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Editorial

Death and the octopus

Florian Maderspacher

In the midst of life, it happens that death comes
and takes a measure of man. That visit is forgotten, and life goes on. But in silence
the suit is being sewn.

Tomas Tranströmer, *Black Postcards*

It does not happen often that a zoology class turns emotional, but I recall vividly how a film we were shown as undergrads, a production of the notoriously unromantic German *Institut für Film und Wissenschaft*, left us with an eerie sense of wonder and sadness. The subject was the life cycle of the octopus, and a female was being observed in an aquarium as she laid her clutch of thousands of eggs. Over the next couple of weeks, she stopped eating and tended to her eggs meticulously, chasing away intruders and fanning her developing offspring with oxygen-rich water — all testament to the rich behavioural repertoire and cognitive skills of these awesome creatures. But when her brood began to finally hatch, a gripping moment unfolded: as her offspring slipped out of its egg cases, the exhausted mother was swimming among them, with increasingly weaker twitches. And soon she was in her death throes. As her lifeless body sank to the bottom of the tank, her countless offspring swam carelessly around her. This is what a 'natural death' looks like for an octopus.

Death may seem a weird choice of topic for a special issue of a biology journal — after all isn't death the very end of biology? In human imagination, death is a merciless, grim reaper that comes knocking when and where you least expect it. At least that's what it was like for the millennia during which our species evolved. But for the octopus (and perhaps for future humans), death appears to be the logical consequence of a sequence of life events: mating, spawning, brooding, and then death.

When brooding begins, the behaviour of the female octopus changes dramatically. Usually, the female refuses further mating and reduces food intake drastically. In an extreme case, the deep-sea octopus *Graneledone boreopacifica*, brooding can take up to four years during which the female does not eat and just guards her eggs while her body deteriorates. However, the obvious suggestion, that death is but a consequence of the brooding-induced hunger strike, is perhaps all too simple. Instead, the — deplorably few — experiments that have been carried out to investigate this fascinating phenomenon seem to suggest that octopus death might be, at least in part, the result of an active death program, a kind of auto-destruct sequence.

These experiments were done nearly 40 years ago on *Octopus hummelincki* and revealed that events ultimately leading to the death of the female are controlled by an endocrine organ in the octopus brain, the optic gland. When the gland is removed experimentally after the eggs have been laid, the female octopus resumes mating and eating just as she did before egg-laying. Most notably, however, they live on for much longer.

What precisely causes death in the octopus is not clear. The classic experiments seem to suggest that some females from which the optic glands have been surgically removed continue to live, even without eating. So, death must have other causes than just food deprivation. Yet, it seems very hard to imagine what such an organism-level auto-destruct mechanism might look like. Of course, such mechanisms have been understood in great detail at the cellular level, where programmed death is a regular occurrence. But what kind of endogenous mechanism it would take to kill off a whole animal seems hard to envisage — clearly, a formidable biological problem awaiting curious and adventurous scientists.

What may be the evolutionary root causes of such a presumed active death mechanism? Sudden death shortly after reproduction, like

that of the female octopus, is not unusual in species that engage in only a single bout of reproduction. Such semelparity is very common among plants (for instance, the grains we live off), but also found in many animals. In some semelparous animals, as in many spiders that engage in dangerous sex acts, death is an inevitable consequence of the mating act — for the male — and it presumably increases the male's fitness, e.g. by providing additional energy boost to the female or by allowing for longer copulation.

In other cases, the causes of death are less obvious. Pacific salmon, for instance, die shortly after spawning and, as in the octopus, changes in the endocrine system are thought to be responsible. In particular, increased glucocorticoid levels might be what pushes the fish over the edge. The benefit here might simply lie in additional energy resources that are being mobilised for reproduction — a classic example of a trade-off.

Such trade-offs lie at the evolutionary heart of senescence and lifespan regulation in general. And ultimately, they are how death shapes life. In principle, death would not seem to have to be inevitable. There is no *a priori* reason why biological beings shouldn't be able to live forever. Biological structures can

be repaired, replaced and renewed, and in principle this renewal could go on indefinitely. And at least in the freshwater polyp *Hydra*, there don't seem to be any signs of senescence.

But from an evolutionary perspective, things look different. Typically, many organisms die before they reach old age, due to circumstances beyond their control, like being eaten by someone else. This means that mutations that might weaken or even kill the organism at a late stage of life are no longer weeded out by selection and accumulate in the population. And likewise, there is selection for mutations that increase fitness early in life, even if they have opposite, negative effects on survival later in life.

From an evolutionary point of view, ageing and death appear to be all but inevitable. Semelparous organisms are no exception. But a sudden, probably self-regulated death after reproduction can only evolve if it entails some sort of fitness benefit for the dying. And what precisely these benefits might be for the female octopus isn't clear.

Eventually, the octopus' controlled death mechanism, no matter how it works and how it evolved, is yet another example of the reign of death over the lives of animals. This is because the evolution of semelparity itself is thought to be a consequence of age-specific patterns of mortality, where adults suffer a comparatively higher risk of death than juveniles, such that it becomes more worthwhile for them to invest as much as possible of their resources into a single 'big bang' of reproduction. No matter how you flip it, death reigns over life and evolving organisms really exemplify that Heideggerian notion of Being-Toward-Death. And of course, ultimately, a large swathe of the evolutionary adaptations that characterise the diversity of life on earth are nothing but devices to escape death.

This dark force of biology is what our special issue tries to cast some light on, in its many guises.

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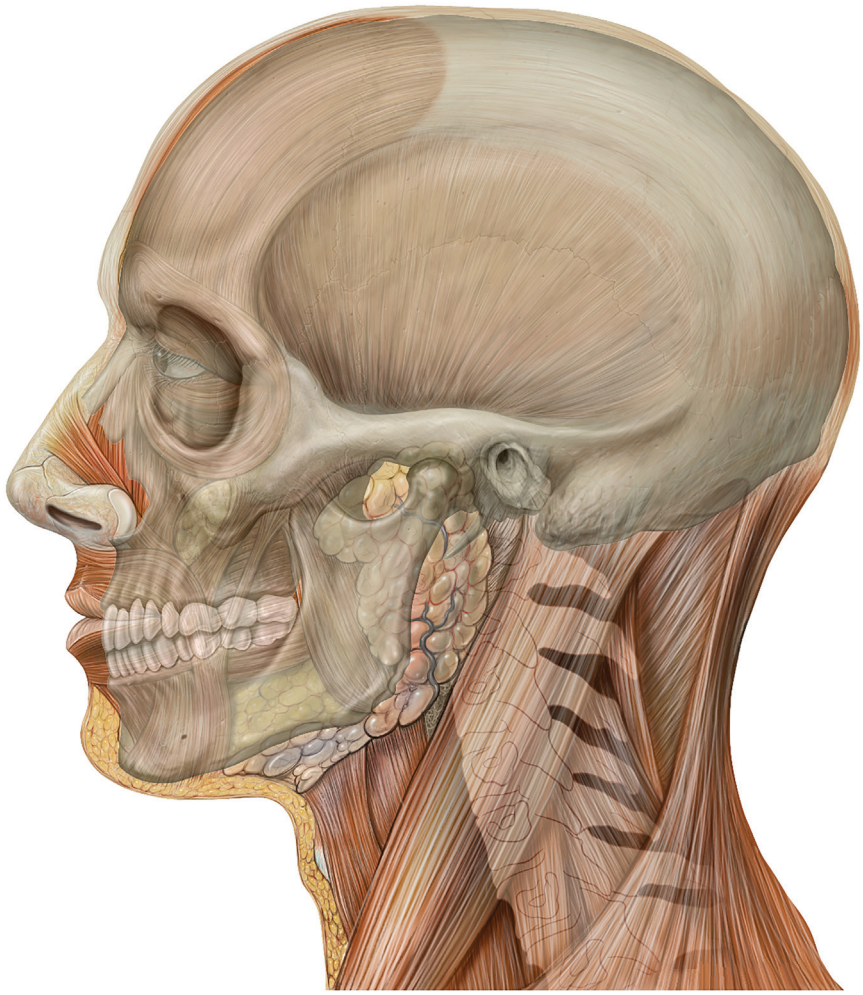
Feature

Heads of the dead

The most recognisable and iconic part of the human skeleton, the skull and its representations have served many different functions in cultures around the world and through the ages, reflecting different ways of dealing with death and remembering family, friends and foes. **Michael Gross** reports.

Gabriel Max (1840–1915) was a highly respected and sought-after painter in late 19th century Germany, to the extent that he could afford to entertain expensive hobbies, such as studying anthropology, which he did in several ways, including by keeping a herd of monkeys at his villa in Ammerland, on the shores of Lake Starnberg near Munich, and by collecting relevant objects from around the world. By the end of his life, this collection comprised around 60,000 objects, including hundreds of human skulls and mummified heads, most of which he had bought from travelling merchants and scientists in the 1870s.

The artist, who had been knighted as Gabriel Ritter von Max in 1900, wanted his collection to be kept intact after his death, which was a task beyond the means of his family. The city of Mannheim bought the complete



Face off: An anatomical illustration of the human skull and face, lateral view. (Credit: Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist.)