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insects and corpse decomposition

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Graduate students and police cadets are not the only visitors to the restful residents at the body farm. The first to arrive are insects. Within minutes after death and being exposed to the elements, the first flies arrive. From a mile away, gravid females, looking for a warm, moist place to lay their eggs, can sense the subtle chemical changes that occur at the moment of death. Within days, the body is swarming with maggots.

The connection between death and insects was recognized as far back as 1235. In the book *Washing Away of Wrongs*, the 13th-century Chinese investigator Sung Ts'u recounted how a magistrate used insect evidence to solve the murder of a man. The victim's wounds appeared to have been made by a rice sickle, so the magistrate ordered all the men to bring their tools and gather in the village. As they lined up, he watched the flies land on one particular blade, attracted by the almost invisible traces of the victim's blood and tissue. When the magistrate confronted the owner of the sickle, the man confessed to the crime.

Six hundred years later, in 1855, insects were key witnesses in another classic forensic entomology case. This time the victim was an infant who was discovered during the remodeling of a house outside of Paris. The small body had been sealed up behind a fireplace. The couple who had recently moved to the house were immediately under suspicion, but when Dr. Bergeret d'Arbois of Switzerland performed an autopsy on the tiny body, he discovered several generations of insect remains, which indicated that the body had been hidden for much longer than a year. He concluded that the child had been dead since 1848, long before the current owners took up residence. The former homeowners were eventually arrested and convicted of the murder.

Using insect evidence to solve a crime is called forensic entomology, and it has been practiced in one form or another in Europe for more than 100 years, but in the United States, insects are relatively new members of the forensic team. Their specialty is providing data to determine the postmortem interval.

Pig Research

Insects are predictable. A species tends to stick with one type of food or stay in one particular environment. Some lay eggs only at high noon or only in the shade. It is this predictability that makes them prime candidates for use in postmortem interval assessments. Research on human cadavers at the Anthropological Research Facility in Tennessee has proven that insects arrive at a corpse in a predictable sequence and are responsible for the majority of the tissue loss on a body.

Not all research, however, is conducted on human cadavers. Most insect research is done with dead pigs. M. Lee Goff at the Chaminade University of Honolulu and one of the founding diplomates of the American Board of Forensic Entomology uses 150-pound (70-kilogram) pigs because they are most like humans. A pig is not very hairy, has a similar intestinal tract, a similar diet, and it closely approximates the decomposition patterns of an adult human.

Goff simulates forensic situations by choosing experiment sites that are popular dumping grounds for dead bodies—unpaved service roads, vacant lots, and agricultural fields. Each experiment involves three pig carcasses that are spaced approximately 54 yards (50 meters) apart and covered with a wide screen mesh cage to prevent scavenging. The first pig is placed directly on the ground with thermocouple probes inserted to record the internal temperature of the pig as it decomposes. It is the control pig and is photographed but left untouched throughout the experiment. The second pig is set on wire mesh on the ground. Overhead, hangs a scale. Pig number 2 will be lifted and weighed each day to monitor the rate of tissue removal. The third pig is also on wire mesh and is the site for sampling insects.

For the first two weeks, the site is visited twice a day. The pigs are photographed, soil samples are taken, and weather gauges are read. A hygrothermograph measures ambient temperature and relative humidity. The rain gauge measures precipitation, and the high-low thermometer records the highest and lowest temperatures reached in a given time period.

Insects arrive at a corpse in a predictable sequence, and each new group of insects feeds on the body, making changes that attract the next group of insects. This second wave also feeds on the body, making it a prime feeding ground for another set of insects. Dr. Goff likens a dead body to a newly emerged volcanic island that attracts to its shores certain species of plants and animals, which take root and change the environment for future species. This orderly succession of species is the timetable on which forensic entomologists base their estimates of the time period between death and the discovery of the body. The timetables that Goff records are specific to tropical Hawaii, but there are other entomologists, such as K. C. Kim at Pennsylvania State University and Gail Anderson at Simon Fraser University in Canada, conducting similar research applicable to their climatic zones.

Insects and Death

What their research has uncovered is an intricate relationship between carrion insects and the decomposition process. Although the species vary from location to location, there are four basic categories of insects that are attracted to the various stages that a body goes through as it decays: those that feed directly on the body; those that prey on or parasitize the insects and spiders already on the body; insects that do both; and insects and spiders that use the remains as an extension of their habitat.

Shortly after death, the first wave of insects appear. These are the necrophagous species, primarily flies (Diptera) and beetles (Coleoptera) that feed directly on the body. Although evidence of decomposition is not yet visible, the flies have already honed in on the chemical changes occurring in the body. They lay their eggs in the moist cavities, such as the nose, eyes, mouth, anus, vagina, and open wounds. Because flies arrive first, they are the most precise indicators of the postmortem interval. Slower to arrive are the beetles, which prefer to feed on slightly older remains.

As decomposition progresses, the body becomes bloated as internal gases produced by putrefaction inflate the body cavity. More flies arrive, and the first maggots hatch and feed on the soft tissue. These large maggot masses can devour a corpse in a matter of days. A second group of insects, such as the burying beetles (Silphidae), rove beetles (Staphylinidae), and hister beetles (Histeridae), come to prey on the maggots. Fluid seeps into the ground, causing the population of insects normally found in the soil to evacuate, but the change in soil composition attracts other insects, some of which are microscopic. Certain wasp species (Hymenoptera) parasitize the flies by laying their eggs on or inside the maggots. When the eggs hatch, the wasp larvae feed on the tissue of the developing fly.

Wasps, ants, and some beetles feed on both the body and the other insects. Wasps will attack adult flies often on the wing, and ants will actually carry maggots off the body. There have been reports that large ant colonies carried away so many maggots that the decomposition timetable was altered.

As the body enters the decay stage, it collapses due to the combined activities of internal decomposition and external insect feeding. The maggots that are nearing pupation wander off the corpse to find drier ground. In the post-decay stage, the body is reduced to roughly 10 percent of its original body weight. Soft tissue is almost gone, and beetles and mites dominate the scene. When only bones and hair remain, spiders can be found building webs across the skeleton. As each new species arrives and departs, they leave behind the evidence of their presence, empty egg and pupal casings as well as dung, all of which are collected for analysis.

Collecting Data

For an entomologist, it's easy to collect the proper evidence, but a forensic entomologist isn't always called to the scene. More often than not, he or she is sent mashed maggots in an envelope or asked to render an opinion based on long dead insects stored in a police evidence room. A forensic entomologist can't provide accurate information with badly handled or recorded insect evidence. To ensure that the right kind of information is collected, some entomologists have started tutoring police investigators in proper insect collection, how many to collect, and how to record the proper information that will yield a postmortem interval estimate that would hold up in court.

Entomologist Ke Chung Kim at Pennsylvania State University takes police investigators out to the woods where they learn to collect information from one of three pig carcasses that are covered with feeding maggot masses. They are looking for representative samples of all the insects on, near, and under the body. The most important specimens are the most mature insects, because they have been on the body the longest period of time and will become the best indicators of time since death. The insects are placed in two sets of vials. One set of insects will be killed immediately to preserve or stop the biological clock. Maggots are difficult to kill because they are covered with a durable skin, or cuticle, which protects them from the elements, but entomologists have developed a fixative from a mixture of kerosene, acetic acid, and ethyl alcohol that does the job. If no fixative is available, the maggots are dropped into hot water, or even hot coffee, before being transported back to the lab.

The second set of insects are kept alive to be reared in an incubating chamber until adulthood. With the naked eye, all maggots look alike, and identifying larvae is difficult for even an expert, but adult insects are much easier to identify, and the length of time that the insects are in the rearing chamber lets the entomologist know when the eggs were laid.

The dead maggot specimens are identified under a dissection microscope by the shape of their breathing apparatus called posterior spiracles. The shape of the spiracles gives an indication as to what species of fly the forensic entomologist is dealing with and also how old the maggot is. Maggots grow in stages called instars. Their outer cuticle can only stretch so far before it must be shed for a larger one. In general, most flies found on corpses have three instars. An egg hatches and the first instar emerges to feed and grow until it molts into the second instar. This maggot will continue to feed until it, too, grows too large for its skin and molts into the third instar. A first instar maggot has a single pair of spiracles, the second instar has two pairs, and the third instar has three distinct sets of openings.

The third instar will stop eating and prepare to pupate. It migrates away from the body, and in some instances the migration of maggots away from the body has been so intensive that the marks left in the soil have been mistaken for tire tracks. Often times maggots reach higher ground by climbing nearby trees. Goff relates one instance at a research site where thousands of maggots were climbing the trees, crawling along the branches only to fall off the ends and start their climb all over again. So many insects were falling from the trees that the forensic entomologists needed to use umbrellas to complete their work.

Besides collecting insects, forensic entomologists collect accurate weather information for the crime scene. Insect development might be predictable and sequential, but it is also affected by temperature, and any estimate has to take into account the environmental factors associated with the time of death. Cold temperatures, for example, slow or even stop insect development, which will continue when the temperatures rise. Heat hastens insect development. The National Oceanic and Atmospheric Administration (NOAA) can supply hourly or daily records of temperature, humidity levels, precipitation, and cloud cover for any of their widely scattered weather stations. Agricultural and military sources also provide weather data.

Maggot Math

The postmortem interval can be determined by the first fly's growth cycle. Researchers know how long each species cycle is under laboratory conditions and can compare that to the conditions found on the body. This is done by converting the time it takes an insect to complete its metamorphosis into Accumulated Degree Hours (ADH). For example, if a maggot is found on a corpse and is identified as a third instar of a calliphorid fly, the forensic entomologist can look back at lab studies and calculate that in controlled conditions it takes that species 45 hours to go from egg to third instar—16 hours as an egg + 18 hours as a first instar maggot + 11 hours as a second instar maggot. This is converted into ADH by multiplying the hours by the mean temperature Celsius:

45 hours × 26.7 degrees C = 1,201.5 Accumulate Degree Hours

This is changed into Accumulated Degree Days (ADD) by dividing ADH by 24 hours to get 50.0625 ADD. That is the figure that the forensic entomologist starts with to work backward through time from the moment of collection until the total number of ADH are reached.

This is done with a new set of calculations involving the mean temperature at the crime scene for each day that has passed from egg laying to insect collection. The forensic entomologist has to calculate how long that process would take under temperatures of the past few days at the crime scene.

Example:

Total ADH for the insect to reach second instar under lab conditions = 907 ADH

Day 1, October 15: A body is found and insects are collected at 9:00 A.M.

Total time elapsed = 9 hours

Mean temperature for that day = 20 degrees C

9 × 20 = 180 ADH for Day 1

Day 2, October 14:

Total time elapsed = 24 hours

Mean temperature for that day = 21 degrees C

24 × 21 = 504 ADH for Day 2

Total ADH for two days = 684 ADH. The forensic entomologist subtracts 684 from the total 907 to find that only 223.8 ADH are left unaccounted for, or less than a day's growth. To figure out what time the eggs were laid on the third day, the ADH remaining (223.8) is divided by the temperature on that day.

Day 3, October 13:

The temperature on October 13 = 20 degrees C

Divide 223.8 ADH remaining by 20 degrees to = 11.2 hours

From midnight, subtracting 11.2 hours places the time of the first insect activity to be between 12 noon and 1:00 p.m. on October 13. This is not the time of death, but the minimum time that had to have elapsed between death and collecting the insects.

Similar calculations are conducted on several species in order to get the most accurate estimate for postmortem interval. This technique of using a single insect's or species' development to determine time since death works well when the species was the first to lay its eggs on the body. But the more time that elapses between death and the discovery of the body, the less accurate the estimate will be, because several factors can alter the timetable. For example, insects are delayed from getting to exposed flesh when a body is tightly clothed or wrapped.

On New Year's Eve 1988, a body of a woman was discovered hidden in some underbrush. The body was tightly wrapped in two blankets, bound with an elastic bandage. Inside the blankets, Dr. Goff recovered several species of insects in various stages. Calculating the ADH for several of the species and taking into account the ambient temperature supplied by the weather station located a half mile away, Goff estimated the onset of insect activity at 10.5 days before the body was discovered.

Witnesses, however, claimed they had last seen the woman alive 13 days before the body was discovered. This left a gap of 2.5 days unaccounted for. To settle this discrepancy, Goff experimented on a pig carcass that he wrapped in the same manner as the victim and set out in a similar location. At the end of the experiment, Goff discovered that the first insects took precisely 2.5 days to make their way through the wrapping to get to the body and lay their eggs.

Succession Patterns

When the maggots leave a corpse, it becomes harder to determine an accurate postmortem interval, so rather than relying on fly species for an estimate, forensic entomologists determine postmortem interval by the arrival and departure of many kinds of insects over time. For example, when the body of a young man was finally discovered, most of the flies had come and gone, leaving behind a host of other insects to analyze. Goff collected a type of fly called a cheese skipper, which arrives at a corpse no later than a week after death. He also found the empty pupa of the hairy maggot blowfly that takes up to 17 days to emerge, as well as 11-day-old soldier fly maggots. Soldier flies do not come to the corpse quickly, but wait until 20 days after death to lay their eggs. Piecing together this entomological puzzle revealed an estimate of approximately 29 to 31 days of insect activity. When the police confronted the two suspects with the entomological evidence, they confessed.

Was the Body Moved?

Entomologists have known for a long time that insect species follow a very specific pattern in life, and this specificity can indicate whether a body had been moved. For example, some flies are heliophilic, which means they prefer to lay their eggs on warm surfaces or bodies sitting out in the sun. Other blowflies prefer cool temperatures and will visit only those bodies that are in the shade. There are species that prefer urban areas like the fly species *Calliphora vicina*, and those that prefer rural environments like the *Calliphora vomitoria*. If an insect is discovered on the body that is not normally from the area, then investigators can assume the corpse had been moved.

Even without a body, entomologists can tell if a corpse had once been located in a certain area by analyzing the insects that live in the soil. When a body decomposes, fluid seeps down into the ground and changes the pH levels. The insects that once were in the area leave and are replaced with insects that are attracted to the altered environment. If the postmortem interval for the soil-dwelling insects does not corroborate the postmortem interval for the insects on the body, then the police can suspect that the body had been moved after death.

Even the absence of insects can be important forensic evidence. If there are no insect larvae on a corpse that is lying outside, the police know that either death just occurred and not enough time has elapsed to attract insects, or death occurred somewhere else and the body was moved. It might also mean that the body had been frozen. Freezing a body temporarily stops decomposition, and insects will not be attracted to the remains until it has thawed.

Insects on a Suspect

Bugs on or under the body are only half the story. Bugs found on the clothes or even the car of a murder suspect could be the key evidence placing him or her at the scene of the crime. One case in Texas hinged on the single leg of a grasshopper. An exam of the body of a murdered woman revealed the remains of a mashed grasshopper. It was put aside with the other evidence, but it was not considered significant until a search of the suspect's clothing revealed a disarticulated leg of a grasshopper in the cuff of the man's pants. Microscopic analysis showed that the fracture marks on the grasshopper leg and grasshopper thorax matched.

Another case hinged on insect bites. During the recovery of a murder victim found in a field, the investigators received many nasty bites from chiggers, which are the larvae of mites. Chiggers have very specific habitat requirements and are limited to certain locations, so when one of the suspects who was brought in for questioning had similar bite marks, the investigators became suspicious. The suspect said that his welts were the result of flea bites acquired at a relative's house. The investigators set traps in and around the house to catch fleas or chiggers that might corroborate or refute the suspect's testimony, but they came up with nothing. The suspect who had prior sexual-assault arrests was linked to the body by chigger bites.

Underwater Insects

In the summer of 1989, divers exploring the murky waters of the Muskegon River in Michigan discovered a car, and when they peered through its submerged window, they saw a female body still buckled into the driver's seat. The police hauled up the car and sent the body to the morgue for an autopsy, which showed that the injuries to the woman's head were not consistent with how the car seemingly plunged into the river. Such inconsistencies usually add up to foul play, and in many cases, the police do not have to look beyond the immediate family of the victim for a murder suspect. In this case, the victim's husband was suspected of the crime.

The victim's husband claimed that he had last seen his wife in June of 1989. He told police that he and his wife had an argument and she had driven away still angry. It had been a foggy night and perhaps she had lost her way and accidentally plunged into the river. But cocoons found on the car's fender proved him to be a liar. In the winter, black flies are in their larval stage, and in the spring, they go underwater in a river or stream and weave cocoons, attaching themselves to rocks or other large hard surfaces, such as a submerged car. Because of the cocoons, the forensic entomologist determined that the car had to have been in the water no later than April or May, but not as late as June. The husband had killed his wife and dumped her car and body into the river in the spring, long before he reported her missing in June. Insects unmasked another murderer. The husband was convicted and sent to prison.

Bugs and Drugs

Because insects feed off of dead flesh, they become intimately linked with the body, capable of revealing not only the time that death may have occurred but also glimpses of how death occurred. In 1980, forensic entomologists used for the first time insect information as an alternate source for drug testing human remains.

The nearly skeletonized body of a 22-year-old woman was found near a creek bed with an empty prescription bottle at her side. Although the soft tissues had almost disappeared, there were many maggots still left on the remains. Part of the autopsy procedure for any apparent suicide would have included a drug test using the soft tissues or organs of the victim, but there was not enough soft tissue available for toxicology testing. Entomologists substituted maggots that had fed on the flesh and therefore ingested any possible drugs from the victim's tissues. Thin-layer chromatography, the same test a pathologist would use on a human liver sample, was used on the maggot material. The maggots were pureed in a blender, then placed on a glass plate and subjected to a developing solvent, which separates out the various components into visible bands. A reagent is applied to highlight the bands, revealing what kind of drug was present. When the first maggot sample was processed it revealed the presence of phenobarbital. The maggots had fed on tissue with a high concentration of the drug, corroborating the assumption that the woman died of an overdose.

Another possible overdose case involved remains that were so old they were completely skeletonized. There were no insects remaining that might have ingested soft tissue, but there were empty pupal cases and beetle droppings scattered around the skeleton. Testing hard casings had never been done before, and Wayne D. Lord at the FBI's Forensic Science Unit Laboratory had to develop a new method, which could break down the durable chitin. The pupal cases were tested and revealed the presence of an antidepressant drug.

Because droppings and pupal cases are so durable and last many years, they offer police investigators an important tool for determining cause of death in skeletonized remains. But the recent influx of designer drugs has increased the array of possibilities in drug testing, as well as confused the assessment of the postmortem interval. More research is needed to determine the effect the drugs have on an insect's development. Entomological research is branching out in other directions too. Soon, scientists will be able to routinely extract human genetic material from bloodsucking insects like mosquitoes, lice, and bedbugs in order to trace the deoxyribonucleic acid (DNA) to the person who was bitten.