'PUTREFACTION IS THE WORK OF THE SPIRITS OF BODIES'

Francis Bacon, English Renaissance scientist.

These notes are the basis of a talk 'Survival of the Dead', first given in 1995.* It is based on humans, but is relevant to processes, especially in land vertebrates, in the early stages of becoming a more familiar fossil.

What happens at death: Basically the heart muscle chemistry and movement stop working (beating). No oxygen or nutrition goes to the rest of the body, thus leading to chemical and physical changes. This is the cycle of nature which transforms flesh into other forms, and hopefully allows us to understand our own mortality and give comfort to the bereaved.

CONSCIOUSNESS

Death awareness is the price we pay for self awareness. What happens to brain activity – 'I', consciousness, 'mind', soul (if you like)? Experimental work has had two approaches – the destination (or dead-researcher) approach and the vehicle approach. Two British experimenters in the first approach were Oliver Lodge, a Birmingham physicist (died 1940) who would communicate a secret message, and Robert Thouless, psychologist (died 1946), who would send a coded message. These do not appear to have been successful (?). In the second approach, if the something has weight, and abandons the vehicle at death, then place the dying person on some scales. One person to do this (from 1901, in American Medicine) was Duncan MacDougall, physician at the Massachusetts tuberculosis sanatorium. He weighed six men as they died and reported a double-tick of the needle by about 20 grams. He had critics – he had used an industrial silk scale; only one measurement went without a hitch; in two the authorities barged in; two died whilst the scale was being zeroed; in the other the scale was jostled. It was also suggested that the minute weight loss was via moisture exhalation and sweat.

If consciousness is information energy (and the First Law of Thermodynamics states that energy is neither created nor destroyed) it will survive death, but in a different form. If we use Einstein's

* when I gave this talk in 2009 'Matthew Tacket' (Ipswich Evening Star, 28th November) commented: 'This is, of course, a subject most of us never want to think about – and frankly I have no interest at all in going along to such a talk.'

formula to convert brain activity into its equivalent mass, we get a very very small amount, measured in picograms (trillionths of a gram).

DECOMPOSITION

Changes start within minutes of death in what may be termed the 'fresh' stage. Carbon dioxide begins to accumulate in the blood, the resulting acidity causing cells to burst and release enzymes which will digest tissues from within. The action of gravity causes skin and muscle to sag, and blood settles in the parts of the body closest to the ground forming purple-red stains (known as livor mortis). The rest of the body turns pale. The cornea of the eyes cloud over as the bacteria which live within us feed on us.

After a short time muscles stiffen as rigor mortis sets in as the body cools. The muscles have contracted as the amount of calcium ions in the cells increase and the phosphorus-rich ATP molecule (which provides energy) is not replenished.

After two or three days the body softens. This has nothing to do with relaxation, but is due to enzymes from within the lysosomes inside each cell breaking down the proteins (that hold the muscles in their contracted state) into amino acids. [This is what happens when you tenderize meat]. As tissue dries out it shrinks away from nail folds and hair shafts.

PUTREFACTION

When enough nutrient-rich fluid has come from burst cells it travels along the structures of the blood and lymphatic systems, rapidly spreading enzymes and bacteria. Aerobic bacteria first exhaust any remaining oxygen in the corpse. They are followed by the anaerobic bacteria which live in the large intestine, mainly coliforms, Clostridium, etc. feeding on sugars and proteins in the tissues. From the outside a green discolouration appears on the right lower abdomen (where the bowel is near the surface), slowly spreading to the chest and upper thighs, and turning to purple and black. The green colour comes from the anaerobic bacteria converting blood haemoglobin to sulfhaemoglobin.

Bacterial metabolism creates gases, including carbon dioxide, methane, ammonia, sulphur dioxide and hydrogen sulphide, contributing to the repulsive smell of rancid organic material. Hydrogen sulphide also combines with the iron in haemoglobin to form iron sulphide,

which turns the skin darker. Gases migrate along the planes of the tissues making the flesh billow; under slight pressure the top layer may slip off. Hair, nails and teeth loosen, red blisters appear on the skin. Methane contributes to the 'corpse candles' of churchyards (when it burns in air). The gases also bloat the body, mainly inflating the face, abdomen and male genitalia; eyes bulge, the tongue protrudes (fluid comes out of the mouth when lungs rupture by pressure) and finally the bloated abdomen ruptures (bursts open).

Internal organs liquefy as enzymes act on cells, breaking down complex fats and proteins. Proteins break down to amino-acids and amino-acids are broken down to ptomains (amines), two foul-smelling colourless nitrogenous compounds formed in corpses. The amino-acid ornithine breaks down to putrescine, $NH_2(CH_2)4NH_2$, and lysine breaks down to syrupy toxic cadaverine, $C_5H_{14}N_2$.

Soluble matter may be removed by the action of water, leachate fluid draining into the ground. Coliform and faecal streptococci bacteria may be rare groundwater contaminants.

The more acid environment of the body is suitable for the growth of fungi (their reproductive bodies show on the surface of the skin). Insects and their larvae feed on the remains.

SKELETAL REMAINS

Once all the flesh is consumed all that is left is the skeleton. The bone minerals are chemically broken down when in contact with acidic soil and water, and mechanically broken up by tree roots (which absorb the phosphorus of the bones) and animals. Any bones found may crumble to powder at a touch. Collagen in bones is one of the last proteins left, to be broken down by bacteria and fungi.

In the end all has been recycled.

SLOWING THE PROCESS

Decay under warm moist conditions will leave only the skeleton in a matter of months. Pathogens such as mad cow disease prions and anthrax spores may last for decades.

Bacteria cannot work in completely dry conditions and tissues will mummify.

Bacteria do not work well in natural preservatives such as peat bogs and ice, and the body's enzymes do not work. If the body is in

cold soil, anaerobic bacteria such Clostridium perfringens when breaking down fat in body tissues may produce adipocere. Also known as corpse, grave, or mortuary wax, adipocere is a wax-like material composed mainly of palmitic, margaric and oxymargaric acids.

The commonest artificial way of temporarily delaying decay is to inject (embalme) the body with formaldehyde. It kills bacteria, repels insects, stops enzymes working and links amino acids making them more resistant to decomposition. Instead of natural decay, it coagulates proteins in any creature that eats the corpse and can pollute groundwater in burial places.

SPEEDING UP THE PROCESS.

In the wild, hungry scavengers such as vultures will speedily skeletonise a body and spread bones far and wide.

Another way to avoid decay is cremation (burning), which releases carbon dioxide. The average body takes 45 minutes to 2 hours at say 900°C. The occiput (nuchal region), scapulae (little covering of flesh) and vertebrae and sacrum are the last to burn (deficient oxygen) if the body is face-up on the floor; foot bones, with no thick muscle surround to protect them, are usually well fired. With the body face down on the floor, it is the frontal bone, facial skeleton, patellae and the medial ends of the clavicles which are the last to burn. Shrinkage is apparently negligible. Such information can be useful when studying cremated archaeological remains. Today, remaining bones are usually ground to fine ash in a cremulator machine. Brown lumps ('clinker') beneath the head (not found with bald or close-cropped males) are mainly transformed keratin from hair.

IN WATER; IN SEDIMENT.

A body with water (not air) in the lungs will sink initially. When bacterial decomposition produces gases it becomes buoyant and floats. Most rise with spine uppermost, but women and obese persons may rise face-up because of gas forming in breasts and large abdomens.

If a body is covered by sediment it is less accessible to the agents of biological breakdown and becomes subject to different chemical and physical changes — to mineralising solutions and to tectonic stresses on a geological timescale. But very few get that far.

R. Markham
