## Nature Notes

By Marjorie Richman

## Zombies!

In the voodoo tradition, a zombie is a deceased person who has returned to our world under the control of an unknown force, usually not a benign one. Scientists have long denied the existence of zombies, which is quite reassuring. However, today's entomologists have a different story: zombies do exist in the world of insects, and the unknown forces controlling zombie-like behavior in insects are fungi, innocent appearing members of a kingdom most of us don't pay much attention to. These fungi exist all over our planet, including right here in our Mid-Atlantic region.

Picture yourself as a fungus, just for a moment. You desperately want to win the evolutionary arms race, but you can't move, you are not mobile, yet conditions are not always the best for spore reproduction in any one place. The key to survival is to spread spores as far as possible, in as many places as possible, assuming that one or more of these locations will be good for reproductive success. What might be the best way to accomplish spreading spores far and wide? Perhaps by finding a host that will carry the spores for you. Certainly, this can't be easy. What creature would volunteer for a job with no discernible benefits?

Since willing creatures might be hard to find, fungi had to develop a novel way to enlist help with spore dispersal. Predation on insects could have begun as much as 400 million years ago when insects begin to appear in the fossil record. By that time fungi were already well established planetary residents. There has been ample time, therefore, to perfect the system we see today: the invasion of the bodies of insects in order to control their behavior.

Several species of fungi are able to bore their way into the bodies of certain insects. Once inside, the fungus destroys the organs of the insect's body, but miraculously the insect seems impervious to the problem. The insect carries on, walking, climbing, flying, but its life style changes radically. The insect is now under the control of the fungus, and the fungus will manipulate the insect to go to places where conditions are best for successful spore dispersal. Sound crazy? Here is the way it works.

For example, the fungus, *Ophiocordyceps unilateralis*, is one of the best documented of these zombie inducing fungi. The victims are ants. The fungus bores through the insect's exterior and, once inside, it slowly digests the insect's body. Under control of the fungus, the ant will leave its safe nest and climb to the top of a plant, exhibiting a syndrome known as "summit disease." It will bite down on a twig or leaf in what is described as a death grip so that the ant will not fall off. The fungus' mycelia (threadlike masses of hyphae) grow from the ant's feet to firmly hold the insect tightly to its perch. Once properly positioned, the insect dies and the fungus sends a fruiting body through the ant's head. Spores can then be sent showering down to the ground, either to create new fungi or, if that fails, find new victims. Either way, as far as the fungus is concerned, mission accomplished.

An even more amazing part of this process is the fact that the fungus seems to know exactly where the insect should perform this task. The location is selected with precision as to temperature and humidity and the ant is oriented towards the sun, therefore establishing the most advantageous conditions for the fungus. When the ant is no longer useful it dies and the fungus completes the task of spore dispersal. A perfect zombie scenario.



Cicada with fungus invasion – photo by Brian Lovett

This spring, those who are vigilant may see another insect affected by pathogenic fungi. Our periodic cicadas are due for a return to our region. They have been living underground for 17 years as nymphs and they are getting ready to emerge and mate. Other creatures are also readying for action, fungi associated with the genus *Massospora*. Some members of this genus specialize in infecting periodic cicadas. Since cicadas spend most of their lives underground, it's unclear when the invasion of the fungus takes place. It could be while the nymph is underground, or it could be during the molting stage after the nymph emerges. During molting, insects are particularly vulnerable, which is perhaps why fungi target them.

On cicadas the infection takes the form of a brown mass on the lower abdomen, obliterating the sex organs of the insect and causing the disintegration of as much as one-third of the insect's body. The central nervous system remains intact so that the animal can walk, fly, climb and attract a mate, all the necessary activities for fungal success. The cicada will climb to a height as directed by the fungus and at some point release spoors from its abdomen. In the meantime, the insect will assume a mating position. Attracted cicadas will be infected by the fungus upon contact. Instead of reproducing its own species the cicada is now enlisted in the process of dispersing spores and infecting other insects.

Researchers have taken to the laboratory to determine the reason for this strange behavior. It's been found that the fungus secretes substances related to stimulants and psilocybin. Psilocybin is the name given to a class of naturally occurring psychedelic compounds present in certain mushrooms commonly referred to as "magic mushrooms." Although the insect's body is invaded, the brain still functions. The physical activity of the insect is probably hyper activated as we would be if under the influence of amphetamine type medication. Similarly, perhaps



Cicada with fungus invasion - photo by Angie Macias

lulled into a state of euphoria from the psilocybin, the insect seems to be in no distress as it is being manipulated by the fungus. Exactly how the fungus manages to accomplish this type of domination is not well understood. Scientists have figured out what happens, but not how a life form with no brain as far we know is able to orchestrate a complex series of chronological events as a means to its own survival.

There is a good reason why you may not have heard of insect zombie-like behavior: not much has been written about it. This may change with the emergence of the periodic cicadas. Dr. Matt Kasson and Dr. Brian Lovett of West Virginia University are involved in research on pathogenic fungi. They are hoping to engage citizen scientists to help with observing and recording instances of fungi infections among the cicadas. A useful tool for recording data is the popular app, iNaturalist. iNaturalist is free and can be downloaded on smart phones. Another app, BugGuide, can also be used (see BugGuide.net). If apps aren't your thing, you can send an email directly to Dr. Lovett (brian.lovett@mail.wvu.edu) or Dr. Kasson (mtkasson@mail.wvu.edu) with a photo and information on location, date and time of the sighting. The cicadas should be emerging sometime in the April/May time frame. Since there is much to learn about Massospora fungi and their insect hosts, documentation from community scientists will be especially welcome during this year's periodic cicada emergence.

Psychedelic effects of mushrooms are well known. People have been using them for centuries. As far as we know, people simply enjoy the experience and then move on with their normal lives. Zombie experiences have not been noted. Yet nature is vast, and we know there could be species out there that have not been discovered. Could there be, in some remote location, fungi that could control us? Best not to think about it.



## They're on their way!

Some people love cicadas and others hate them. A few even consider them delectable and call them "shrimp of the land." There's no denying it though, cicada Brood X will invade the C&O Canal this spring. They should appear in mid-May and be with us until late-June. They will indeed make quite a racket during our towpath travels. Visit www.cicadamania.com for more info about these creatures. Cicadas pictured are from Brood II in 2013.

– Steve Dean