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Effect of embalming on the decomposition of pigs

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EFFECT OF EMBALMING ON THE DECOMPOSITION OF PIGS

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Abstract

Numerous studies have been conducted on the taphonomy of human remains since the inception of forensic anthropology. Through these studies, the rates of decomposition, animal activity, and insect activity have been investigated in a diverse range of situations. One area where few studies have been carried out concerns embalmed bodies left to decompose in the open. This study considers the effect of embalming fluid on the decomposition rate of bodies. Using the pig as an experimental model, three juvenile specimens were injected with increasing levels of formaldehyde –1%, 5%, and 10%– and a fourth pig, the control, was not embalmed. Subjects were placed in wire cages in an open field, and their progress in decomposition was monitored for 50 days. The results showed differences between the embalmed and non-embalmed pigs in insect activity and sequence of decomposition. The 1% formaldehyde embalmed pig began decomposing after 10 days and had maggot activity for the majority of the experiment. The 5% and 10% formaldehyde embalmed pigs quickly mummified and had little fly activity. The embalmed pigs followed a pattern of decomposition that was related to the strength of the formaldehyde. These results can be used to estimate the time an embalmed body was exposed to the elements.

Chapter 1: Introduction

The taphonomy of human remains has been an integral part of forensic anthropology since its beginning. Over the years, numerous studies have covered the rates of decomposition, animal activity, and insect activity of human remains in a diverse range of situations. Because of the variation in the manner that people attempt to conceal bodies, taphonomic studies are conducted in many different situations. This diversity of studies has resulted in a considerable amount of information on the taphonomy of human remains, but little information can be found about embalmed bodies. Although a study exists of disinterred embalmed individuals from a cemetery, the study did not follow the decay of the embalmed bodies from beginning to end in a methodical manner (Haglund and Sorg 1997).

Literature documents instances of personnel at funeral homes or crematoriums failing to properly dispose of, inter, or cremate the remains of embalmed individuals (Bass and Jefferson 2003). The lack of documented information on the decay of embalmed bodies complicates identification of embalmed bodies and makes apparent the need for additional research on the taphonomy of embalmed bodies. The experiment in the present study, conducted in an open hayfield, was designed to replicate the context in which embalmed human remains would be found in places other than their final resting place. This study will answer some of these questions: how long the bodies have been exposed; the appearance of un-interred embalmed bodies; what insect activity has occurred; and what, if any, animal activity transpired.

The hypothesis of this study is that an embalmed body will decompose much slower than a body that is not embalmed. Insect or animal activity around an embalmed body should be minimal, as opposed to a non-embalmed body, which would feature substantial insect and animal activity. In addition, the expected etiology of decomposition for an embalmed body should be weathering due to the exposure of the carcass to the elements.

Chapter 2: Literature Review

History of Embalming in the United States

Embalming of the dead is a relatively recent practice in the United States. As early as the 15th century, Europeans began embalming major political figures and developed more sophisticated techniques of embalming over time. With the advancement of embalming techniques, a considerable amount of literature was written on the subject of embalming, and around 1840 a key text, *The History of Embalming, and of Preparations in Anatomy, Pathology, and Natural History; Including an Account of a New Process for Embalming* (Jean Nicolas Gannal 1840, as cited by Mayer 2005), was translated and printed in the United States. The translation of Jean Gannal's book is the beginning of the transfer of knowledge of embalming in the United States and the beginning of embalming as a profession (Mayer 2005). By the middle of the 1840s, entrepreneurs in New York had franchises for manufacturing embalming chemicals and acquired the latest embalming techniques from Europe (Mayer 2005).

By 1861, in the United States embalmers were up to date on the knowledge of embalming that was coming out of Europe and had begun their own contributions to the knowledge. However, in the United States embalming was still rare. Usually, bodies were embalmed for anatomical cadavers or long distance transport.

The onset of the Civil War in 1861 was the beginning of the boom of embalming popularity in the United States. Before the Civil War, the policy of the United States Army was to bury soldiers on the field of the battle where they had died. The Army returned soldiers' remains only after the families petitioned the Army and sent a coffin

capable of a hermetic seal. The Army would then exhume the remains, place them in the coffin, seal it, and ship it back to the family. However, many difficulties were encountered in identifying the remains due to the lack of documentation of where the burials occurred (Mayer 2005).

During the Civil War the policies of the United States Army towards the dead changed. The Army ordered that all of the hospitals would provide accurate death records, and materials for headstones would be provided for the graves of soldiers. The Army required commanders to set land aside for graves near battlefields to bury fallen soldiers. During this time, embalming began playing a bigger role when the public demanded that prominent figures be shipped back home when they died. Soon, due to public pressure, the majority of the dead soldiers from the Union Army were embalmed for shipping. Since embalming was not readily available to the Confederate Army, Confederate soldiers were not embalmed (Mayer 2005).

After the Civil War, many of the civilian embalmers who worked for the U.S. Army started their own practices in various locations around the United States. The general acceptance of embalming increased when President Lincoln was embalmed for the cross-country viewing of his body (Quigley 1998). As the population in the west grew, the need for embalming bodies for shipment to the deceased's hometown also grew (Quigley 1998). The popularity of shipping the dead back to their home led to the establishment of several embalming schools for undertakers around the 1890s (Mayer 2005).

As embalming became a more accepted funeral practice, new technologies were developed to make the process more efficient. The embalming process moved from the

family bedroom to a specialized preparation room, and formalin began to be used as the key component of the embalming fluid as a substitute for more toxic and expensive chemicals such as arsenic and bichloride of mercury (Quigley 1998). The process became more complex as new chemical formulas were developed for targeting different aspects of the embalming process, such as a formula specifically for arterial injection and another for cavity injection. With the addition of motorized pumps for the arterial injection of embalming fluid, the whole process became less expensive and less time consuming, thereby making it more accessible to the general public for their deceased. Eventually, the practice became so commonplace that funeral homes no longer inquired if families wanted to embalm their loved ones; they performed embalming automatically (Mayer 2005).

Embalming in the Present Day

Embalming in the United States has become complicated, with the development of new technology and chemicals. Autopsies and accidents no longer prevent families from displaying deceased relatives in open caskets, or prevent the families from expecting their loved ones to remain untouched by decay. In truth, perfect preservation is not possible, but funeral homes strive to satisfy the bereaveds' desires as much as possible.

Embalming fluids have become complex chemical solutions (Quigley 1998) with numerous chemical agents. They commonly contain in varying amounts:

- preservatives, such as alcohol, phenol, and formaldehyde,
- anticoagulants (that reduce the thickness of the blood),
- surfactants (that increase the saturation of the preservatives),
- germicides,

- modifying agents (that control the preservatives),
- dyes,
- deodorants, and
- various solvents and stabilizers (Quigley 1998).

Typically, these chemical agents are injected intra-arterially using either the carotid artery or the femoral artery or vein. Other techniques require formulas for cavity injections, surface embalming of the skin, and hypodermic embalming for infants and small children (Mayer 2005).

Sealed caskets are commonly used in burials, which limit the access of scavengers and insects. A hermetic seal from the lid of a casket can prevent bacterial access, as seen on iron and lead caskets. A hermetically sealed casket with an embalmed body creates an antibacterial combination that prevents bacterial growth. Germicidal/fungicidal powder or a container of calcium chloride (to prevent moisture from forming) placed in the casket prior to sealing retards fungal growth even though moisture can occur in a sealed casket due to condensation. In spite of these efforts, even the best embalmer cannot prevent decay. The best that an embalmer can hope to do is retard the rate of decomposition (Quigley 1998).

Embalmed individuals decay despite all the preservation techniques that modern embalmers employ (Quigley1998). Shrinkage of the skin occurs giving it a cracked and peeled appearance akin to old paint. Fleshy areas where the tissue is dense on the body, such as the buttocks, are more likely to decompose first, due to a poor penetration of the embalming fluid into the dense flesh, while less fleshy areas, such as the arms, may show

a better level of preservation due to a better absorption of the embalming fluid (Quigley 1998).

Taphonomy

Individuals that are not embalmed follow a relatively set process of decomposition. The first stage of decomposition is just after the body has died, and has not yet begun to bloat (Reed 1958). The second stage, bloating, is caused by putrefaction and autolysis due to the breakdown of tissues into gas and liquid (Vass 2001). The third stage is decay where the skin breaks down from protein decomposition, allowing insect activity to occur, and scavenger animal activity takes place (Reed 1958). The final stage is drying where the remaining scraps of decaying flesh and bones begin to lose their moisture. Surprisingly, weight and size are not significant factors in the rate of decomposition; rather location, temperature, insect access and scavenger access are significant factors in the decomposition rate (Mann et al. 1990).

Numerous studies of decomposition exist. One such study is Dix and Graham's (2000) *Time of Death, Decomposition and Identification: an Atlas*, which is a useful text that provides photographic examples of the stages of decomposition to illustrate the common descriptions of decomposition that are presented in most texts. Another is Haglund and Sorg's (1997*) Forensic Taphonomy: the Postmortem Fate of Human Remains*, which covers, at length, decomposition and the different settings in which a body may be found; additionally, the authors discuss forensic techniques for collecting evidence. Haglund and Sorg (2000) also wrote *Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives*, which is a similar book about

taphonomy but covers more recent developments in the study of taphonomy, and covers the uses of archaeology and how mass graves can affect the decomposition of individuals.

Mann et al. (1990) were helpful for the present experiment as they discuss the differences in the rates of decomposition that can occur in various situations and offer examples of how these might happen. Mann et al. (1990) were instrumental in decisions about the placement of the bodies and size of bodies to be used in this experiment. The location that the present experiment would occur was decided due to Mann et al.'s (1990) discussion that the surface where a body is placed influences the rate of decomposition; for example, bodies placed on concrete usually decompose at a slower rate compared to bodies placed on the ground. For this reason, it was decided to use the same surface type for all pigs; the bodies were placed on the ground. Mann et al. (1990) discuss how weight can be a factor in decomposition. In a comparison of an obese individual with one who was not overweight, the former quickly decomposed due to the liquefaction of body fats, whereas the latter took twice as long to decompose. Payne (1965) performed one of the first taphonomic studies that used infant pigs placed in cages. With Payne's (1965) use of wire cages, he was able to exclude animals, but not insects, from the pigs. Payne (1965) was helpful to this researcher in deciding the size of wire fencing to be used for the present experiment.

Two other articles that were influential in the decisions made about this study were Campobasso et al. (2001) and Bustard and McClellan (1966). For this study, facilities that conduct taphonomic studies on human cadavers would not allow the use of embalming fluid on any of the cadavers due to environmental concerns. Using a human cadaver for a taphonomic study outside of a taphonomic research facility was not

possible, due to the legal and biohazard concerns that such a study would create. Therefore, a nonhuman specimen had to be used for this study. Campobasso et al. (2001) were helpful in choosing what type of nonhuman specimen to use. From their discussion on the similarities between human and pig decomposition and whether pigs are an appropriate substitute for humans in a taphonomy study, pigs were chosen as the experimental animal in this study (Campobasso et al. 2001). Bustard and McClellan (1966) also supported the conclusion that pigs would be a good substitute for human cadavers with their study on the use of pigs in biomedical research. According to Bustard and McClellan (1966), pigs are an excellent substitute because of the number of anatomical similarities they share with humans, such as the cardiovascular system and skin.

Though numerous studies on decomposition have been performed in various environments, few consider decomposition for embalmed bodies. McQuinn (2011) studied the decomposition of embalmed pigs that were buried at depths of 2 to 4 feet in eastern Kentucky. McQuinn demonstrated that formaldehyde does not affect the leaching of volatile fatty acids into the soil, and that embalmed remains that are buried will mummify. Researchers who discuss cemetery remains and how to recognize them include Rogers (2004), who looked at remains from historic cemeteries and discussed how to identify skeletons from historic cemeteries, and Berryman et al. (1990), who identified cemetery remains by the appliances that embalmers use, such as eye caps, and the alcoholic concentration found in embalmed flesh as well as the condition of the bodies. Little documentation about the decomposition rates of embalmed bodies exists, but the

present experiment will assist in rectifying this gap in taphonomic data using embalmed pigs.

Chapter 3: Materials and Methods

For this experiment, three pigs were embalmed with 1%, 5% and 10% formaldehyde solutions and a fourth pig was not embalmed. Through a study of the partially published formulas of commercial embalming solutions, it was determined that 5% and 10% are the most commonly used concentrations in commercial embalming fluids, while the LSU School of Veterinary Medicine uses a 1% solution to preserve anatomical specimens for dissection.

Substantial variation exists in the composition of commercial embalming fluid, with each company developing its own proprietary formula. Formaldehyde is the most common embalming chemical and the primary preservative in commercial embalming fluids (Quigley 1988). Most manufacturers of embalming fluids do not share the composition of their formulas, but a few, through their descriptions of their products, do disclose the percentage of formaldehyde in their solutions and reveal other chemical concentrations in the embalming fluids.

Formaldehyde, the main preservative, was varied in this study. In order to keep the embalming solution in this project similar to that of commercial embalming fluids, phenol and glycerin, two additional chemicals commonly found in embalming fluid, were included (Mayer 2005). The phenol and glycerin amounts remained constant in the formula for the 5% and 10% solutions; only the concentration of formaldehyde varied. The 1% solution contained neither phenol nor glycerin since the LSU School of Veterinary Medicine's formula was used for this pig, and their solution only used formaldehyde.

The embalming fluid was mixed in four liter batches with 40 ml, 200 ml and 400 ml of formaldehyde respectively for the 1%, 5% and 10% solutions. To the 5% and 10% batches, 80 ml of phenol and 80 ml of glycerin were added, and the remaining volume filled with distilled water. For the 1% solution, only distilled water was used to complete the batch.

Currently, the most common method of embalming in the United States is to use a specially motorized pump to pump the cadaver's blood out of the circulatory system, while simultaneously replacing the blood with the embalming fluid (Quigley 1998). This was the preferred approach for this experiment. The LSU School of Veterinary Medicine provided the use of its facilities and embalming equipment, and Dr. Hillmann assisted with the embalming.

Juvenile pigs were donated to this experiment by the LSU Central Research Station's Swine Unit. All four of the pigs, which were under a year old, either died of natural causes or for the Swine Unit's own research. The pigs weighed between 8lbs to 15lbs. This was the narrowest size range that the Swine Unit had available at the time of the experiment. Each pig was designated a letter to indicate the embalming solution used:

- Pig C ("C" is for control) or the pig that was not embalmed,
- Pig V ("V" is for the LSU Veterinary School of Medicine) for the pig embalmed with the 1% solution,
- Pig F ("F" is for 5%) for the pig embalmed with the 5% solution, and
- Pig T ("T" is for 10%) for the pig embalmed with the 10% solution.

Upon receipt of Pig C, it was kept in a freezer for six days. On the 6th day, the pig was removed and then placed in a cooler to defrost slowly. On the 7th day, the non-

embalmed pig was placed in a clean plastic bag for transportation to the site of the experiment.

Pig V was embalmed using an intra-arterial technique. The jugular veins were damaged when the LSU Central Research Station's Swine Unit removed the thyroid for study. The femoral artery was accessed to pump the embalming fluid through the arterial system. The small size of the pig's veins and arteries led to a concern that a thorough saturation of the pig's system would not be achieved. For complete saturation, a scalpel was used to make an incision on the ventral side of the pig, beginning below the sternum, through the abdomen to end above the pelvis. The pig was then immersed in the tank holding the embalming solution for a period of seven days so that the fluid could fully penetrate the body.

Pig F was administered the formaldehyde solution intra-arterially. Pig F had a green tint to its stomach, and Dr. Hillmann indicated that this was due to fluid that came from a ruptured gall bladder. Additionally, the pig was less fresh when the Central Research Station's Swine Unit froze the body as evidenced by the small amount of bloating seen in the abdomen. The jugular vein was accessed with a 60 cc syringe, and the embalming solution was pumped into the circulatory system. To ensure complete saturation, Pig F was immersed in the embalming solution. As with Pig V, a scalpel was used to make an incision on the ventral side of the pig beginning below the sternum, through the abdomen to end above the pelvis. The pig was then placed in a plastic bag filled with the embalming solution and left to saturate for a period of seven days.

Pig T was small in size, and finding a vein or artery large enough for the needle of the intravenous pump was not possible. Instead, a cut was made across the stomach of the

pig similar to that of the Pig V and F, and the pig was placed in a bag filled with the solution for seven days so that it could achieve the same level of saturation as the other two pigs.

After the 7th day, the three embalmed pigs were removed from their solutions and placed in clean, empty plastic bags for transport. All four pigs were carried in a ten gallon ice chest covered in ice to maintain a cold temperature for the pigs and retard any possible decomposition.

At the beginning of the study, animal activity was an unknown variable, but the possibility that animals would scavenge the embalmed pigs' carcasses remained. Embalmed flesh would be toxic to animals. To prevent consumption of toxic flesh by animals, the pigs were encased in wire cages (1 x 0.5 meter). The cages were built from wire fencing with gaps of a quarter of an inch to ensure that small rodents could not access the pigs, but the carcasses could be accessed by insects. The cages were staked to the ground to prevent the pigs from being removed from their designated locations. The cages were spaced at 50 meter intervals in the back of an unused hay field just behind an electric fence at the LSU Central Research Station located off Parsimony Lane in East Baton Rouge Parish.

This hayfield location was chosen to reduce the chances of accidental human interference. Locating the pig carcasses outside the electric fence also prevented interference from domestic livestock if the hayfield were to be used for grazing by the LSU Central Research Station.

The study was conducted over a 50-day period in the summer, beginning on July 15, 2010, and ending on September 2, 2010. Throughout the course of the study, insect

activity, animal activity, and decomposition were observed, tracked and recorded. Photographs were taken throughout the study to document changes and decomposition progress, and a written log of observations was maintained to support the photographic documentation (Appendix 1). Daily temperature and rainfall data were obtained from the LSU Central Research Station's Louisiana Agriclimatic Information System (LAIS) in order to evaluate weather as a factor affecting the insect activity.

Chapter 4: Results

Pig C – Not Embalmed, Control Subject

The control pig, Pig C, was not embalmed and was laid out at five p.m. on July 15, 2010, the first day of the study (Fig. 1A). July 16 at eight a.m. Pig C's orifices were full of fly eggs (Fig. 1B). The afternoon of July 16, a maggot mass was covering the head of Pig C (Fig. 1C). The morning of the 3rd day, July 17, the maggot mass covered the entire body of the pig (Fig. 1D). By the evening of the July 17th, the majority of Pig C was skeletonized with the only flesh remaining on the hooves (Fig. 1E). On July 18, the 4th morning of the experiment, only the bones remained of the control pig (Fig. 1F). By the 4th afternoon, July18, all signs of the maggot mass were gone with the maggots having migrated for their pupation.

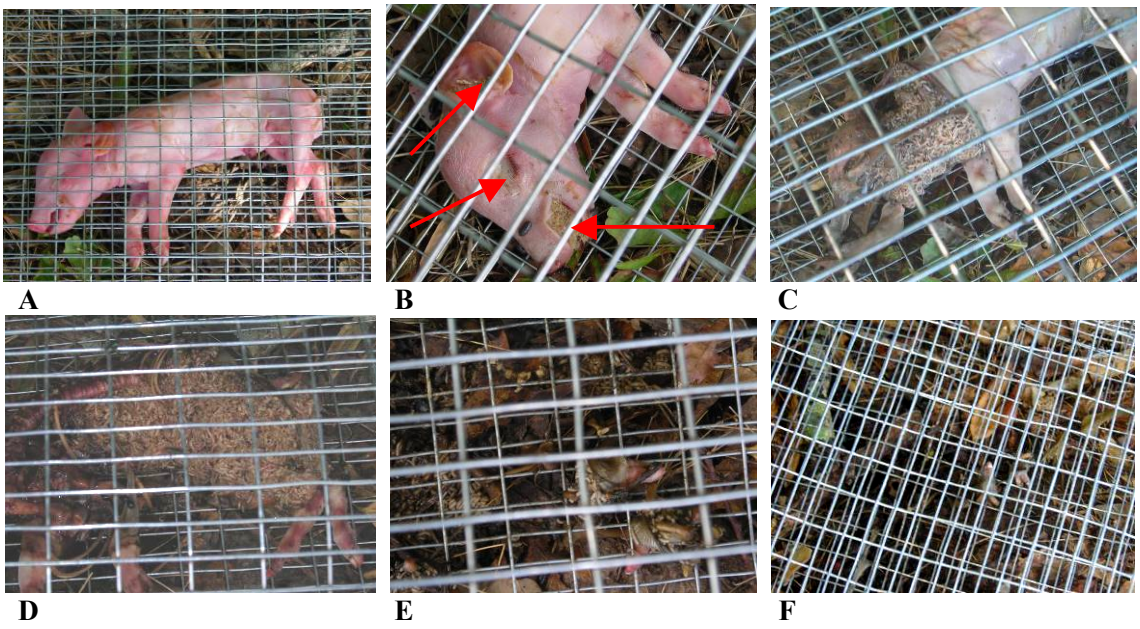

Figure 1: Pig C, Sequence of Decomposition (A-F). (A) Day 1, 5:30 P.M., (B) Day 2, 8:00 A.M.- fly eggs in eye, ear and mouth, (C) Day 2, 5:00 P.M.- maggots consuming head, (D) Day 3, 8:00 A.M.- maggots consuming body, (E) Day 3, 5:30 P.M.- only hooves have flesh, (F) Day 4, 8:00 A.M.- only bones remain in cage.

Pig V – 1% Formaldehyde Subject

Pig V was embalmed with the 1% formaldehyde solution. Decomposition of Pig V is shown graphically in Figure 2. As can be seen from Figure 2, decomposition did not follow Pig C's rate of decay. Decomposition took longer to develop and had not reached the complete skeletonization stage by the end of the experiment on the 50th day. Pig V was laid out at 5:30 p.m. on July 15, 2010 (Fig. 3A). Very little decomposition was observed during the first few days of the experiment, but by the 7th day, the eyes had mummified, the skin had begun to flake in some areas, and a large dent had appeared on the abdomen (Fig. 3B). By the 10th day, clusters of fly eggs around the head had appeared (Fig. 3C). However, maggot activity stopped after the 13th day. Flies continued to lay eggs after the 13th day, but no new maggot activity was observed until the 18th day when new maggots were observed around the head wound (Fig. 3D). Maggot activity continued until the 45th day of the experiment. After the 21st day, portions of the pig's skin developed a bubbled texture from a yellow residue-like substance.

The majority of the maggot activity was observed to take place underneath the skin. The flesh beneath the skin was consumed but not the skin itself. Skin began to slough off the head as it decayed, and as a result, parts of the skull were exposed through the holes in the skin (Fig. 3E). On the 45th day, a grey fluid appeared as the pig began to liquefy. From the area of Pig V's anus, maggots began migrating away from the pig. After this migration, no new eggs were observed on Pig V. The skin around the neck and head darkened due to putrefaction and maggot activity (Fig. 3F). By the 42nd day, mold and a white residue were observed on the hindquarters, and no maggot activity took place (Fig. 3G). By the end of the 50th day, no maggot activity was observed, the skin had a leather-like texture, and a yellow residue-like substance was on the abdomen (Fig. 3H).

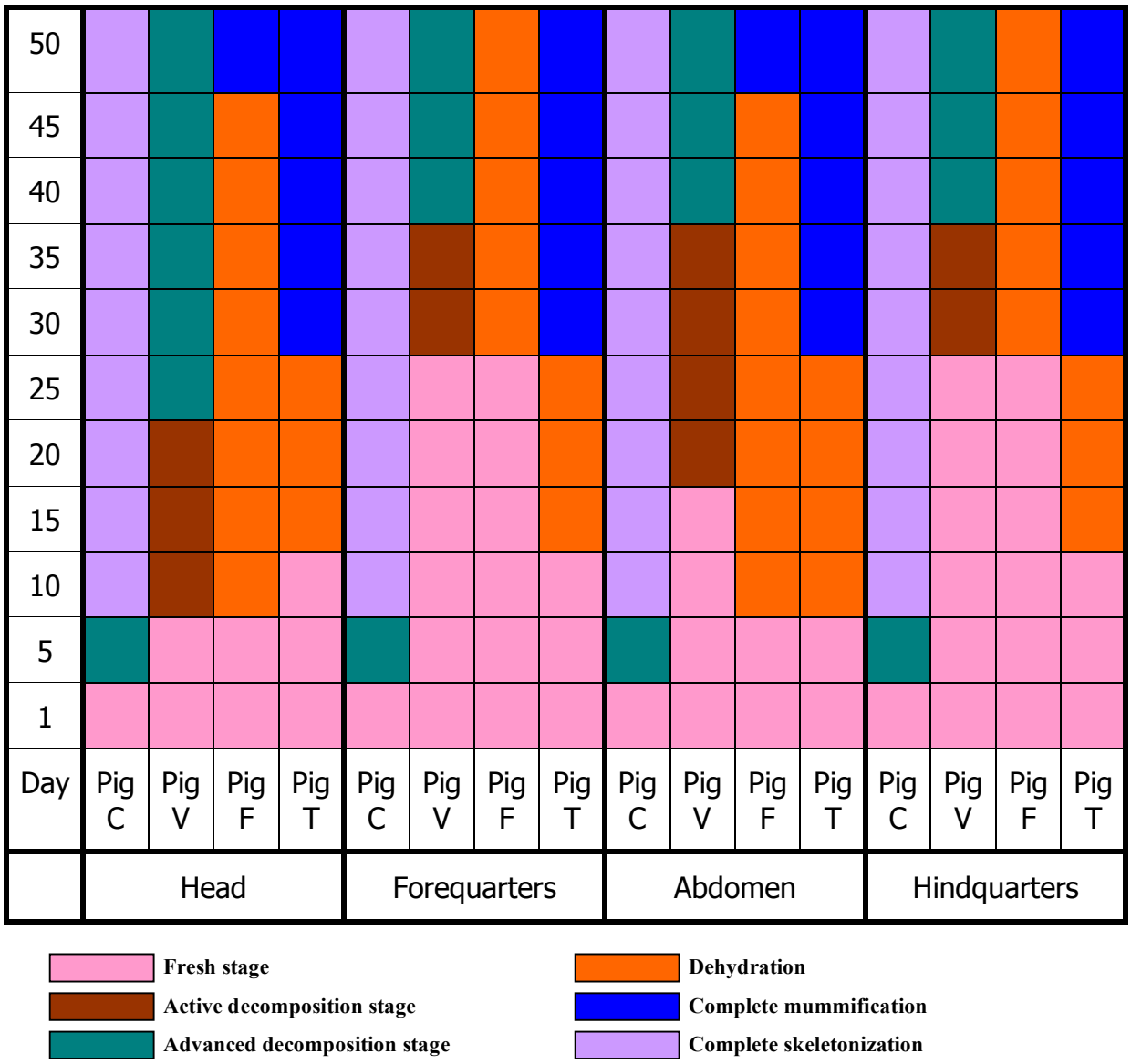

Figure 2: Differential Decomposition of Embalmed Pigs. Time frame of differential decomposition over 50 days.

Figure 3: Pig V, Sequence of Decomposition (A- H). (A) Day1, 5:30 P.M., (B) Day 7- arrow points to dent, (C) Day 14 - arrow points to maggots around the head wound, (D) Day 21- arrow points to dead maggots, (E) Day 28 - maggot activity increased and skin started sloughing off of skull, (F) Day 35 - maggot activity seen beneath skin but skin not consumed by maggots, (G) Day 42 - arrow points to mold on hindquarters and residue on skin, (H) Day 50 - arrow points to dried residue on skin.

Pig F – 5% Formaldehyde Subject

Pig F was embalmed with a 5% formaldehyde solution. Decomposition of Pig F is shown graphically in Figure 2. As can be seen in Figure 2, Pig F showed no decomposition similar to that of Pig C or Pig V. Beginning on the 11th day, Pig F's decomposition showed signs of drying and mummification of the exposed intestine at the incision site on the abdomen. By the 13th day, Pig F's tongue had blackened, and the lips began to dry and withdraw from the teeth. The dehydration and mummification of the skin and muscle continued so that Pig F was almost entirely mummified by the end of the study.

Pig F was laid out on the first day, July 15, 2010, at 5:30 p.m. (Fig. 4A). Minor changes were observed on Pig F starting on the 5th day. The intestines exposed by the incision made in the abdomen became discolored, and some skin flaking was seen on the hindquarters (Fig. 4B). Fly eggs were observed in the creases of the skin on the hindquarters on the 10th day, but those eggs did not hatch, resulting in no maggot activity on Pig F for the duration of the experiment. By the 14th day, fly eggs were observed on the hindquarters of Pig F. Pig F began to show signs of mummification as the skin had begun to dehydrate and tighten across the body. The skin could be seen withdrawing from the bone that was exposed from the incision on the chest made by the Swine Unit (Fig. 4C). Fire ants were observed on the 15th day; they remained active on and around Pig F for the duration of the experiment, and eventually built a mound in the carcass of Pig F.

The eyes took on a black discoloration, and the exposed intestines were totally mummified by the 21st day (Fig. 4D). The intestines were black by the 28th day (Fig. 4E)

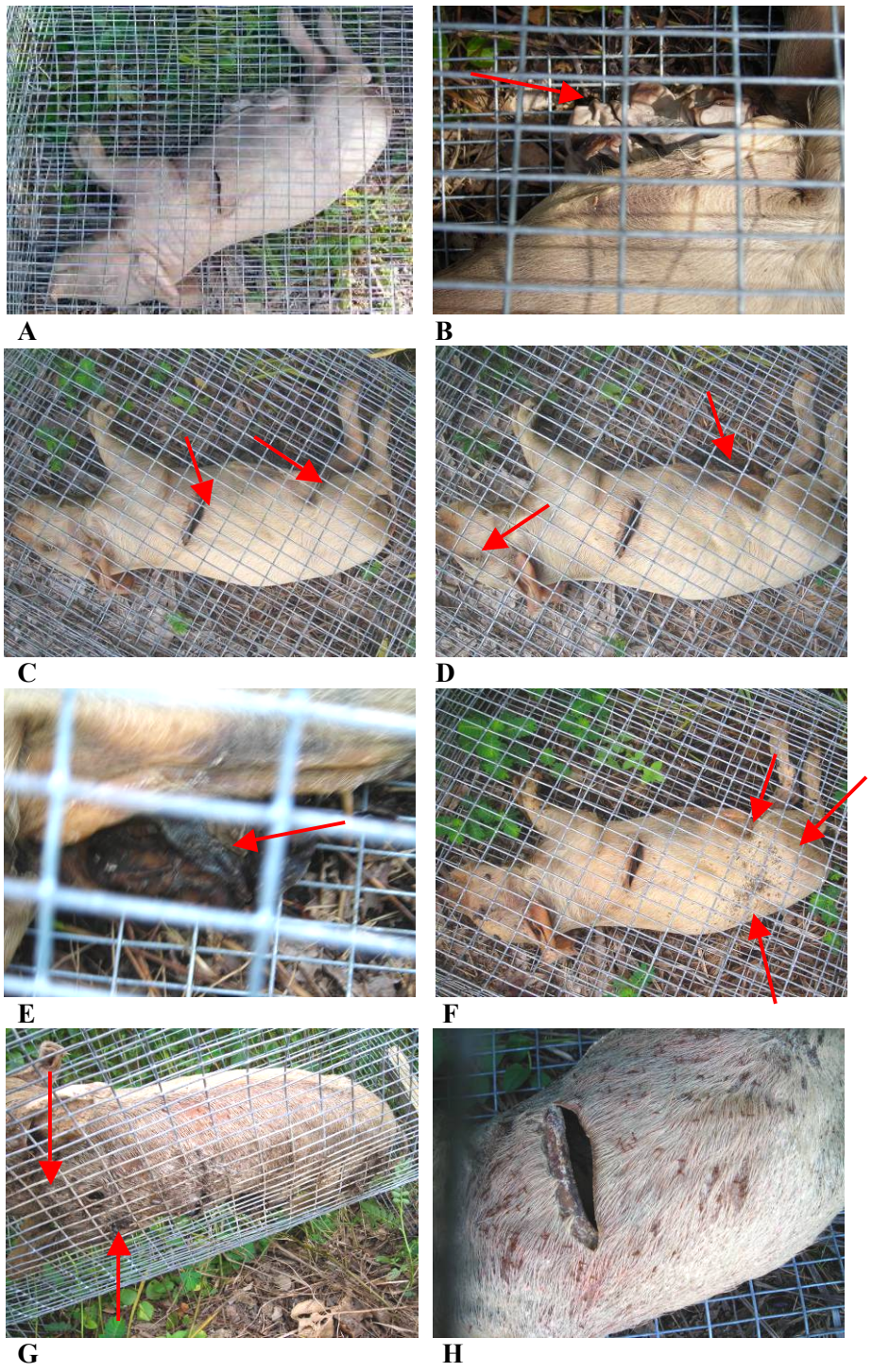

Figure 4: Pig F, Sequence of Decomposition (A- H). (A) Day 1 5:30 P.M., (B) Day 7- point to discoloration on exposed intestines, (C) Day 14- arrows point to fly eggs and exposed bone, (D) Day 21- arrows point to exposed organs and black discoloration around eye, (E) Day 28- arrow points to exposed organs, (F) Day 35- arrows point to fly eggs and fire ants consuming fly eggs, (G) Day 42- arrows point to holes, (H) Day 50- increased red discoloration and black mold has appeared.

and by the 35th day fire ants were seen eating fly eggs on the hindquarters and back of the pig (Fig. 4F).

On the 32nd day, white mold appeared on the forehead and spread to cover a greater surface area on the head. By the end of the 35th day, openings in the skin could be seen on the top of the leg, which appear to have occurred due to the skin tightening across the bones. These openings exposed bone on the distal portion of the legs where there was less muscle. By the 43rd day, the skin began to show signs of deterioration, as indicated by the development of holes where it had been in contact with the ground, and bones could be seen through the holes (Fig. 4G). A red discoloration appeared on the abdomen, and the chest and parts of the head were covered in a fire ant mound. By the 50th day, the skin on the abdomen had a pink and red discoloration, and a number of dead fire ants were found in the abdominal area. Black mold appeared on the 50th day as well (Fig. 4H). The pink and red discoloration may have been due to fire ant (*Solenopsis invicta*) bites.

Pig T – 10% Formaldehyde Subject

Pig T, embalmed with a 10 % formaldehyde solution, was laid out on the first day July 15, 2010– at 5:30 p.m. (Fig. 5A). Decomposition of Pig T is shown graphically in Figure 2. As can be seen in Figure 2, Pig T began to show signs of mummification by the 12th day when the skin began drying and tightening on the legs so that puckering appeared. On day 19, the mummification of the skin was evident across the body as the skin tightened as it dried, and the bones of Pig T could be observed. After the 30th day, the body of Pig T had achieved complete mummification (Figure 2).

For the first eight days, no changes and no signs of decomposition were observed (Fig. 5B). The first change on Pig T was seen on the 9th day with the appearance of a white residue-like substance on the tail. On the 10th day, the white residue was observed on the edge of the ear that was not in contact with the ground (Fig. 5C). By the 12th day, mummification began with the skin tightening on the hindquarters. White mold was also observed on the 12th day and continued to spread throughout the experiment (Fig. 5D). On the 13th day, fly eggs were observed on the mouth and snout of Pig T, but none of the eggs hatched. The eyes were completely mummified by the 14th day, and the intestines exposed by the incision made in the abdomen began to dehydrate and gained a dark, almost black discoloration. By the 15th day, more of the white residue appeared on the exposed intestines, and mold growth expanded over other parts of the pig. For the remainder of the experiment, mold was seen on most of the surface area of the skin, and several varieties of mold were observed. On the 20th day of the experiment, the skin had tightened to the point that the skin had begun to pucker around the bones of the hindlegs. On the 22nd day, fly eggs were laid on the nostrils; these eggs remained and did not hatch. For the duration of the experiment, no further fly activity was observed. Black mold was observed on the throat on the 25th day. Figure 5E shows both black and white mold. On the 26th day, fire ant activity started at the site. By the 28th day, pink mold appeared on the head. On the 30th day, small holes in the skin were observed on the hindquarters of Pig T as dehydration continued. By the 32nd day, the holes observed on the hindlegs extended down into the muscles due to the effects of mummification and weathering. The cage containing Pig T had been uprooted and pulled a meter away from the original site.

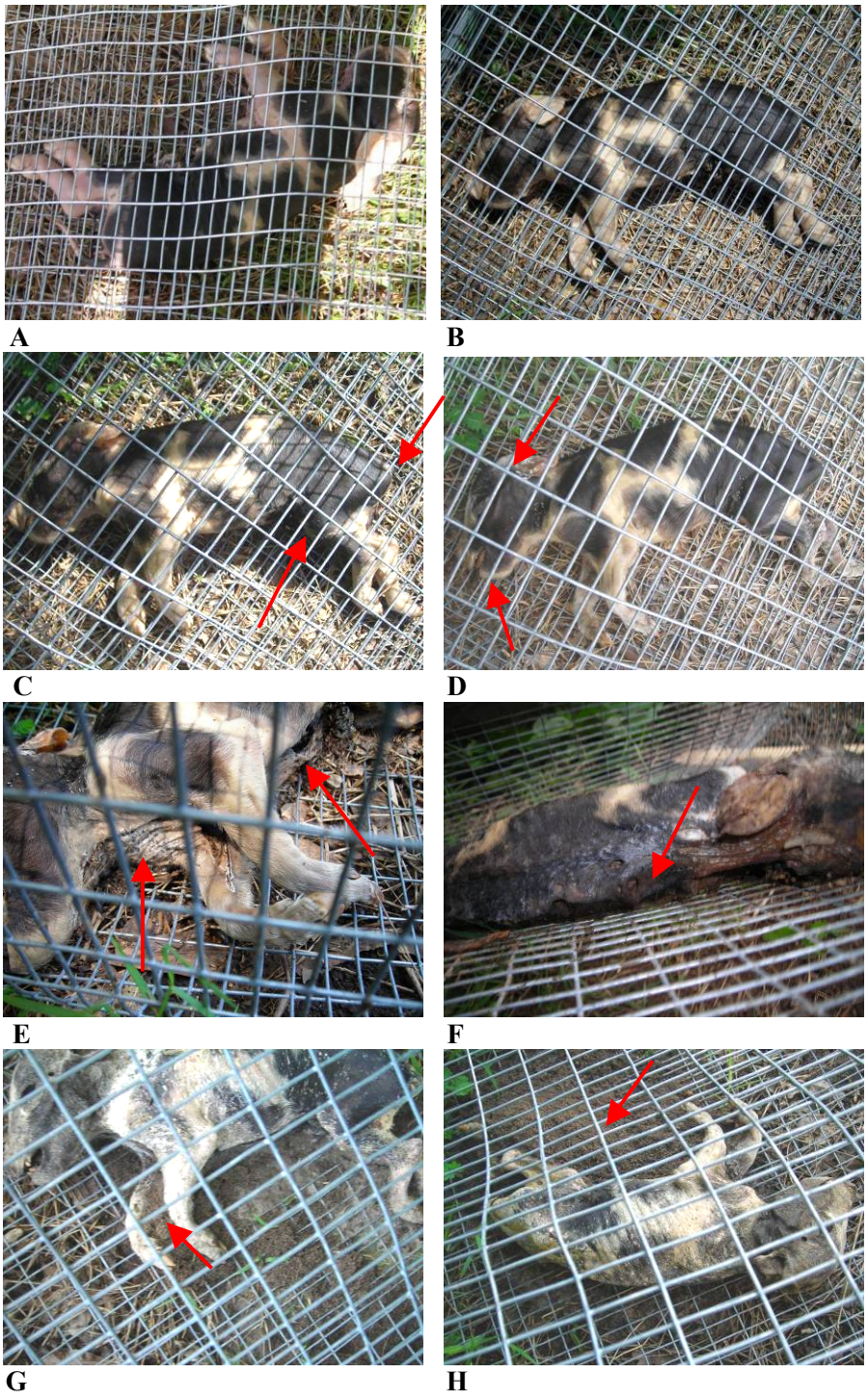

Figure 5: Pig T, Sequence of Decomposition (A- F). (A) Day 1 5:30 P.M., (B) Day 7- no signs of decomposition, (C) Day 14- arrows point to dried white substance on tail and exposed dehydrating intestines, (D) Day 21- arrows point to white mold and fly eggs, (E) Day 28- arrows point to new mold growth and skin dehydrating, (F) Day 35- arrows point to holes from contact with the ground, (G) Day 42- arrow points to fire ant mound underneath body, (H) Day 50- arrow points to fire ant mound inside and on top of body.

Tracks around the cage and signs of digging underneath the area of the cage suggested raccoon or other scavenger activity. The disturbance of the cage revealed that the skin in contact with the ground had deteriorated to the point where the skeleton was exposed on the underside of the pig (Fig. 5F). On the 34th day, a fire ant mound was observed inside the cage. Mold growth continued with yellow mold appearing on the hindquarters on the 39th day. By the 45th day, the majority of the pig's skin was covered in mold (Fig. 5G). On the 49th day, an ant mound was built around Pig T and almost covered the hindquarters (Fig. 5H). Further scavenger activity was observed again on the 50th day, when the cage was moved from the site.

Daily Temperature and Rainfall

The daily temperature and rainfall for the duration of the experiment are reported in Appendix 2. The mean maximum temperature was 91.4 ºF with a range of 19º; the mean minimum temperature was 75.5 °F with a range of 11º (Fig. 6). The mean daily rainfall during the experiment was 0.21 inches with a range of 2.02 inches. The maximum rainfall in one day was 2.02 inches during the experiment (Fig. 6).

Insects

Table 1 shows the insect species found on all four pigs. The insect species were ordered according to date and from which pig the insects were collected. Not all insects collected may be logged in Table 1, since seven of the containers were damaged in transit to the U.S. Department of Agriculture Systematic Entomology Laboratory Taxonomic Services Unit, when the box that containers were in was crushed and the insects in these damaged containers were either lost or too badly damaged for identification.

Other than the flies, one of the first insects observed in the experiment was the pill

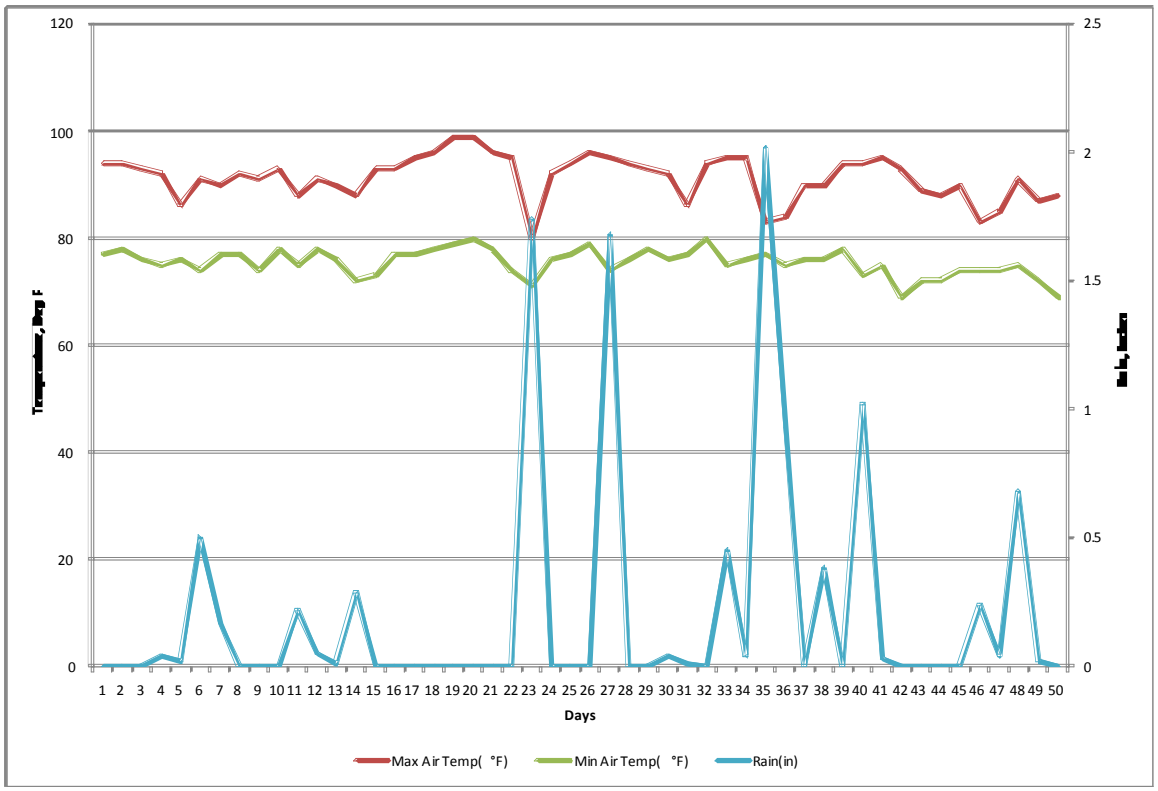

Figure 6 Temperature and Rainfall: Minimum air temperature, maximum air temperature and rainfall over the 50 days of the experiment.

bug (*Armadillidium vulgare*). Pill bugs were periodically observed throughout the experiment on all four of the pigs (Table 1). Of the embalmed pigs, Pig V was the only pig observed to have maggot activity from bottle flies, blow flies, and screwworm flies. Screwworm flies (*Cochliomyia macellaria Fabricius*) were the most frequent fly on Pig V. The fly specimens that could only be identified as to order or family on Pig V were either blowflies (*Diptera Chrysomyinae*) or green bottle flies (*Diptera Calliphoridae Lucilia*).

The first ants to visit the experiment site were black carpenter ants (*Camponotus pennsylvanicus*) which were observed on Pig V, but they were only present for one day. After the 32nd day, fire ants (*Solenopsis invicta*) were the most prominent species of

insect on all three of the embalmed pigs. By the end of the experiment, fire ant mounds had been built on top of (Fig. 7A), inside (Fig. 7B), and around (Fig. 7C) Pig F and Pig T.

Table 1: Insects collected and identified from all four pigs.

Date	**Order**	**Family**	***Species***	**Common Name**	**Stage**
Pig C					
16-Jul	Isopoda	Armadillidiidae	*Armadillidium vulgare*	Pill Bug	Adult
18-Jul	Diptera	Calliphoridae	*Lucilia (Phaenicia) sp. (*probably *coeruleiviridis Macquart)*	Green Bottle Fly	Larva
Pig V					
16-Jul	Isopoda	Armadillidiidae	*Armadillidium vulgare*	Pill Bug	Adult
26-Jul	Diptera	Chrysomyinae		Blow Fly	Larva
27-Jul	Hymenoptera	Formicidae	*Camponotus pennsylvanicus*	Black Carpenter Ant	Adult
29-Jul	Diptera	Calliphoridae	*Lucilia (Phaenicia)*	Green Bottle Fly	Larva
2-Aug	Diptera	Calliphoridae	*Cochliomyia macellaria Fabricius*	Screw Fly	Larva
4-Aug	Diptera	Chrysomyinae		Blow Fly	Larva

Table 1 continued

Date	**Order**	**Family**	***Species***	**Common Name**	**Stage**
6-Aug	Diptera	Calliphoridae	*Lucilia (Phaenicia) sp.*	Green Bottle Fly	Larva
6-Aug	Diptera	Chrysomyinae	*Cochliomyia macellaria*	Screw Fly	Larva
7-Aug	Diptera	Chrysomyinae	*Cochliomyia macellaria Fabricius*	Screw Fly	Larva
13-Aug	Diptera	Calliphoridae	*Cochliomyia macellaria Fabricius*	Screw Fly	Larva
Pig F					
27-Jul	Isopoda	Armadillidiidae	*Armadillidium vulgare*	Pill Bug	Adult
28-Jul	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
29-Jul	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
10-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
15-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
17-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
19-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult

Table 1 continued

Date	**Order**	**Family**	***Species***	**Common Name**	**Stage**
21-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
23-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
24-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
26-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
1-Sep	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
Pig T					
23-Jul	Isopoda	Armadillidiidae	*Armadillidium vulgare*	Pill Bug	Adult
19-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult
26-Aug	Hymenoptera	Formicidae	*Solenopsis invicta*	Fire Ant	Adult

A

B

C

Figure 7 Fire Ant Mounds Associated with Pigs (A-C): (A) fire ant mound built on the head of Pig F, (B) fire ant mound built around Pig T, (C) signs of fire ants building a mound inside of Pig T.

Chapter 5: Discussion

The embalmed pigs decomposed at a delayed rate in comparison to the pig that was not embalmed. Flies and fly eggs were present within 12 hours of Pig C being laid out and maggot activity had begun within 24 hours. However, with the embalmed pigs, fly activity was not present until the 8th day, and the fly eggs that were laid remained un-hatched. Pig C was completely skeletonized within four days, and Pig C did not retain flesh long enough to show signs of mold or mummification. Pigs with a 5% or higher solution of formaldehyde showed mold growth and signs of mummification, beginning with the desiccation of the eyes and exposed organs. By the 50th day, mummification was complete, and the skin had begun to deteriorate.

The differences seen in the decomposition of the pigs can be attributed to the rate of biodegradation of the chemicals used in the embalming fluids. Formaldehyde begins to degrade immediately upon exposure to aerobic conditions. According to a study at the Hazardous Substances Data Bank, the degradation of formaldehyde was complete within 30 hours when it was mixed with water from a stagnant lake (Howard 1989). In another study, when formaldehyde was mixed with sewage water, the chemical was degraded in 48-72 hours (Howard 1989). In a third study, formaldehyde mixed with an active bacterial culture and mud was 91% degraded in two weeks (Howard 1989). Further experiments determined that rate of biodegradation for formaldehyde ranged from less than one day to 17.3 days (Howard 1989). The difference in the rate of degradation of formaldehyde is probably due to other substances combined with the formaldehyde. These studies for industrial production are the best references for the rate of degradation of formaldehyde, since specific degradation rates for formaldehyde are not available.

These industrial experiments can give a rough time range to the formaldehyde's rate of degradation in this experiment.

Glycerin degrades faster than formaldehyde, and after 24 hours glycerin is degraded by 94-97% (Matsui et al. 1989). Phenol also has a short degradation period, and, in an aerobic test, the complete degradation of the chemical could be observed in 4-5 days (Howard 1989).

Ant activity may have played a role in the rate of decomposition of the embalmed pigs. Fire ants (*Solenopsis invicta*) were active around Pigs V, F, and T. Fire ants are known to prey on maggot populations and fly eggs, which would retard the decomposition process (Catts and Haskell 1990). Another ant species– black carpenter ant– was observed consuming fly eggs on Pig V. The predation of fly eggs by black carpenter ants and fire ants on Pig V might have retarded the decomposition rate by reducing the maggot population, but this is unlikely since the majority of the eggs laid during that period did not hatch. However, fire ant mound building may have accelerated decomposition, either through tissue consumption (as evidenced by dead ants on the pigs) or by breaking the skin.

During the last few days of the experiment, fire ant mounds were built in the bodies of Pigs F and T. This might be the reason for the lack of other insect species being present during this period on Pigs F and T.

Pill bugs were present throughout the experiment on all three of the embalmed pigs. Pill bugs are frequently seen at decomposing remains and have been collected at all stages of decomposition (Catts and Haskell 1990). The reason for the presence of pill bugs at decomposing remains is unknown, since they consume rotting vegetable matter.

No dead pill bugs were observed, so it is unlikely that they were consuming pig tissue and thus not contributing to the decay rate.

Insect activity was observed to be lower on pigs with higher concentrations of formaldehyde in their embalming fluid, suggesting that insect activity is affected by the embalming chemical concentration and the degradation rate of the embalming chemicals. For example, no fly activity was observed for 10 days on Pig V, whereas flies were present almost immediately on Pig C. Pig V was embalmed with the most diluted solution of formaldehyde, 1%, and had no phenol or glycerin. Therefore, the degredation of formaldehyde to a non-toxic level would have been faster in Pig V compared to the other two embalmed pigs, which had 5% and 10% formaldehyde solutions.

After the first ten days, fly eggs were laid periodically during the experiment on Pig F. The eggs never hatched, most likely because the pig's skin was toxic due to the higher concentration of formaldehyde –5%–, which took longer to degrade to non-toxic levels. Since flies were attracted to Pig F, the inference is that the pig's body was decaying enough to be attractive to oviating flies, but too toxic for the eggs to hatch. The presence of numerous dead fire ants early in the experiment suggests that the flesh of Pig F was toxic.

Pig T's chemical solution was the strongest of the three embalmed pigs and, consequently, almost no fly activity was associated with Pig T. For the duration of the experiment, most of the insect activity came from pill bugs and fire ants. On Pig T, fly eggs were present only twice during the experiment, on the 12^{th} and the 22^{nd} days, in small numbers around the snout of Pig T, and these never hatched. The eggs were gone within a couple of days, most likely due to predation by other insects.

The low temperatures during the experiment (range of 69°F to 80°F) would not have hindered maggot growth–cool temperatures below 40°F can kill fly eggs and can slow maggot growth (Catts and Haskell 1990). The temperature highs were never above 100°F during the experiment, which would inhibit maggot growth (Catts and Haskell 1990). Instead, the high temperature range promoted rapid maggot development. Rainfall was not in a quantity to significantly affect insect activity - moderate or heavy rainfall can reduce or stop fly activity (Catts and Haskell 1990).

Mold appeared on Pig F and Pig T. On the 32nd day, white mold appeared on Pig F, starting on the forehead and spreading to most of the head. On the 50th day, black mold appeared. On Pig T, mold first appeared on the head on the 15th day, and as the experiment progressed, the mold increased, covering most of the surface of the skin. By the end of the experiment, four possibly different species of mold were visible on the skin of the pig.

The decomposition rate was observed to progress more rapidly for the pigs with lower embalming fluid chemical compositions, suggesting that the concentration of the chemicals in the embalming fluids was a key factor in the rate of decomposition. With 10% formaldehyde concentration, the pigs skipped the decomposition phase and progressed directly to the mummification phase (see Figure 2).

The skin of Pig V decayed in a manner that was unlike any of the other three pigs. Pig V was the only pig that displayed a textured, bubbled appearance. In addition, maggots did not consume the skin. Instead of mummifying like the other two embalmed pigs, the skin of Pig V turned black and decayed around the head and anus. The skin of the head, where most maggot activity was observed, showed the earliest and the greatest

amount of decay. The skin sloughed away on the head and near the anus. By the end of the 46th day of the experiment, the pig's skin had begun to take on a leathery texture, beginning the process of the mummification. However, decomposition was not apparent on the body until the last two weeks of the experiment when the body began noticeably deteriorating. Pig V decomposed due to the low concentration of formaldehyde and fast degradation of the chemical to non-toxic levels. The lack of additional chemicals (e.g., phenol and glycerin) in the embalming solution for Pig V could have contributed to the maggot activity on Pig V.

Pig F underwent a decomposition process different from Pig V's, the key difference being the skipping of the decomposition phase. Pig F showed signs of dehydration on the 18th day. Pig F had less fly activity than Pig V, and although new batches of fly eggs were found throughout the experiment, the fly eggs did not hatch. A possible reason for this is that Pig F's embalming solution contained a high enough concentration of formaldehyde to be toxic and prohibit the eggs from hatching.

Pig F had a lesser level of deterioration of the skin than Pig T, though holes did appear on the hindquarters on the 30th day. On the 43rd day, the underside of the pig was examined, and the examination revealed that the skin in contact with the ground had deteriorated similarly to Pig T's skin. The holes in the skin were large enough to see portions of the skeleton. In addition to the damage on the underside of the skin, further skin damage was observed near the anus in the form of two large holes and a third smaller hole higher on the hindquarters. The decay of the dried skin might be attributed to weathering from being exposed to the elements, mold, and the fire ant activity when ants built a mound underneath and inside the carcass of Pig F.

Pig T mummified more rapidly than Pig F. The rapid mummification of Pig T was most likely due to the highest concentration of formaldehyde among the three embalmed pigs. Pig T almost went directly from fresh to dried remains. On the 12th day, the skin on the hindlegs had begun to pucker, and the intestines had already begun to dehydrate and show discoloration. The muscles and internal organs were almost completely mummified by the end of the 3rd week. The greatest causes of decay and damage seen on Pig T were mold and weathering (since the body was on the ground, exposed to the elements).

A hole in the skin of Pig T first appeared on the 32nd day and was relatively small. Two days later, when the pig's cage was disturbed by possible raccoon activity, decay was discovered on the underside of Pig T. The skin was damaged and decayed enough that the majority of the skeleton was visible. The pig's skin in contact with the ground may have decayed due to the fire ants' activity.

Other than Pig C, the control pig, the only embalmed pig to go through a stage of decay was Pig V. The other two embalmed pigs went from showing no signs of decay to complete mummification. Pig V passed through the fresh stage to advanced decay. The darkening of the skin around the mouth to a black color on the 9th day was the first visible sign of the pig reaching the stage of decay. With the low concentration of formaldehyde in the embalming fluid, the degradation of chemicals to non-toxic levels occurred fast enough to allow decomposition and make Pig V a viable host to the fly eggs. In spite of the maggot activity on the pig, the majority of the skin, hindquarters and forelegs remained unconsumed.

The concentration of formaldehyde played a significant role in the rate of mummification. The higher the concentration of formaldehyde in an embalming solution,

the faster an embalmed body will attain complete mummification. A smaller concentration, less than 5%, results in mummification taking longer, increased fly activity, and maggot activity under the skin. The resulting carcass at 50 days had skin relatively intact, and the body was mostly skeletonized underneath. Skin in contact with the ground showed signs of deterioration, and by 43 days the skin that was in contact with the ground deteriorated to the point where the skeleton was completely exposed from the underside.

Phenol and glycerin are chemicals regularly used in most embalming fluids. Both phenol and glycerin degrade quickly – a degradation percentage of 90% or above can be seen in four days. Phenol and glycerin should have little effect on decay.

Being able to estimate the length of time an embalmed body is exposed to the elements will make tracing a body easier and narrow the number of individuals to whom the body belongs. This study documents that embalming fluid had an influence on decomposition, insect activity, and mold growth. Whether the body goes through any part of the decay stage or straight to mummification can help identify the original levels of formaldehyde in the embalming fluid, since the level of formaldehyde in embalming fluid has an effect not only on the rate of decomposition, but on which stages of decomposition will be seen with an embalmed body.

Chapter 6: Conclusion

This study contributes key information for establishing a timeline for remains that were embalmed but not interred. Having been conducted in southern Louisiana, U.S.A., this information is particularly relevant to embalmed remains found in similar warm climates (75ºF to 99ºF in the summer). Unlike non-embalmed bodies, the presence of the embalming solution delays decomposition and retards or prevents insect activity.

Based on juvenile pigs, a body embalmed with a low concentration of formaldehyde (1% or less) can be expected to have fly activity after eight days and maggot activity after 13 days. The flesh will decompose from maggot activity while the maggots will not consume the skin. The body of the embalmed pig decomposes and liquefies, but at a slower rate than a body that was not embalmed.

Bodies embalmed with a solution of 5% or higher formaldehyde do not go through the stages of bloat and decay; instead, they progress directly from the fresh stage to mummification. No maggot activity will be present, although unhatched eggs will be found. Mold growth is expected, covering small areas at first, and then spreading to the entire body. Dehydration of the skin creates holes in the skin, particularly in the less fleshy areas of the body. Skin in contact with the ground decays allowing exposure of the skeleton. Ants will be attracted to the site of the embalmed body, and some dead ants are expected. In areas where fire ants are present, fire ant mounds inside and around the body are present.

Bodies embalmed with a concentration of 10% formaldehyde exhibit virtually no fly activity, and few fly eggs are found. Mold appears after 15 days and will cover the majority of the body with multiple species. The body will mummify quickly beginning on

the 9th day of exposure and complete mummification by the 30th day.

Additional research would be helpful in resolving some of the questions that have arisen from this experiment. Mold that grew on the skin of the pigs and appeared on the pigs' skin at different times was probably from four different species. Perhaps the species of mold could be used to pinpoint how long the body was exposed. Testing the embalmed pigs' tissue for formaldehyde concentrations is another factor that could help determine how long the body was exposed, especially since a difference can be seen in the decomposition rates of embalmed pigs with different strengths of formaldehyde. Skin deterioration from contact with the ground is another factor that may provide timeline information. Further investigation of maggot activity on muscle versus skin may provide useful data on how the body was embalmed.

Many questions about the decomposition of embalmed, but not interred, bodies are answered by this experiment. Determining a rough timeline of how long embalmed remains were exposed is possible with the information contained in this study.

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Appendix 1: Observation Log

Day	Date	Pig	Observations
1	7/15	C	Pig laid out; no insect activity present.
		V	Pig laid out; no insect activity present.
		F	Pig laid out; no insect activity present.
		T	Pig laid out; no insect activity present.
2	7/16	C	Maggot mass present in mouth and ear of pig, ants and pill bugs present on body, and flies swarms the cage. Maggot mass temperature taken and maggots and flies were collected.
		V	No change in the pig. Pill bugs present on body.
		F	No changes visible.
		T	No changes visible.
3	7/17	C	Extreme deterioration on the exposed side of the head and some of the skin has begun to slough off. By 4:55 pm the majority of the head and torso have been consumed by the maggot mass. Maggot mass temperature was collected, as were maggot and fly samples.
		V	No changes visible.
		F	No insect activity. The exposed intestines have a deflated appearance and appear to be dryer than the parts of the intestines that were not exposed.
		T	No changes visible.
4	7/18	C	The majority of the body is consumed so that the bones are exposed, flesh remains only on the hooves. Clumps of the maggot mass remain in the cage. Maggots were collected. By 4:58 pm no flesh remains on the pig and the maggots are closer the soil.
		V	No changes visible.
		F	No changes visible.
		T	No changes visible.

5	7/19	C	No changes visible.
		V	A circular dent has appeared near the hindlegs.
		F	Some of the intestines that are exposed are displaying a black discoloration that seems to be spreading along the exposed intestines.
		T	No changes visible.
6	7/20	C	No changes visible.
		V	Dent remains.
		F	No changes visible.
		T	No changes visible.
7	7/21	C	No changes visible.
		V	Dent on pig appears to have increased in depth.
		F	No changes visible.
		T	No changes visible.
8	7/22	C	No changes visible.
		V	A crease in the abdomen of the pig has appeared near the dent running from the spine to the abdomen.
		F	Skin flaking on hindlegs and near the sphincter.
		T	No changes visible.
9	7/23	C	No changes visible.
		V	Discoloration has appeared around the pig's mouth.
		F	The skin around the wound on the side drawing away and widening the opening.
		T	Some pill bugs present on ear and white crust on tail. This crust is possibly from the solution drying on the skin of the pig.
10	7/24	C	No changes visible.

		V	Denting on stomach has occurred due to the movement of internal organs. Two flies are present on the pig, and fly eggs are around the mouth and nose.
		F	Organs that are exposed through the opening on the stomach are turning black and are becoming mummified around the edges that are farthest from the body of the pig. Fly eggs have been laid in a crease of the hindleg.
		T	A few flies are present, and the same white crust now appears along the edge of the exposed ear.
11	7/25	C	No changes visible.
		V	A few flies are present and clusters of fly eggs are present around the area of the ear. New maggots are present around the nostrils but there are only around seven of them.
		F	Exposed organs are becoming more discolored and mummified.
		T	Dried white chemical substance has progressed to cover the entirety of the tail, but otherwise there is no change.
12	7/26	C	No changes visible.
		V	Clusters of fly eggs are now present on the face and neck of the pig and are especially concentrated around the circular head wound.
		F	No changes visible.
		T	Skin near the hindleg has begun to pucker, and the skin is tightening along the hindquarters making the bones more visible and prominent. The exposed organs through the stomach wound have become mummified and taken on a black discoloration.
13	7/27	C	No changes visible.
		V	A small amount of maggots is around the nose and mouth, and large black ants are present on the pig but only in localities where fly eggs are present.
		F	Bone exposed through the side wound has a black discoloration, and the tongue is exposed as the lips dry and withdraw from the mouth. Pill bugs are now present around the tail.

		T	Fly eggs present around the mouth, and pill bugs and flies are around the head. A white substance is present on the blackened exposed organs.
14	7/28	C	No changes visible.
		V	No changes visible.
		F	Fire ants are present around the mouth area, but otherwise no change is visible.
		T	No changes visible.
15	7/29	C	No changes visible.
		V	Fly eggs appear to be un-hatched.
		F	There are dead fire ants present around the mouth and snout of the pig and some live fire ants are on the body. No changes visible.
		T	White mold has appeared on the forehead and ears; also pill bugs and a fly are present. There are fewer fly eggs in the mouth than yesterday and remain un-hatched.
16	7/30	C	No changes visible.
		V	New cluster of fly eggs are in the crease between the abdomen and the hindleg that is in contact with the ground.
		F	No changes visible.
		T	Eye that is not in contact with the ground has begun to dehydrate. Fly eggs are now completely gone with no sign of maggot activity.
17	7/31	C	No changes visible.
		V	Eye not in contact with the ground has taken on a bruised appearance, black around the eyelids and extending out a centimeter with a red tint at the edge of the black discoloration. More flies are present, and fly egg clusters have increased around the creases on the abdomen near the hindlegs
		F	Black discoloration is starting to appear on the skin around the eye, and fly eggs are present around the hindlegs and anus.
		T	Exposed eye has completely mummified, and the white mold has

		T	Exposed eye has completely mummified, and the white mold has increased to cover the majority of the ear.
18	8/1	C	No changes visible.
		V	Maggots are now active around the eye and the opening of the abdomen. Skin on the forehead is now completely black, and the circular wound on the forehead is covered in maggots.
		F	Organs that are exposed through the stomach opening are now completely black and mummified.
		T	Mold has appeared on the hindlegs, and forehead and skin have begun to tighten across the body.
19	8/2	C	No changes visible.
		V	The eye on the exposed side of the body has mummified and shriveled. There is an increase in the number of fly eggs on the body.
		F	No changes visible.
		T	The tightening of the skin has increased to the point where the skin has puckered on the legs.
20	8/3	C	No changes visible.
		V	Small maggots are present around the eye and mouth, and larger maggots are dead around the exposed skull.
		F	No changes visible.
		T	Skin has shrunk on the skull, and the skin is tight enough that the cheekbones are visible. Pill bugs are present on the body.
21	8/4	C	No changes visible.
		V	Maggot population has increased at the throat wound, head wounds, nose, eye and mouth. The skin has developed a bubbly rough, yellow texture in patches along abdomen and close to spine.
		F	No changes visible.
		T	No changes visible.

		V	A grey fluid has begun to leak from the wound on the neck.
		F	No changes visible, but the smell of formaldehyde is strong.
		T	Fly eggs present on the nostril.
23	8/6	C	No changes visible.
		V	Maggots are present but no visible external consumption is visible; the consumption appears to be mostly internal.
		F	No changes visible.
		T	The fly eggs have not changed, and the skin on the hindquarters of the pig has visibly tightened.
24	8/7	C	No changes visible.
		V	There is maggot activity behind the ears, and the skin is sloughing off the head above the ear that has contact with the ground.
		F	No changes visible.
		T	No changes visible.
25	8/8	C	No changes visible.
		V	Flesh behind the ears has been consumed. The skin on the head has begun to rot, but the skin on the abdomen has taken on a yellow, bubbly texture from the chemicals.
		F	No changes visible.
		T	Mold has appeared at the throat incision. One mold is white and the other spots of mold are black.
26	8/9	C	No changes visible.
		V	Maggot activity is present at the throat. A skin discoloration and bubbled texture are spread across the abdomen.
		F	No changes visible.
		T	The eyelids have mummified enough to see the desiccated eyeballs.

27	8/10	C	No changes visible.
		V	The maggots' consumption and the decay have not visibly increased. The majority of the decay is focused around the neck wound.
		F	No changes visible.
		T	Mold growth has increased to cover the nose.
28	8/11	C	No changes visible.
		V	The maggots' consumption still has not progressed below the neck area. The decay of the head's flesh has resulted in parts of the skull having fallen free of the flesh. Pink mold has grown on the forelegs and hindlegs.
		F	Fire ants have appeared on the ears.
		T	Pink mold now covers the top of the head, and a new growth of white mold is present on the tongue.
29	8/12	C	No changes visible.
		V	Organs exposed through the stomach wound have taken on a dark burnt appearance.
		F	No changes visible.
		T	No changes visible.
30	8/13	C	No changes visible.
		V	The smell of decay has become more prevalent, and the remaining skin on the back has turned black.
		F	Flies are now present, and sore-like openings have appeared on the topmost hindleg.
		T	No changes visible.
31	8/14	C	No changes visible.
		V	No changes visible.
		F	A few fly eggs have been laid on the hindquarters, and fire ants are

		F	A few fly eggs have been laid on the hindquarters, and fire ants are present on the body. A depression the size of a quarter has appeared on the hindlegs
		T	The mold now covers a larger area on the forehead.
32	8/15	C	No changes visible.
		V	Maggots from the head have begun to pupate, and no maggots are present on head. Maggots are now present at the anus and a fold of skin on the abdomen.
		F	Dead fire ants are present along the incision on the abdomen, and pink mold is now present on the head.
		T	Mold has not noticeably increased, and there is now an abscess on the muscular part of the hindleg.
33	8/16	C	No changes visible.
		V	Maggot activity can be seen under the skin on the head.
		F	No changes visible.
		T	No changes visible.
34	8/17	C	No changes visible.
		V	No sign of new maggots or fly eggs, and the current generation of maggots is pupating.
		F	Fire ant activity has increased, and ants are consuming fly eggs.
		T	The cage and ground underneath the cage have been disturbed. Because of the tracks and claw marks from the digging, a raccoon was the most likely animal to have disturbed the cage. The skin of the pig that was in contact with the ground has decayed to the point where the bones are visible. Black mold has appeared on the body.
35	8/18	C	No changes visible.
		V	No changes visible.
		F	No changes visible.

36	8/19	C	No changes visible.
		V	Maggots are still consuming flesh of the abdomen, and mold has begun to appear on the hindquarters. Patches of skin on the hindquarters have taken on a flakey, crust-like appearance. This is most likely from chemicals drying.
		F	Fire ants have made a mound on and around the head of the pig and underneath the pig.
		T	Fire ants have made a mound under the pig and destroyed the remaining skin on the underside of the pig. Additionally, the ants appear to be making the inside of the pig part of their nest.
37	8/20	C	No changes visible.
		V	Rough, flakey skin patches and mold have appeared on the abdomen.
		F	No changes visible.
		T	Mold has grown to cover the shoulders.
38	8/21	C	No changes visible.
		V	Maggots are no longer present, and the smell of decomposition has grown stronger.
		F	Fire ants have moved the mound to the top of the abdomen.
		T	Yellow mold is now present on the hindquarters.
39	8/22	C	No changes visible.
		V	No changes visible.
		F	Hair has begun to fall free of the skin.
		T	Yellow mold has appeared on the hindlegs.
40	8/23	C	No changes visible.
		V	Maggot mass on the move from the anus of the pig.
		F	Ants are consuming fly eggs on the eye.

		T	No changes visible.
41	8/24	C	No changes visible.
		V	Skin on the stomach is now discolored. The bones of the forelegs are now showing, and maggot activity continues.
		F	Dead fire ants have accumulated in a fold of skin on the stomach.
		T	No changes visible.
42	8/25	C	No changes visible.
		V	Remaining skin has tightened across the bones.
		F	Dead fire ants are gone, and the stomach is covered in fire ants. Mold has begun to grow around the mouth.
		T	No changes visible.
43	8/26	C	No changes visible.
		V	A hole in the skin near the anus has appeared, and the skin in contact with the ground has begun to decay.
		F	A hole is in the skin near the anus and on abdomen. Fire ants are present. The skin in contact with the ground has decayed, and the bones are exposed.
		T	Fire ants are present. The skin in contact with the ground is gone, and the bones are exposed.
44	8/27	C	No changes visible.
		V	Fire ants are present and are consuming old fly eggs that have not hatched.
		F	Pinkish coloring has appeared on the shoulder, and the ear has taken on a mottled red appearance.
		T	No changes visible.
45	8/28	C	No changes visible.
		V	A new mass of flies has appeared around the cage, and a yellowish chemical looking spot has appeared on the stomach.

		V	A new mass of flies has appeared around the cage, and a yellowish chemical looking spot has appeared on the stomach. Decomposition fluids have appeared around the stomach.
		F	Pinkish coloring is spreading across the stomach.
		T	The back of the head and both forelegs are now entirely covered in mold. The lower portion of the stomach and the hindquarters remain relatively mold free.
46	8/29	C	No changes visible.
		V	Skin has taken on a leathery texture and is showing signs of mummification.
		F	No changes visible.
		T	No changes visible.
47	8/30	C	No changes visible.
		V	No changes visible.
		F	No changes visible.
		T	No changes visible.
48	8/31	C	No changes visible.
		V	No changes visible.
		F	No changes visible.
		T	No changes visible.
49	9/1	C	No changes visible.
		V	No changes visible.
		F	The amount of black mold on the skin has increased and so has the amount of fire ant activity.
		T	A fire ant hill now covers the hindlegs of the pig.
50	9/2	C	No changes visible.

		F	No changes visible.
		T	Signs of possible raccoon activity are seen around the cage.

Appendix 2: Daily Temperature and Rain Data[1]

Date Time Collected	Max Air Temp (°F)	Min Air Temp (°F)	Rain (in)
7/15/10	94	77	0
7/16/10	94	78	0
7/17/10	93	76	0
7/18/10	92	75	0.04
7/19/10	86	76	0.02
7/20/10	91	74	0.5
7/21/10	90	77	0.17
7/22/10	92	77	0
7/23/10	91	74	0
7/24/10	93	78	0
7/25/10	88	75	0.22
7/26/10	91	78	0.05
7/27/10	90	76	0.01
7/28/10	88	72	0.29
7/29/10	93	73	0
7/30/10	93	77	0
7/31/10	95	77	0
8/1/10	96	78	0
8/2/10	99	79	0
8/3/10	99	80	0
8/4/10	96	78	0
8/5/10	95	74	0
8/6/10	80	71	1.74
8/7/10	92	76	0
8/8/10	94	77	0
8/9/10	96	79	0
8/10/10	95	74	1.68
8/11/10	94	76	0
8/12/10	93	78	0
8/13/10	92	76	0.04
8/14/10	86	77	0.01

[1]Data from LSU Central Research Station's Louisiana Agriclimatic Information System

8/15/10	94	80	0
8/16/10	95	75	0.45
8/17/10	95	76	0.04
8/18/10	83	77	2.02
8/19/10	84	75	0.93
8/20/10	90	76	0
8/21/10	90	76	0.38
8/22/10	94	78	0
8/23/10	94	73	1.02
8/24/10	95	75	0.03
8/25/10	93	69	0
8/26/10	89	72	0
8/27/10	88	72	0
8/28/10	90	74	0
8/29/10	83	74	0.24
8/30/10	85	74	0.04
8/31/10	91	75	0.68
9/1/10	87	72	0.02
9/2/10	88	69	0

Vita

Michael Anne Keaton was born in June 1984 in Corpus Christi, Texas, grew up in Houston, Texas, and was graduated from Langham Creek High School in May 2002. She was graduated from the University of Texas at Austin in May 2006 with a Bachelor of Art. She studied anthropology at the University of Tennessee and volunteered in the Forensic Center prior to entering LSU's master's program. Michael Anne has presented her research at conferences, including her research on the effect of tooth height on the Lamendin aging technique at the 2010 American Anthropological Association meeting in New Orleans and her thesis research on embalmed pigs at the February 2011 annual meeting of the American Association of Forensic Scientists in Chicago. Her plans include furthering her studies in anthropology to acquire her doctorate, and performing research and teaching in the field of anthropology.