THE ZOMBIES ARE COMING

... and they want brains!

(But not OUR brains)

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This summer, many of us in eastern North America will be treated to a very rare phenomenon: flying zombies. But don't worry, they are not after our human brains; there is no chance of being harmed or even mildly afflicted. These zombies will be of the insect variety and about the size of a shaker of salt. More on that later.

By now, we have all read about "zombie fungi," those hypocrealean (ascomycete) fungi of the families *Cordycipitaceae* and *Ophiocordycipitaceae* that parasitize arthropods and fungi. There is another distantly related group that has also evolved the ability to not only parasitize insects, but to zombify their hosts into doing their bidding until ultimately succumbing to a grim death.

This zombifying fungus, of sorts, is *Massospora cicadina*. This very strange entomophthoralean (zygomycete) fungus is one of 14 species of a small, specialized genus. Charles Horton Peck,

New York State Botanist from 1867 to 1915, made 36,000 collections of fungi, mosses, ferns, and seed plants during his famed career. Though not trained in mycology, he named 2,700 species of fungi. Possibly the strangest fungus that he named was *Massospora cicadina*. *Massospora cicadina* infects periodical cicadas and produces psychedelic compounds that cause the host to fly around frenetically, attempting to mate with others of its kind—thus spreading the infectious spores. As the zombified cicada host nears death, the fungal pathogen produces thick-walled resting spores … and then things get really gruesome. The terminal segments of insect's abdomen fall off, and resting spores spill out. The spores will rest there in the soil for years—or decades—awaiting a new cicada juvenile to crawl through the soil.

Annual and Periodical Cicadas

No matter where you live, you are probably familiar with the song of the cicada. Annual cicadas are rather large

flying insects belonging to a huge group (more than 3,000 species) of true bugs or hemipterans. They spend most of their lives—from two to nine years, depending on the species—underground as larvae sucking juices from tree roots then emerge in the summer to drive humans crazy with their very loud incessant drone. Aural irritants though they may be, cicadas have an amazing story … and an equally strange fungal symbiont that goes along for the ride.

There is one small cicada group known only from eastern North America, *Magicicada*, that does things differently. They do not emerge every year. They live underground for exactly 13 or 17 years (depending on the species), before emerging in a coordinated fashion. In a year when the "periodical" cicadas emerge, their numbers reach nearly 1 billion/acre during the 3–4 weeks-long breeding season. Predators gorge themselves on the bugs but consume only a tiny fraction. It's likely that a predator became closely attuned to the lifecycle of these cicadas and nearly

extinguished them before, by chance, a new species came along with a lifecycle impossible to overlap. Even if the predator had a "boom" year every second or third year, there is no way to encounter something along every 13 or 17 years (those are prime numbers and not divisible by any other number).

It turns out species of *Magicicada* species do have one enemy … lurking within. *Massospora cicadina* is a zygomycete fungus that latches onto cicada nymphs as they crawl through their chimneys before emergence. Fungal hyphae grow throughout the host's body, and its abdomen fills with conidia. The fungus produces psilocybin, a psychedelic, and cathinone, an amphetamine; the host spends the rest of its few remaining days frenetically flying and attempting to copulate with unwitting partners, who then become infected. The fungus that germinates in the secondarily infected host will produce sexual spores that can remain dormant in the soil for many years—lab research shows they will not germinate for, you guessed it, 13–17 years, or more. In the final stages of infection, the terminal segments of periodical cicadas fall off and as they fly around, they resemble flying salt shakers sprinkling the earth with spores that will lie in wait for the next generation of hosts.

The Cicada Spectacle: A Historic Emergence in Eastern North America

Eastern North America is on the brink of a rare entomological event as billions of cicadas prepare to emerge—this year—in a double brood phenomenon, unseen since Thomas Jefferson's presidency in 1803. Scientists warn billions of cicadas will emerge in eastern North America starting in April. What can you expect if you live in the emergence zone? Millions per acre.

As described above, when periodical cicadas do emerge, they do so in tremendous numbers. For about 99.5% of their lives, periodic cicadas are underground. But when it's their year to emerge, and when the soil temperature down there reaches about 64 degrees, they will be triggered to begin heading towards the surface

where they will climb up any surface nearby—tree trunks, walls, any and everything this summer! The ground will be pockmarked with emergence tunnels wherever they're coming out and this summer in the emergence zone, scientists predict something on the order of 15–20 per square foot.

One other puzzling note about periodic cicadas: three species surface every 17 years, the other four species surface every 13 years. But, once every 221 years, their emergence overlaps, and two broods come out at the same time. And that time is this year. The next co-emergence of these broods won't happen for another 221 years in the year 2245.

Part of this article was excerpted from the book The Lives of the Fungi *(B.A. Bunyard, 2022; Princeton University Press), and with permission of the author and publisher. To learn more about* Massospora *and* Magicicada, *see "Outracing all your devoted enemies: the periodic cicada (and its bizarre fungal pathogen)" by Tovi Lehmann, 2013;* FUNGI *6(3): 15–17.* 🍄

The sad end of the infected cicadas (their rear) showing broken abdomens that were dedicated to production of fungal spores. Photo by Tovi Lehmann.