.

DNA technology can be utilized by forensic entomologists for species identification. Once the species determination is made, the life stage of the insect must be established. It is possible to determine how long it would take for an insect species to reach the life stage under any given temperature. However, we know that organisms will start to suffer ill effects at temperatures approaching their upper and lower temperature survival ranges. The heat input (temperature) needed for a species to develop is obtained from the exposure to the environment in which it exists. Therefore, the higher the surrounding temperature, the more rapid the development and vice versa.

Many fly species in their larval stage appear similar, sharing many of the same morphological characters. The key element in determining species is to search for subtle morphological differences that are unique to an individual species. Distinct differences in body shape, color, or texture may be of aid. Blowfly eggs are 2–3 mm in length, elongated and white to white-

yellow in color. They may be hidden in eyelids or in the nostrils. From each fly egg appears a larva. The larval body is tapered from the anterior (front) to the posterior (back). The anterior end contains the mouth hooks and the posterior end contains the breathing apparatus, called spiracles. The shape of the spiracles, along with the body size and shape provide entomologists with important diagnostic features for species identification. The larvae of blowflies grow rapidly, and will pass through three distinct molts (instars) before becoming fully grown. Large numbers of larvae typically hatch at the same time and remain in a group while they feed on a corpse. Blowfly larvae are considered fully grown (mature) when they reach the third instar. Depending on species, environmental conditions, and number of larvae present, maturity can occur in several days or may require several weeks. Tables 4 and 5 show developmental data for two species of flies that you might find on a dead deer.

Table 4. Developmental data for *Cochliomyia macellaria* (Secondary Screwworm).

	21.1 ± 2°C (Time to reach stage in hours)	26.7 ± 2°C (Time to reach stage in hours)
Stage	Average	Average
1st Instar	12	18
2nd Instar	30	32
3rd Instar	72	56
Pupal Stage	172	112
Adult	297	177

Table 5. Developmental data for *Sarcophaga bullata* (Grey Fleshfly).

	21.1 ± 3°C (Time to reach stage in hours)	26.7 ± 3°C (Time to reach stage in hours)
Stage	Average	Average
1st Instar	*	*
2nd Instar	12	6
3rd Instar	48	26
Pupal Stage	160	110
Adult	504	252

* *S. bullata* do not typically deposit eggs. Therefore, the first molt is from the 1st instar to the 2nd instar stage.

G. Analysis of Soil Samples

The color of a soil is generally related to the presence of specific types of compounds. For example, white or gray soil may contain lime, while black or dark gray soil may contain organic materials and/or moisture. Red, brown, or yellow soil usually indicates the presence of iron compounds. The texture of soil is also related to the presence of certain types of compounds and is usually classified as sand, silt, or clay.

The types of substances present in the soil and the type of drainage condition of the soil will affect the acidity of the soil. If a soil contains lime (CaO) or metallic carbonates, it will probably be basic, while a soil that contains sulfates or nitrates will probably be acidic. The color of the universal indicator is used to determine the acidity: a red color (low pH) is characteristic of acids; violet color (high pH) is characteristic of bases; olive color is characteristic of neutral solutions (pH=7).

pH Procedure

1. Tare the microcentrifuge tube on the balance.
2. Add 0.5 g soil to the tube. Use the balance brush to clean the balance if necessary.
3. Add 1 mL dH2O to the soil, and mix well.
4. Use the centrifuge for a few seconds to separate the soil and water.
5. Use pH paper to determine the pH.
6. Discard the microcentrifuge tube and soil in the blue bag. Wash and dry all other supplies used.

Objectives

1. Learn how to solve a problem using resources that are available.

2. Learn how biology is often applied to forensics in various ways.

Cleanup

Make sure hair slides are in appropriate boxes and not left on microscopes.
Make sure all microscope wheels are turned to "1," all microscopes are off, and objectives are on 43.
Make sure soil tube is in the blue bag and loose soil is cleaned from the benchtop and balance.
Make sure your table has 1 contents sheet, 16 folders, and 1 magnifying glass.

Forensics Evidence Log

Name: _____ Lab Day/Time: _____

Please bring your laptop and worksheet to lab each week of Forensics lab! Note that this worksheet is to be used at your own discretion to collect and organize data. Every blank does not necessarily need to be filled out.

1.Hair/Human DNA Analysis

Refer to parts B and F of the lab manual to complete this exercise. Also remember to use the appendix on microscope use when examining the hair slides. Examine the hair slides from the scene of the crime and for each suspect. Make sketches and notes about the difference in medulla, cortex, and cuticle of each hair sample.

Suspect/victim	**Hair description or sketch**
Abby	
Sally	
Joe	
Ezra	
Harold	
Robert	

Piece of evidence	**Hair description or sketch**	**Hair matches which person?**	**DNA matches which person?**
Hair Sample 1 Abby's clothing			
Hair Sample 2 Abby's sink			
Hair Sample 3 Abby's clothing			
Hair Sample 4 Sally's clothing			
Hair Sample 5 Abby's clothing			
Hair Sample 6 Abby's sink			
Hair Sample 7 Joe's clothing			

Piece of evidence	DNA matches which person?
DNA under Abby's nails	
DNA on Abby's body	
DNA in Abby's body	
DNA under Sally's nails	

2.Leaf Fragment DNA
Which DNA from leaf fragments, if any, from Abby, Joe, and Ezra, match the DNA of the plant from the crime scene?
3.Plant Fragments
Identify the plant fragments associated with each suspect or victim, using the floral guide provided.

Plant fragments associated with….	Species of plant fragments
Abby	
Sally	
Joe	
Ezra	
Harold	
Robert	

4.Fingerprinting

Refer to part C of the lab manual to complete this exercise. Examine the crime scene fingerprints and prints collected from each suspect and the victim. Make notes about each.

Suspect/victim	**Fingerprint description or sketch**
Abby	
Sally	
Joe	
Ezra	
Harold	
Robert	

Piece of evidence	**Fingerprint matches which person?**
Print A1: ammunition & casings	
Print A2: ammunition & casings	
Print A3: ammunition & casings	
Print A4: ammunition & casings	
Print A5: ammunition & casings	
Print A6: ammunition & casings	
Print A7: ammunition & casings	
Print A8: ammunition & casings	
Print B1: rifle	
Print B2: rifle	
Print B3: rifle	
Print B4: rifle	
Print C1: apartment	
Print C2: apartment	
Print C3: apartment	
Print C4: apartment	
Print C5: apartment	
Print C6: apartment	
Print C7: apartment	
Print C8: apartment	

5.Tire Tracks

Piece of evidence	Tire track matches which person?
Tire track 1	
Tire track 2	
Tire track 3	
Tire track 4	
Tire track 5	
Tire track 6	

6.Shoe Prints

Refer to part D of the lab manual to complete this exercise. Examine the footprint patterns found at the scene of the crime with the footprints of the suspects. Which suspect's footprints are present?

7.Blood Typing

Refer to Part E of the lab manual for more information on blood typing. Whose blood matches that found on the deer antler?

8.Forensic Entomology

Refer to part G of the lab manual to complete this exercise. Using the 3 tables (developmental data of two species, plus meteorological data) in the lab manual, determine how long ago (including dates and times), from the time the deer and victim were found (October 20, 2:00 pm), that it died. How did you come to this conclusion?

9.Soil Samples

Refer to part H of the lab manual to complete this exercise. Record in the table below your observations about the appearance of each soil sample, as well as the approximate pH of each soil sample.

Soil Sample	Appearance	pH
Crime Scene		
Joe's truck tires		
Ezra's truck tires		
Ezra's truck, under the fenders		
Abby's truck tires		

10.Phone Records

Look carefully through the phone records. What do these records tell you about the guilt or innocence of each person?

11.Death Certificate

Now look at the death certificate. What can you learn from this?

12.Suspect Statements

Do these give you any more clues about what happened? Who do you think is telling the truth, and who do you think is lying?

13.Compiling Evidence

Now compile all of your evidence below, and decide how Abby died, and whether there was any foul play involved. Summarize below the table what you think happened.

Evidence at Scene of Crime	**Results**
Hair	
Plant fragments	
Leaf DNA	
Fingerprints	
Tire tracks	
Shoe prints	
Blood type	
Forensic entomology	
Soil samples	
Phone records	
Death certificate	
Suspect statements	

Group Work Rubric

TA Name: _____

Lab Day and Time: _____ Room #: _____

For each of the following categories, give a grade for each group member, including yourself as the first one. Give a grade: A, B, C, D, or F. Please comment on how each person contributed to each area.

Your name:		
Category	**Grade**	**Comments**
Data analysis		
Preparation of presentation		
Oral presentation		
Overall project		

Group member name:		
Category	**Grade**	**Comments**
Data analysis		
Preparation of presentation		
Oral presentation		
Overall project		

Group member name:		
Category	**Grade**	**Comments**
Data analysis		
Preparation of presentation		
Oral presentation		
Overall project		

Group member name:		
Category	**Grade**	**Comments**
Data analysis		
Preparation of presentation		
Oral presentation		
Overall project		

Group Presentation Rubric Be sure to write comments!

Your name: _____Class day and time: _____

Speakers' Name	**Contents (__/40)**	**Slideshow (_/30)**	**Delivery (__/30)**	**Total (__/100)**
1.	a) Introduction b) Material & Methods c) Results d) Discussion Comments:	a) Organization b) Slide Appearance c) Graphs & Tables Comments:	a) Speaking b) Posture & appearance Comments:	Total: _____ Comments:
2.	a) Introduction b) Material & Methods c) Results d) Discussion Comments:	a) Organization b) Slide Appearance c) Graphs & Tables Comments:	a) Speaking b) Posture & appearance Comments:	Total: _____ Comments:
3.	a) Introduction b) Material & Methods c) Results d) Discussion Comments:	a) Organization b) Slide Appearance c) Graphs & Tables Comments:	a) Speaking b) Posture & appearance Comments:	Total: _____ Comments:
4.	a) Introduction b) Material & Methods c) Results d) Discussion Comments:	a) Organization b) Slide Appearance c) Graphs & Tables Comments:	a) Speaking b) Posture & appearance Comments:	Total: _____ Comments:
5.	a) Introduction b) Material & Methods c) Results d) Discussion Comments:	a) Organization b) Slide Appearance c) Graphs & Tables Comments:	a) Speaking b) Posture & appearance Comments:	Total: _____ Comments:

Materials

First Two Weeks (for 24 students)

On Each Student Bench (4 students per bench; 6 benches per classroom)

Lens Paper
Immersion oil
250-mL bottle of ethanol >80% (for cleaning off immersion oil)
Large box containing the following:

- Magnifying glass
- Laminated sheet: Contents of Forensics Evidence Box
- Folders, as indicated in the table below

Folder #	Folder Title	Inner Title
1	Human DNA Analysis	DNA Analysis of Suspects and Hair Samples Found at the Crime Scene
2	Plant DNA	DNA Analysis of Leaf Fragments
3	Plant Fragments	Photographs of Plant Fragments Associated with the Victim and Each of the Identified Suspects
4	Plant ID Guide	Floral Guide of SW Virginia
5	Fingerprints from Suspects	Fingerprints of Deceased and Suspects
6	Fingerprints from Evidence	Fingerprints from Crime Scene
7	Tire Treads from Suspects	Tire Treads of Suspects' Vehicles
8	Tire Tracks from Evidence	Tire Tracks from Crime Scene
9	Shoe Prints from Suspects	Photographs of Suspects' Footwear
10	Shoe Prints from Evidence	Shoe Print Data from Crime Scene
11	Suspects' Blood Types	Suspects' Blood Types
12	Insect Forensics Data	Insect Forensics Data Sheet
13	Soil Samples	Soil Samples Taken From Crime Scene and Suspects' Vehicles
14	Phone Records	Phone Log for Victim and Suspects Near Time of Estimated Death of Victim
15	Death Certificate	Certificate of Death
16	Suspects' Statements	Excerpts from the Suspects' Statements
17	Weather Data	Weather Data for Crime Scene
18	Hair of Suspects	Hair Samples from Deceased and Suspects
19	Hair from Evidence	Hair Samples from Crime Scene

Side Bench

2 compound microscopes

2 boxes of hair slides, each containing

- Hair Sample Abby
- Hair Sample Sally
- Hair Sample Joe
- Hair Sample Ezra
- Hair Sample Harold
- Hair Sample Robert
- Crime Scene Unknown #1
- Crime Scene Unknown #2
- Crime Scene Unknown #3
- Crime Scene Unknown #4
- Crime Scene Unknown #5
- Crime Scene Unknown #6
- Crime Scene Unknown #7

Soil samples in beverage cups (will need to refill; labeled as indicated)

- Use most of topsoil being used as it is; don't add anything, and fill the cups, labeled as follows:
  - Crime Scene
  - Joe's truck tires
  - Abby's truck tires
  - Ezra's truck tires
  - Ezra's truck, under the fenders

- Add enough hydrated lime (Ca(OH)2) to one-sixth of topsoil being used to change pH by ~1 pH unit, and fill the cup, labeled as follows:
  - Sally's truck tires

~50 1.5-mL microcentrifuge tubes (these don't need to be sterile)
6 spatulas
6 small funnels
6 small weigh boats
3 balances with brushes for cleaning
250 ml distilled water
1000-uL micropipette and tips (these don't need to be sterile)
Mini-centrifuge with tubes for counter weights (if you do not have access to a centrifuge, please consider an alternative method, such as described here: https://www.youtube.com/watch?v=iysygdLJKpI)
~50 pH testing strips or paper covering the range from pH 4 to 8

Third Week

Timer on Instructor desk

Notes for the Instructor

Have students bring laptop and worksheet each week!! Also, they can bring cameras if they want to take pictures of evidence for the presentation.

Students sort through ALL evidence and make notes about it, as indicated on the worksheet. They should work together in groups of four, but all must be familiar with all the evidence and the group's conclusions. They must all contribute equally and communicate with each other. There is not one correct answer. You'll be provided with an answer sheet with the facts (which fingerprint matches which person, etc.), but coming up with cause of death will be different for each group. That's ok; we want students to really think through everything and come up with their own conclusions. Also, don't completely grade worksheets on correctness; much of the data are difficult to interpret, and everyone is bound to misinterpret some of it.

Below are parts of the lab, named according to the worksheet titles, grouped in a way for you to have an idea of relative timing of each activity.

- Most time-consuming
  - Hair/Human DNA Analysis
  - Fingerprinting
  - Death Certificate
  - Plant Fragments
- Intermediate
  - Forensic Entomology
  - Soil Samples
  - Phone records
  - Suspects' Statements
- Least time-consuming
  - Leaf Fragment DNA
  - Tire Tracks
  - Shoe Prints
  - Blood Typing

Option for Completion of Lab in Two Instead of Three Weeks

You will need to combine weeks 1 and 2. It is ok if students don't get through all the evidence. Have them all start at different points and make sure each piece of evidence is covered by at least one group. They will present on whatever they have gotten through.

Weekly Schedule

Week 1

Go over presentation and group work expectations. Be sure to plan enough time for group evaluations and post-test as you plan week 3 and communicate expectations. Work through as much evidence as possible.

Week 2

Work through remaining evidence. Compile all the evidence, generate conclusions, and begin work on presentation. Any remaining work will be homework.

Week 3

- Presentations (10 minutes per group, plus 3 minutes each for questions); total is about 1 hour 20 minutes.
- Group work evaluations; ~10 minutes
- Post-test; ~20 minutes

Clean Up for Weeks 1 and 2

- Make sure hair slides are in appropriate boxes and not left on microscopes.
- Make sure all microscopes are off.
- Make sure soil tubes have been placed in the appropriate waste container and soil cleaned from benchtops, balances, and sinks.
- Turn off all balances.
- Make sure each table has 1 Contents sheet, 19 folders, and 1 magnifying glass.

Week 1 Notes

Rubric

Give out the rubric you will use to grade presentations. I will provide one for you to use (slightly geared more toward student use). You may modify this as necessary. This should be the same or very similar to what they will use to grade each other (see next paragraph and Week 3 below).

Students Grading Each Other

Let students know that they will be grading each other and that they need to ask each other questions. Provide the rubric ahead of time (this week) that they will use. See Week 3 below for more information.

Group Evaluations

Since this is a group project, please have each student complete a peer evaluation form after presentations. This week (the first week), go ahead and hand out the rubric they will use so they can be thinking about what is expected of them throughout the three weeks. (These will be provided to you and are available online for your students.) This will allow students to grade their group members as well as themselves, so if someone did not do their share of the work, you will know and can adjust their grade accordingly. If everyone agrees that they all did the same amount of work, give them all the same grade.

Week 2 Notes

Before Presentation Week

Although this is not a requirement, to make grading the presentations easier on you, you can have the presentation ppt due BEFORE the actual presentations. This will give you enough time to look over them before hearing them, so that you can pay more attention to content ahead of time, and focus a little more on presentation style during the actual presentation. This may also help you to come up with good questions.

Week 3 Notes

During Presentations

- Write comments on grading rubric.
- Observe who answers questions during presentations; who appears to be the leader? Does it match with the group evaluations? (See below.)
- You, as their instructor, should ask at least one question of each group. This should be fairly easy for you since you should have been communicating with each group from the beginning.
- Have students ask each other questions and critique each other. (See below.)
- Guests may be present and may ask questions.

Presentation Evaluations

Have each student "grade" all the other group presentations. If you have six groups, each student will "grade" five groups. This will ensure that students pay attention to each other. Make sure they write comments. Include this as part of their (the students in the audience – not the ones presenting) grade – maybe as a worksheet grade, or part of the presentation grade. You may or may not decide to use the student evaluations of presentations as part of the grade for the presenters. Your rubric should be the same or similar to the one you use to grade the presentations.

Grading

- Have a rubric on how you will grade presentations.
- Grade on how well they supported their conclusions using the evidence, rather than on the conclusion itself. Did they consider ALL of the evidence, and is their conclusion consistent with ALL of the evidence?
- Grade each group not only on their presentation but also on how well they graded each other. Have students ask questions of the presenters; you might include this as a participation grade or part of their own presentation grade.
- Suggestions and things to consider about students asking questions:
- The point is to get students participating and engaged, and to see how well the presenters know their material they're presenting
- Must be good, thought-out, quality questions (not a question just for the sake of asking a question); grade accordingly
- Have each student ask a question at some point during presentation and use a checklist of students

Group Evaluations

Please have each student complete a peer evaluation form. It's best to have them turn these in after they are done with the presentations. That way they can evaluate each other on helping with the presentation as well. Please see Week 1, above, for more information.

Sample Results

There is purposefully no correct answer to this assignment. Students are expected to review the data and come to a group consensus that can be presented and defended to their classmates. Possible causes of death include, but are not limited to, a jealous or angry lover, angry father of the baby, jealous sister, physical abuse, drug overdose, orthostatic intolerance, exposure to the elements, suicide, or cannot be

determined.

Answer Key: Forensics Evidence Log

Please bring your laptop and worksheet to lab each week of Forensics lab! Note that this worksheet is to be used at your own discretion to collect and organize data. Every blank does not necessarily need to be filled out.

1. Hair/Human DNA Analysis

Refer to parts B and F of the lab manual to complete this exercise. Also remember to use the appendix on microscope use when examining the hair slides. Examine the hair slides from the scene of the crime and for each suspect. Make sketches and notes about the difference in medulla, cortex, and cuticle of each hair sample.

Suspect/victim	**Hair description or sketch**
Abby	
Sally	
Joe	
Ezra	
Harold	
Robert	

Piece of evidence	**Hair description or sketch**	**Hair matches which person?**	**DNA matches which person?**
Hair Sample 1 Abby's clothing		*Joe*	*None*
Hair Sample 2 Abby's sink		*Robert*	*Robert*
Hair Sample 3 Abby's clothing		*Ezra*	*Ezra*
Hair Sample 4 Sally's clothing		*Abby*	*Abby*
Hair Sample 5 Abby's clothing		*Sally*	*Sally*
Hair Sample 6 Abby's sink	*This one may be more difficult than others*	*Harold*	*None*
Hair Sample 7 Joe's clothing		*Dog*	*No match*

Piece of evidence	**DNA matches which person?**
DNA under Abby's nails	*Sally*
DNA on Abby's body	*Joe*
DNA in Abby's body	*Abby and Joe*
DNA under Sally's nails	*Abby and Ezra (it appears that Sally's DNA is here too, but it happens to overlap with the others; or maybe she scratched herself)*

2.Leaf Fragment DNA

Which DNA from leaf fragments, if any, from Abby, Joe, and Ezra, match the DNA of the plant from the crime scene?

3.Plant Fragments

Identify the plant fragments associated with each suspect or victim, using the floral guide provided.

Plant fragments associated with….	**Species of plant fragments**
Abby	*American chestnut*
	Black ash
	Black oak
	Black oak
	Northern red oak
	Tulip poplar
Sally	*American chestnut*
	Black walnut
Joe	*American chestnut*
	American holly
	Black ash
	Black oak
	Juneberry
	Northern red oak
Ezra	*American holly*
	Black ash
	Mountain laurel
	Sugar maple
	Tulip poplar
Harold	*American chestnut*
	Black ash
	Northern red oak
	Tulip poplar
Robert	*Juneberry*
	Unknown

4.Fingerprinting

Refer to part C of the lab manual to complete this exercise. Examine the crime scene fingerprints and prints collected from each suspect and the victim. Make notes about each.

Suspect/victim	Fingerprint description or sketch
Abby	
Sally	
Joe	
Ezra	
Harold	
Robert	

Piece of evidence	Fingerprint matches which person?
Print A1: ammunition & casings	*Joe*
Print A2: ammunition & casings	*Abby*
Print A3: ammunition & casings	*Ezra*
Print A4: ammunition & casings	*Ezra*
Print A5: ammunition & casings	*Sally*
Print A6: ammunition & casings	*Abby*
Print A7: ammunition & casings	*Joe*
Print A8: ammunition & casings	*Sally*
Print B1: rifle	*Joe*
Print B2: rifle	*Abby*
Print B3: rifle	*Ezra*
Print B4: rifle	*Sally*
Print C1: apartment	*Abby*
Print C2: apartment	*Joe*
Print C3: apartment	*Abby*
Print C4: apartment	*Ezra*
Print C5: apartment	*Joe*
Print C6: apartment	*Harold*
Print C7: apartment	*Robert*
Print C8: apartment	*Harold*

5.Tire Tracks

Piece of evidence	Tire track matches which person?
Tire track 1	
Tire track 2	
Tire track 3	
Tire track 4	
Tire track 5	
Tire track 6	

6.Shoe Prints

Refer to part D of the lab manual to complete this exercise. Examine the footprint patterns found at the scene of the crime with the footprints of the suspects. Which suspect's footprints are present? *Abby Shoe 1 and 2, Sally Shoe 5, Joe Shoe 6 (x2), Ezra Shoe 9, plus some unknown ones*

7.Blood Typing

Refer to Part E of the lab manual for more information on blood typing. Whose blood matches that found on the deer antler? *Possibly Joe, Ezra, or Harold*

8.Forensic Entomology

Refer to part G of the lab manual to complete this exercise. Using the 3 tables (developmental data of two species, plus meteorological data) in the lab manual, determine how long ago (including dates and times), from the time the deer and victim were found (October 20, 2:00 pm), that it died. How did you come to this conclusion? *Died at least 26 hrs ago, but less than 72 hrs ago. The average temperature for the past few days has been variable, so without more information, it's difficult to really pinpoint which temperature chart to use for each species in the lab manual, since the average temperature tends to be somewhere in the middle. Of the stages found on the corpses, and considering both temperature charts, the shortest development time is 26 hours (S. bullata 3rd instar), and the longest is 48 hours (S. bullata 3rd instar). The next stage of any of the insects found (C. macellaria, 3rd instar) wouldn't show up until 56 hours at the earliest, 72 hours at the latest.*

26 hours ago = Oct. 19, noon

48 hours ago = Oct. 18, 2 pm

56 hours ago = Oct. 18, 6 am

72 hours ago = Oct. 17, 2 pm

Based on all this, without more detailed information, Abby most likely died on Oct. 18. Remember there has to be enough time for C. macellaria 2nd instar and S. bullata 3rd instar to develop, but also remember that Abby was found ANY time after these stages developed, but BEFORE the next stages developed, which is a fairly big time gap.

9.Soil Samples

Refer to part H of the lab manual to complete this exercise. Record in the table below your observations about the appearance of each soil sample, as well as the approximate pH of each soil sample.

Soil Sample	**Appearance**	**pH**
Crime Scene	*All five samples should look the same and have the same pH.*	
Joe's truck tires		
Ezra's truck tires		
Ezra's truck, under the fenders		
Abby's truck tires		

10.Phone Records

Look carefully through the phone records. What do these records tell you about the guilt or innocence of each person? *Answers will vary.*

11.Death Certificate

Now look at the death certificate. What can you learn from this? *Time of death is accurate. She has a puncture wound, but it's not from the deer, since the blood on the deer antler doesn't match her blood type. She has taken some illegal drugs, but they're under the detectable level. She did not overdose on Zoloft, since she was prescribed 200 mg/day. As for all the other information on the death certificate, students will need to search for this online and come up with their own conclusions.*

12.Suspect Statements

Do these give you any more clues about what happened? Who do you think is telling the truth, and who do you think is lying? *Answers will vary.*

13.Compiling Evidence

Now compile all of your evidence below, and decide how Abby died, and whether there was any foul play involved. Summarize below the table what you think happened.

Evidence at Scene of Crime	Results
Hair	
Plant fragments	
Leaf DNA	
Fingerprints	
Tire tracks	
Shoe prints	
Blood type	
Forensic entomology	
Soil samples	
Phone records	
Death certificate	
Suspect statements	

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Literature Cited

Deedrick, D.W. and S.L. Koch. 2004. Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs. *Forensic Science Communications*. 6(1). <http://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/jan2004/research/2004_01_research01b.htm> Accessed 24OCT2012.

Hamlin, T. and J. Gregory. 1998. *North Carolina State Crime Laboratory Procedures and Protocols*. *Trace Evidence. Procedures for Hair Analysis.* <http://www.ncids.com/forensic/SBI/Trace/Technical/3_HAIR_proc_cover.pdf>; <http://www.ncids.com/forensic/sbi/Trace/Technical/4_HAIR_Proc.pdf> Accessed 24OCT2012.

Sapp, B. n.d. *Complete Curriculum for High School Forensic Science.* Worksheets. Unit 4-Fingerprints. Modus Operandi. <http://www.bsapp.com/forensics_illustrated/forensic_worksheets/Unit%204%20Fingerprints/MODUS_OPERANDI.pdf> Accessed 17APRIL2014.

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