How invading fungus forces zombie ant's death grip

July 18 2019

Image of an ant who received honeydew from aphid. Photo: Dawidi, Johannesburg, South Africa, via Wikipedia.

If it's thoughts of zombies that keep you awake at night, you shouldn't be worried about zombie humans; it's the carpenter ants (*Camponotus castaneus*) that should concern you most. When infected by a specialised fungus (*Ophiocordyceps unilateralis sensu lato*), the hapless ants are unable to resist its potent power. Losing free will, the unfortunate victims locate tall pieces of vegetation, marching to a high point before the fungal infection forces them to clamp their mandibles—jaws—tightly onto a leaf vein or twig. There, the ill-fated host expires, only to be consumed from within by its evil fungal lodger, ready to scatter its spores below in the hope of infecting the next unsuspecting victim. Yet, despite the insects' loss of control, Colleen Mangold from Pennsylvania State University, USA, explains that the fungus does not attack their brains directly: 'the mandibular muscles ...

of infected ants are extensively colonised by the fungus', she says. Wondering how the fungus exerts control over the ants' powerful jaw muscles, Mangold and PI David Hughes decided to take a closer look inside the muscle itself. They have discovered that the fungus invades the mandibular muscles, breaks open the membrane covering the muscle fibres and forces the muscle to contract so forcefully that it wrecks the minute muscle filaments that slide past each other. The team publishes the discovery in *Journal of Experimental Biology* at jeb.biologists.org.

'The most difficult aspect of the study was the infections', says Mangold, explaining that the fungus cannot take hold inside ant nests; the insects must be roaming free to be susceptible. Even then, the fungus only thrives in the humidity of Brazil or South Carolina, so Mangold, Melissa Ishler and Rachel Loreto had to recreate a warm humid environment in the lab in order to collect the infectious spores from diseased individuals. The team also had to figure out the correct dose of spores to ensure that the ants could not defeat the fungus before it took effect and forced them to lock their jaws tightly onto a piece of foliage.

Swiftly freezing the dying insects and removing their jaw muscles before preserving them and scrutinising the structures in an electron microscope , Missy Hazen and Mangold could see that fungus filaments had penetrated the muscle. However, when the team investigated the structures where nerve signals enter the muscle, they were unaffected; the fungus had not disabled the nervous system to weld the jaws in place. Instead, it looked as if the fungus had caused the muscle to contract so forcefully that the filaments in the muscle fibres—which slide past each other when the muscle contracts—were damaged and swollen. In addition, the fungus had broken the membrane covering the muscle fibres, leaving the fibres exposed and potentially vulnerable to toxins released by the invader. They also noticed tiny bead structures (vesicles) attached to the fungus filaments, which they suspect could be part of the ants' attempts to fight back at the lethal infection, or be packed with fungal toxins that could send the muscle into spasm, causing it to over-contract, clamping the jaws of the zombified ant in place.

However, Mangold adds that there is still more to learn about the fungus's influence on its innocent ant hosts. 'The next steps we want to take include isolating those vesicles and determining whether they are coming from the fungus or the host', she says; and she is keen to find out exactly what is packaged within. In the meantime, I hope your dreams aren't too haunted by the prospect of hordes of zombie ants scrambling to their final destiny.

More information: Colleen A. Mangold et al, Zombie ant death grip due to hypercontracted mandibular muscles, *The Journal of Experimental Biology* (2019). DOI: 10.1242/jeb.200683

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