**Lesson 2 – Insect Pathogenic Fungi** Teacher Notes

Goals

The purpose of this lesson is to introduce high schools students the diversity of insect pathogenic Fungi. Specifically the goals are:

1. To introduce the concept of insect pathogenesis
2. To identify common insect pathogenic fungal lineages.
3. To learn about modes of infection.
4. To understand the phenomenon “summit disease” and why it occurs.
5. To become aware of the diversity of insect pathogenic Fungi.
6. To introduce the concept of biocontrol using insect pathogens.

Desired Prerequisites for Students

This lesson should be taught to advanced high school or college students, who have background knowledge in cellular biology and concepts of Eukaryotes and organelles. Prior knowledge of Fungi (hopefully the preceding Lesson 1 on Kingdom Fungi) is strongly recommended.

Materials

* Computer and projector.
* Access to the internet is needed to play the 2 relatively short videos which are on vimeo and YouTube.

Slide Notes

1. Today’s topic – insect pathogenic Fungi. Explain the picture presented on the first slide. This is an *Ophiocordyceps* fungus growing out of and fruiting from a beetle larva that was buried in wood. Ask students to recall why a fungus needs to produce an elevated fruiting body. (To get their spores into the air stream.) If applicable, ask students if they remember an extreme example of spore ejection from Lesson 1.
2. Review what Fungi are.
3. Then lead straight into a review of the fact that different fungi obtain their nutrition from different sources. Go through the provided examples again.
4. Segue into how insect pathogenic fungi parasitize and obtain nutrition from insects. Mention that some fungi live in and on insect without parasitizing them or causing disease, so we don’t call them pathogens. Today’s topic will only be those fungi that are pathogens of insects.
5. There are three major groups of insect pathogens within Kingdom Fungi. These are Entomophthorales, Ascosphaera, and Hypocreales. We will discuss each of these in depth, with a focus on those pathogens in Hypocreales.
6. Go through slide. Introduce *E. muscae*, which is pictured on the slide (and the previous slide as well). Explain that summit disease is when the fungus chemically manipulates the host insect’s behavior. This behavior is that the insect will climb up the nearest plant or blade of grass, where it will then die, and the fungus will continue to grow out of and produce fruiting structures and spores from the dead insect. Point out that all of the white parts seen in the image of the fly are spores of *E. muscae*. Ask students why it would benefit the fungus to cause “summit disease” in its host? (Hopefully someone will offer that this could help the fungus disperse spores to infect more flies.)
7. Go through the life cycle of *E. muscae*, pointing out the stages with text labels. The horizontal line is supposed to represent the soil.
8. Next introduce *Ascosphaera*. This genus contains many non-pathogenic species. All species that are pathogens only infect and kill larvae. Ask students if they know what larvae are. If they don’t, explain that larvae are immature (non-adult) forms of certain insects. A common larvae that everyone is familiar with are caterpillars. Some insect larvae can do and see more than others.
9. Explain that *A. apis* causes chalkbrood disease of bees, which kills bee larvae inside the hive. This is a contributor to Colony Collapse Disorder, which is causing serious declines in honey bee populations across the country. Honey bees are important pollinators for agricultural crops and native plants. Show the video (3:07) about current research into *A. apis* infections.
10. Transition into the largest group of insect pathogens, the Hypocreales. Explain that we are going to use the term “*Cordyceps*-like” for most of these species, because Cordyceps is a general and older term for many of these. But the idea is to introduce the fact that some species do have different names, such as *Ophiocordyceps*, and we will not go in depth into nomenclature or how these different genera are related, here in this lesson!
11. Continue introduction to *Cordyceps*.
12. Explain that fungi have both sexual and asexual means of reproduction. Some Cordyceps are only known to do asexual or sexual, but some do both at different times, and some (like this species pictured here, C. takaomontana) do both at the same time! The white parts of the asexual structures are asexual spores (called conidia), and the yellow fruiting structure contains many of the flask shaped fruiting bodies, called perithecia. Segue to next slide.
13. Explain that the “pimpled” surface of the top picture is just the tops of the rows of the flask shaped fruiting bodies, called perithecia. The middle picture is a magnified view (10X) of a row of these flasks. You can almost see how the top portion of each perithecium sticks out above the tissue connecting them together, creating the bumpy look. Inside each perithecium are hundreds of skinny asci (sacks) containing 8 ascospores that can each divide into multiple partspores. If you look closely at the bottom picture (40X) you can see that there are tiny dividing lines which are all the partspores that have separated.
14. Host association is one of the coolest aspects of *Cordyceps*-like Fungi. Many species have a very narrow host range, others can kill almost any insect they encounter. Researchers are still trying to understand how these different strategies have evolved. Now we will look at different *Cordyceps*-like species found on different hosts. We’ll point out some generalists along the way!
15. Spider pathogens! Ask students if they notice anything about where these spider pathogens are located (excluding the bottom left). They are all affixed to plant surfaces. If you want to find these spider pathogens, students should look on the underside of leaves!
16. Beetle pathogens. Point out that one of these has attacked and killed an adult, and one an immature (larva). Start a discussion about what differences there might be in attacking an adult versus an immature. Ask them to think about things like location of each, movement of each, contact with other individuals (who might be carrying spores), etc.
17. Two grasshopper pathogens, both from South American rainforests!
18. These two wasp pathogens are long and skinny! They are both several inches in length, and both were collected in China. Notice they are both on adults.
19. Moth/Butterfly pathogens. Perhaps the greatest number (and most frequently collected) Cordyceps-like fungi are found on the larvae or pupae (cocoon) of butterflies and moths. The top two pictures show larvae, and the bottom two show pupae.
20. The most famous Cordyceps in the world is *Ophiocordyceps sinensis* (pictured here), a moth pathogen. It is also one of the most expensive natural products in the world – usually worth as much by the ounce as gold! It is sold as a natural product in Asia (especially in China), and only grows high on the Tibetan plateau. Many people hunt for this fungus and there is some evidence that it is becoming harder to find. (The host is a ghost moth.)
21. Explain that the dots on the leaf pictured are actually tiny, flat insects called scales, that have been parasitized by a special kind of *Cordyceps*. The inset picture is a closeup of the perithecia on top of the dead scale.
22. Finish with ant pathogens. This shows the great variety of ant pathogens, some of which are among the most famous *Cordyceps*.
23. Segue into the “Zombie ants.” Of course *O. unilateralis* doesn’t really turn ants into zombies! Ask the students to recognize that these zombie-like behaviors are just symptoms of being infected with *O. unilateralis*. Along with *O. sinensis*, *O. unilateralis* is one of the most well-known *Cordyceps* to non-scientists around the world. Watch the video from Planet Earth (3:03) and explain that the video shows time lapse growth of O. unilateralis. Normally this process would take several days.
24. Lead a discussion on summit disease. Much of this will be review but hopefully students can add their own insights. (Spore will be shot down onto other ants crawling on the forest floor, if the ant is upside down on a leaf that is elevated off the ground.) Ask students why I have turned the picture this direction. (This is orientation of the ant when it was collected in the forest – on the *underside* of a leaf.)
25. If students want to see more photos of Cordyceps or learn about how they are related to one another, they can visit Cordyceps.us.
26. Encourage students to be on the lookout for insect pathogens – they are small!
27. Things that you will probably need/ things scientists carry into the field when looking for insect pathogens.
28. Optional: Bring up the use of insect pathogens as a source of biocontrol for unwanted insect pests (agricultural pests). Also, ask students to think about what kind of Cordyceps (generalist or specialist) would be most suited for biocontrol, and what are potential benefits and risks of spraying a (non-native? Native?) pathogen’s spores for biocontrol use.
29. End the slide show with a thought about the fact that there are also pathogens of pathogens! And these happen to be other *Cordyceps*! The species *O. nutans* is picture – not parasitized – and then below one of the two fruiting structures has been parasitized by another type of *Cordyceps* called *Polycephalomyces*, which are producing the white colored structures which contain asexual spores. There are lots of Fungi that parasitize other Fungi – not just in *Cordyceps*. (Lesson 3 goes into this topic of Mycoparasites.) The End.
30. Photo credits.