Do you know what happens to you after you die?

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When we die, we will decompose and we may be colonized by carrion insects. These insects recycle our bodies back to the earth but, as insects develop at a predictable rate and colonize in a predictable sequence, they can be used to indicate the minimum elapsed time since death, which is extremely important in a homicide investigation. Insects are often the first witnesses to a crime. Knowing the time of death can make or break an alibi and help identify an unknown victim. Carrion insects can also indicate whether the body has been moved or disturbed, has suffered wounds or has been poisoned, and can even be used to identify a victim when no body is found. In living victims, insects may cleanse necrotic wounds and can be used to estimate how long an abused or neglected person or pet has suffered.

Most people don't want to think about it, but what does happen to our body after death? You probably won't be pleased to hear that, mostly, we get eaten. We are just a big bag of nutrients – in other words, food; and many organisms love us. Our bodies support an entire ecosystem. In life, we have a vast array of microbes, on and in us, most of which are beneficial, helping us fend off diseases, digest food, etc. but once we die, they, and others that join in, start to break down our bodies. But interacting with the microbes are the animals that I am more interested in, the insects.

Insects

There are vast numbers of insects in the world. It is estimated that there are around 1.4 billion insects per person in the world, and the *Globe and Mail Newspaper* in Canada recently estimated that all the insects in the world outweigh all the humans by 70 times. But most of them, 99%, don't directly interact with humans at all, and of the 1% that do, probably less than 0.1% have a negative impact on us. Yet most of us still consider them nasty, irritating and even dangerous. In actual fact, insects are extremely beneficial, and without them, we would probably not exist, but there is no room here to get into all the beneficial aspects of insects, so let's just talk about one: the role insects play in recycling a dead body (not just ours, but any animal's body) back to the earth and, in so doing, allow forensic entomologists to estimate the elapsed time since death of a person, as well as many other factors about a crime scene, such as whether a body has been moved or disturbed after death.

Decomposition, insects and dead bodies

Immediately after death, a body begins to break down biochemically, due to enzyme and microbial activity. This autolysis and putrefaction results in the gaseous release of many volatile organic compounds (VOCs), which change in strength and variety over time as the body goes from fresh through decomposition. The body's proteins, fats and carbohydrates are broken down by a variety of biochemical processes. Proteins are broken down by proteolysis, starting with the neuronal and epithelial tissues such as those lining the gastro-intestinal tract, or gut, then other tissues such as muscles, collagen and epidermis. These tissues are broken into peptones, amino acids, polypeptides and proteoses, then further into compounds containing sulphur, nitrogen and phosphorous. The majority of adipose or fatty tissue is made up of lipids, which in turn are primarily triglycerides. Triglycerides are broken down into glycerin and free fatty acids via saponification and other lipids are broken down via hydrolysis into fatty acids, and then down to saturated and unsaturated fatty acids. In moist, anaerobic conditions, adipose tissue may break down to adipocere, a pasty or chalky soap, which may be preserved for decades or more and I have heard from colleagues that it can even preserve a knife wound so well that the weapon itself can be identified. Complex polysaccharides or carbohydrates are broken down to simple sugars by the actions of microorganisms, and eventually to water and carbon dioxide. This process can also result in the production of alcohol, which can create problems when samples are taken from a body to determine pre-mortem alcohol consumption. All

these processes are greatly impacted by bacterial action, humidity and temperature.

Certain groups of insects, the carrion insects, are attracted to these products of decomposition. The first group of insects, the blow flies (Calliphoridae), which are the big, buzzy, blue, green, metallic flies you see flying around your recycling bin and BBQ, are attracted by the very first VOCs to be released and can detect a dead body over substantial distances. Once they are closer, they locate the remains visually. They are attracted to a body primarily to lay their eggs. They may arrive in minutes or even seconds if the conditions are appropriate. They lay their eggs on the body, usually in an orifice or wound, and those eggs hatch into larvae or maggots within less than 24 hours. They then feed on the body, recycling nutrients back to the earth to be utilized by plants, which are eaten by animals, and life continues.

Using maggots to estimate time since death

Insects are cold blooded, meaning their activity and rate of development is dependent on ambient temperature. As temperature increases, they develop faster and as it decreases, they develop more slowly and this is a linear relationship, making it predictable. Eggs hatch into first instar or stage larvae (maggots); then as they feed and moult, they go through a second and third instar. They often form large maggot masses during the third instar (Figure 1). After feeding for some days, the third instar larvae leave the food source in search of a safe, dry place in which to pupariate (Figure 2). They then form an outer hard, pupal case, much like a caterpillar forms a chrysalis, inside which they metamorphose or change to the adult fly. As the immature blow flies develop through their life cycle at a predictable rate, forensic entomologists can estimate the length of time that insects have been associated with the body, using four factors:

- The oldest stage that the insects have reached (so are the ones that reached the body first)
- The species of insect(s) (as all insects develop at a different rate)
- The local ambient temperature (usually using nearby government weather stations)
- Published, peer-reviewed literature on insect development rates

The forensic entomologist estimates the length of time that insects have colonized the remains, based on the minimum age of the insects on the body. For example,

Figure 1. Blow fly maggot masses on a pig carcass (G.S. Anderson)

Figure 2. Pre-puparial third instar blow fly larvae leaving the food source in search of a suitable site in which to pupate. Note darkened crop area, which contains the DNA of the host (G.S. Anderson).

they may state that the oldest insects associated with the body are 7 days old, therefore, the insects have been on the body for a minimum of 7 days, inferring that the person died 7 or more days prior to discovery. It could be more (we estimate a minimum) but could not be less, and this is what we will stand on in court. Such timing can make or break an alibi and provide investigators with a timeline, which may be helpful in identifying the victim and investigating the death.

Using insect succession to estimate time since death

A decomposing body supports a rapidly changing ecosystem. As the body decomposes, microbial activity results in the body progressing through a number of rapid, physical, biological and chemical changes, as discussed earlier. As decomposition progresses over time, the chemical constituency of the body changes, going from fresh, through putrefaction and eventually very desiccated tissue, while releasing different VOCs over time. Different species of insects are attracted over this time by the differences in the released VOCs and by the consistency of the tissues. Some insects, such as the blow flies, have mouthparts, digestive enzymes and behaviours, such as massing, that allow them to consume fresh and early putrefying tissue, but precludes them feeding on dried tissues, whereas later colonizing species do not feed on wet tissues, but are specialized to feed on more desiccated tissues. Therefore, each decompositional stage attracts a different group of organisms. This sequence of insects that colonizes the body over time is predictable. It is different if the body is dumped in spring, summer or fall; if buried, exposed or hanging from a tree; in sun, in shade, in fresh or marine waters, or in different geographical areas; but within these parameters, it is predictable. Forensic entomologists worldwide develop local databases of insect succession on carrion in different geographical regions, seasons and habitats to be used in such investigations. This technique can be used for up to a year or more after death.

What else can insects tell us about a homicide?

In almost all forensic entomology cases, the entomologist is asked to estimate the minimum elapsed time since death; however, insects can also be used to assist in other parts of the investigation.

Has the body been moved after death? Many insects have very specific habitat preferences. For example, some insects are synanthropic, evolving to live in close proximity to human habitation. For blow

flies, this means that some species prefer to develop on human garbage and roadkill, as opposed to those, who you might consider continue to live the 'old-fashioned life' in rural areas, on naturally dead wildlife. Research in many areas has shown that some species are much more commonly found in urban environments and others in rural environments, with some studies showing a gradation through species from urban to rural. If a body is found in a rural area, with older, urban species on the remains, it is suggestive that the body has been moved from an urban area, which will help investigators to determine the manner of death (homicide, suicide, natural or accident) as well as indicate where the body may first have lain.

Has the body been disturbed after death? If a killer returns to the body, possibly to remove evidence, and they disturb the body, then insects may be able to indicate not just the time of death, but time of disturbance. For example, if a body is colonized, then buried deeply, then exposed again before reburial, there will be two distinct colonization times.

Are wound sites present? Wound sites may no longer be visible due to decomposition by the time the body is recovered, especially if the wounds did not impact the hard tissues. However, as very young blow fly larvae cannot penetrate adult, dry skin, the female blow fly usually lays her eggs at areas with liquid protein such as orifices or wounds. If maggots are found in an area such as the palms of the hand, it may suggest a wound site. It is up to the forensic pathologist to prove this, but the insects can point the way.

Did the victim use drugs or was the victim poisoned? Once a body is decomposed, it may not be possible to conduct traditional toxicological analyses on degraded tissue. However, the maggots are alive and therefore 'fresh' and bioaccumulate toxins so can be used as alternate toxicological specimens.

Can insects be used to identify the victim? Nobody cases, in which the body cannot be found, are notoriously difficult to solve. However, when blow flies feed, they retain food in a food storage organ called a crop (Figure 2), which is slowly used up during the pre-puparial stage when the maggot is searching for a suitable place to pupariate. This crop is filled with the tissue, and, therefore, the DNA, of the host, or victim, so can be used to indicate that the maggots fed on a specific person, even without locating the body itself.

Body farms

A great deal of research is required to understand development, succession and the many other dynamics that are involved in insect colonization of a body. For obvious reasons, animal carcasses have been traditionally used, and pigs are the most common human proxy as they are easy to obtain, can be acquired in large numbers for replication and have gut microbiomes and skin very similar to humans. But as we are applying the data to human homicide cases, wouldn't it be better to study human decomposition? Originally, it seemed unlikely to be possible. Where would you get human bodies? But, of course, humans have been donating their bodies for decades to medical research, why not for decomposition? Over 40 years ago, forensic anthropologist, Bill Bass, started the first human donor facility to study human decomposition at the University of Tennessee, in Knoxville, TN, USA. For years, it was the only facility in the world, but as interest in such research has grown, and people consider a green burial or decomposition to be much preferable to traditional environmentally damaging funeral practices such as embalming, and want their bodies to have a use after death, donations have climbed exponentially and at present there are eight such facilities in the USA, one in the Netherlands, one in Canada and one in Australia.

What if you are not dead?

Ok, you are thinking, at least I'll be dead, so I am not going to worry about insects eating me. But what if you aren't quite dead or not even a little bit dead? Will insects still eat you? Let's not worry about insect parasites that feed on the living but go back to our friends, the blow flies, that so kindly deal with our mortal remains. Some blow fly species, the same ones we were just talking about that feed on dead bodies, feed on dead organic matter, and living people can have dead organic matter on them, in the form of wounds that may have become necrotic if not treated. In such situations, the blow flies will be attracted to necrotic areas, lay eggs and the life cycle will proceed as normal. The only difference is that the rest of the person is alive. This is termed myiasis.

Medical maggots

This may sound horrific, but the insects are helping the person, by eating away the dead infected tissue, essentially cleaning the wound. In fact, maggots have been used in maggot debridement therapy for centuries and are still used today to clean stubborn wounds. They eat the dead tissue, without eating the live tissue (but please don't try this at home, as some species will eat live tissue); secrete antibiotics; alkalinize the wound, making it inhospitable for bacteria; secrete allantoin, which helps

heal; and their presence appears to jump start the body's own immune system.

Forensic importance of myiasis

In medicine, sterile maggots are placed on a wound in a controlled setting, but in a forensic case, flies lay eggs on the wounds of a person or animal that has an injury which has not received medical treatment. Usually, the person is incapable or unwilling to keep the area clean, such as a young baby in filthy diapers, a bedridden person with bedsores or a pet with hotspots that have not been cleaned. In such cases, a forensic entomologist can estimate the length of time that the person or animal has been neglected, based on the maggot age. For example, forensic entomology has been used in cases to indicate child abuse by showing that a child has not had a diaper change in many days, or animal abuse, to indicate that an injury was not treated so the animal suffered for days before being seized by animal protection officers.

Conclusion

So, in answer to the original question, you will decompose and, quite possibly, depending on how and where you died, you may be fed upon by insects. But think of this as a good thing. It is a natural way to be recycled back to the earth you would be supporting a great ecosystem, and if you are unfortunate enough to have been murdered, the insects may help solve the crime. ■

Further Reading

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