

Beyond the grave – understanding human decomposition

Arpad A. Vass

Eventually all human lives come to an end. Forensic anthropologist Arpad Vass explains the role of microbes in our bodies after death.

Human decomposition begins approximately 4 minutes after death has occurred. The onset is governed by a process called autolysis – or self-digestion. As cells of the body are deprived of oxygen, carbon dioxide in the blood increases, pH decreases and wastes accumulate which poison the cells. Concomitantly, unchecked cellular enzymes (lipases, proteases, amylases, etc.) begin to dissolve the cells from the inside out, eventually causing them to rupture, and releasing nutrient-rich fluids. This process begins and progresses more rapidly in tissues that have a high enzyme content (such as the liver) and a high water content such as the brain, but eventually affects all the cells in the body. Autolysis usually does not become visually apparent for a few days. It is first observed by the appearance of fluid-filled blisters on the skin and skin slippage where large sheets of skin slough off the body. Meanwhile, the body has acclimated to ambient temperature (*algor mortis*), blood has settled in the body causing discoloration of the skin (*livor mortis*) and cellular cytoplasm has gelled due to increased acidity (*rigor mortis*). After enough cells have ruptured, nutrient-rich fluids become available and the process of putrefaction can begin.

Putrefaction is the destruction of the soft tissues of the body by the action of micro-organisms (bacteria, fungi and protozoa) and results in the catabolism of tissue into gases, liquids and simple molecules. Usually, the first visible sign of putrefaction is a greenish discoloration of the skin due to the formation of sulfhaemoglobin in settled blood. The process progresses into distension of tissues due to the formation of various gases (hydrogen sulfide, carbon dioxide, methane, ammonia, sulfur dioxide and hydrogen), especially in the bowels, but I have seen this in many parts of the body, including the face, lips and groin. This is associated with anaerobic fermentation, primarily in the gut, releasing by-products rich in volatile fatty acids, mainly butyric and propionic acids. Gas and fluid accumulation in the intestines usually purge from the rectum, but can be severe enough to rip apart the skin causing additional post-mortem injuries. Shortly after the purging of gases due to putrefaction, active decay begins. Muscle, composed of protein, which in turn is composed of amino acids, readily yields to the formation of additional volatile fatty acids through bacterial action. Further protein and fat decomposition yields phenolic compounds and glycerols. Compounds, including indole, 3-methylindole (skatole), putrescine, cadaverine and various fatty acids have been detected and are significant decomposition products. At this point in the decay cycle electrolytes are rapidly leaching out of the body, both aerobic and anaerobic bacteria are present in large numbers, insect activity

is very prominent and carnivores can contribute significantly to the decline of the corpse.

Saponification (the formation of soap from fat under high pH conditions) or adipocere formation typically occurs after the onset of putrefaction in warm, moist, environments and is seen as deposits of a yellowish-white, greasy, wax-like substance. Adipocere develops as the result of fat hydrolysis with the release of fatty acids. Adipocere consistency varies with the type of material to which it is bound and gives some indication as to the rate of decomposition. Rapid decomposition is indicated by a hard and crumbly composition if bound with sodium (primarily from interstitial fluids), but a soft, paste-like complex is formed when bound with potassium (from the breakdown of cell membranes), potentially



indicating slower decay rates. Adipocere formation is accelerated by the post-mortem invasion of tissues by bacteria, especially putrefactive species such as *Clostridium* and it takes from several weeks to months to form.

Mummification is typically the end result of tissue, usually skin, with no nutritional value, which has survived the active decay process and is formed by the dehydration or desiccation of the tissue. Remaining skin is converted into a leathery or parchment-like sheet which clings to bone. Mummification most commonly develops in conditions of dry heat or in areas that have very low humidity, such as in arctic regions or deserts.

Bone goes through yet another complex process called diagenesis. Diagenesis is a natural process

that serves to alter the proportions of organic (collagen) and inorganic components (hydroxyapatite, calcium, magnesium) of bone exposed to environmental conditions, especially moisture. This is accomplished by the exchange of natural bone constituents, deposition in voids or defects, adsorption onto the bone surface and leaching from the bone.

Historically, the progression of human decomposition has been described as taking place in four stages: fresh (autolysis), bloat (putrefaction), decay (putrefaction and carnivores) and dry (diagenesis). Current thinking is that it should be segregated into pre- and post-skeletonization, since stages are not always observed and in fact may be totally absent, depending on the taphonomy of the corpse. All these processes together (autolysis, putrefaction and diagenesis) eventually result in complex structures composed of proteins, carbohydrates, sugars, collagen and lipids returning to their simplest building blocks – essentially dust to dust.

● How long does decomposition take?

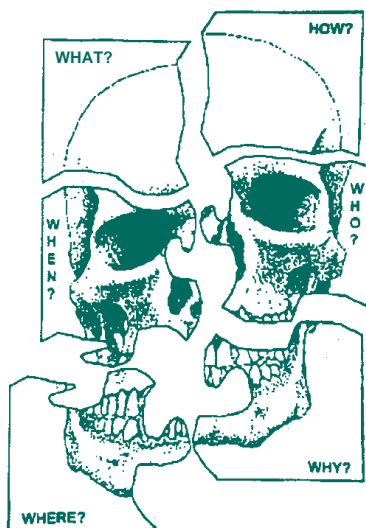
Decomposition is a complicated process, but is primarily dependant on temperature and to a lesser extent on moisture. In our studies we have worked out a simple formula, which describes the soft tissue decomposition process for persons lying on the ground. The formula is $y=1285/x$ (where y is the number of days it takes to become skeletonized or mummified and x is the average temperature in Centigrade during the decomposition process). So, if the average temperature is 10 °C, then $1285/10 = 128.5$ days for someone to become skeletonized. Of course, this is a rough estimate since many factors affect this rate and it is typically used at a crime scene when investigators need some time frame from which to begin their investigation. Buried individuals and ones submerged in water have different rates of decomposition. Injuries affect the rate as well since damage to the skin increases blood loss, insect and bacterial action. In severe environments, such as in the arctic or in deserts, rapid desiccation occurs and this makes any accurate determination extremely difficult. Carnivore activity is yet another factor which can radically affect decomposition. Exclusion of insects and carnivores will slow down the process, whereas exposure to many (or larger) carnivores will increase the rate. Remember that decomposition does not end after the soft tissue has disappeared. The skeleton also has a decompositional rate that is based on the loss of organic (collagen) and inorganic components. Some of the inorganic compounds we use to determine the length of time since death include calcium, potassium and magnesium. As with soft tissue, these leach out of bone at a rate determined primarily by temperature and exposure to moisture. As a general rule, bones, within the first year, will begin to bleach and one may see growth of algae or moss on them. Within the first decade one will expect to see exfoliation and the formation of large cracks in the bone. Roots from nearby vegetation may grow into the bone mass, significant rodent gnawing will be present and the appearance of annual leaf falls is evident.

● The role of microbes

When I began studying human decomposition over a decade ago in an attempt to determine a more accurate method for estimating the post-mortem interval, I began by investigating bacteria. The concept was that since insects can be used for this task, given that they arrive in characteristic, identifiable waves, why shouldn't bacteria behave in a similar fashion? It only took 3 months to quickly abandon this concept. Even in the very early stages of decomposition, I was inundated by the sheer numbers of organisms isolated – *Staphylococcus*, *Candida*, *Malasseria*, *Bacillus* and *Streptococcus* spp. – just to mention a few. As decomposition progressed, putrefactive bacteria were thrown into the mix followed rapidly by anaerobes.



LEFT: Examples of two stages of human decomposition. The top photograph shows a male subject in active decay after 12 days. The lower photograph shows the same subject after 97 days in the dry stage of decomposition where only mummified skin remains. In temperate regions of the United States individuals can be completely skeletonized in 30–40 days in the summer. PHOTOS A. VASS



ABOVE:
The five 'W's.
COURTESY STACEY BARSHACK,
OAK RIDGE

These included micrococci, coliforms, diptheroids and *Clostridium* spp. There was a preponderance of certain organisms such as *Serratia* spp., *Klebsiella* spp., *Proteus* spp., *Salmonella* sp. and even gliding bacteria like *Cytophaga* – not to mention pseudomonads and flavobacteria. As these mixed with environmental micro-organisms such as *Agrobacterium*, amoebae and many colourful varieties of fungi and, of course, those brought to the corpse by flies and other insects, I relented. I came to the conclusion, somewhat facetiously, that with the exception of micro-organisms living in deep-sea vents, every micro-organism known is involved in some aspect of the human decompositional cycle from *Acetobacter* to *Zooglea*. While many of the organisms isolated come from the bowel and respiratory tract, literally hundreds of species are involved in the decompositional process and decomposition would not progress without them.

One particular forensic case comes to mind that illustrates this point. Workmen clearing limbs from a roadside guardrail (in the summer) discovered a fully clothed woman dead for an undetermined time. No indication of decomposition and no insect activity led investigators to initially believe this was a very recent homicide. In actuality the woman had been dead for nearly 4 months. She had been sprayed with insecticide (and other chemicals) by the perpetrator to mask the odour of decomposition so she wouldn't be found. Unwittingly, the murderer had essentially sterilized the body and prevented flies from laying eggs. Autopsy showed some internal decomposition, but it was significantly reduced. Apparently, the chemicals seeped into her lungs and then spread throughout her body.

Taphonomic circumstances also play a role in the response of micro-organisms. Several years ago, grave robbers, searching for artefacts, unearthed the coffin of an American Civil War Colonel (Col. Shy). The caretaker of the cemetery called in the police who found a fresh corpse in the grave. After significant investigation, it was ascertained that the fresh corpse was indeed Col. Shy, who 'still had red meat on his bones'. At that time prominent soldiers were buried in solid lead coffins – the lead had 'sterilized' the body by poisoning the microflora and decomposition had not progressed past initial autolysis.

● Why study human decomposition?

It is critical that the decomposition process be understood because it impacts on forensic investigations in a variety of ways. At every crime scene many questions are asked, but to solve the crime the five 'W's' (who, what, when, where and why) must be answered. Studies into human decomposition help answer four questions: who is the victim, how did the victim die, where and when did the victim die? In addition to being extremely useful for 'Time Since Death' determinations, the identification

of decompositional products may also be relevant to victim identification. The presence of melanin, for example, may help establish the race of the victim, especially when key skeletal elements are absent. The quantity of various decompositional products, such as fatty acids, may help determine the weight of an individual, which can also be useful in determining the victim's identity. This would be crucial, especially when articles of clothing are unavailable at the crime scene. Knowledge of any trace amounts of chemicals, drugs, medications or toxins present in decomposed tissue may also be of help to investigators in attempting to determine cause of death. Additionally, the study of decompositional products may even be useful in locating human remains or clandestine grave sites by improving the training procedures for cadaver recovery dogs, through the determination of the alerting scent emanating from a corpse, or in the development of field instrumentation for assisting in cadaver recovery searches.

● The future

Current techniques to determine the post mortem interval using decompositional products (volatile fatty acids) can range from ± 2 days for soft tissue decay and ± 3 weeks using inorganics for skeletonized material, up to approximately 5 years. Currently we are looking at specific organ biomarkers, which we hope will narrow the estimated range down to less than 12 hours for the first several weeks of decomposition. New, sophisticated hand-held devices are being planned which can be used by police at a crime scene to give them immediate answers as to how long the victim has been dead and to help locate clandestine graves. Novel fingerprint and DNA recovery techniques will aid in both victim and perpetrator identification – all of which are made possible by an intimate knowledge of the decompositional process.

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