Behavioral Hijacking: How Entomophthora muscae Controls Its Fly Hosts

Angela Cui

Abstract

The parasitic fungus *Entomophthora muscae* has a unique way of controlling the behavior of its fly hosts. This paper examines how the fungus causes infected flies to climb to high places before they die, a behavior known as "summit disease." By making the flies do this, the fungus increases its chances of spreading spores to new hosts. This study looks at the chemical signals and evolutionary benefits behind this behavior, helping us understand how parasites can control their hosts. The research highlights the complex strategies parasites use to survive and offers insights into the role of behavior manipulation in nature.

Introduction

In fiction and horror stories, there are many examples of parasitic organisms manipulating and harming other organisms; however, this is also prevalent in real life. One particular example of this is Entomophthora muscae, a parasitic fungus that infects various species of flies. This fungus doesn't just rely on the typical parasitic approach of feeding on its host; it goes a step further by taking control of the fly's behavior. Infected flies, under the influence of the fungus, exhibit an odd behavior known as "summit disease," where they climb to elevated positions before dying of the infection. [2] This paper explores the mechanisms by which Entomophthora muscae manipulates the behavior of its fly hosts, ensuring its own survival.

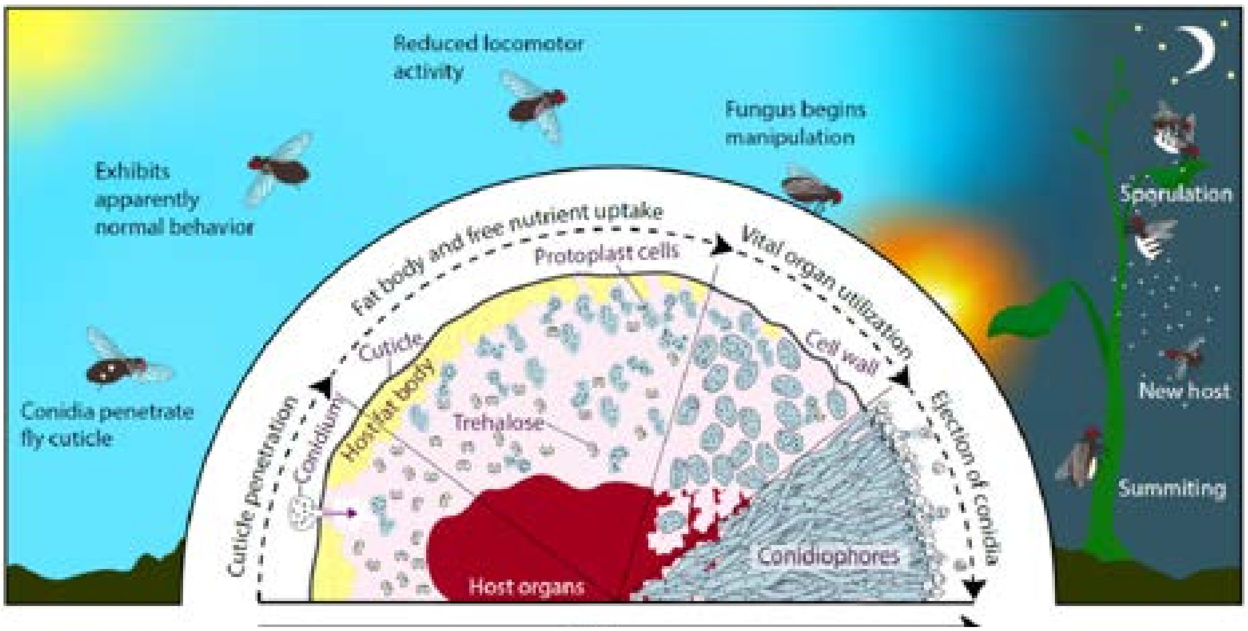
Entomophthora muscae Explained

Entomophthora muscae is a species of fungi that infect various types of flies. According to information from the University of Wisconsin-Madison, the transmission of this particular fungus occurs through spores that fly through the air, targeting adult flies. Once this spore lands on a fly, it bores through the exoskeleton and into the body. [1]
To the right shows an infected fruit fly with spores coming out of its body. After the fly dies, the fungus begins to emerge, using its spore launcher to shoot out spores in hopes to land on another fly. This gives the deceased fly a white, bloating appearance.

Additionally, if the spore lands on a fly's wings (which it cannot bore into), the spore will then have a secondary launcher in order to increase its chances of thriving.

Life Cycle of Entomophthora muscae

Below shows an image of the life cycle of this particular fungus. Based on the schematic illustration, the life cycle of Entomophthora muscae involves several distinct stages that highlight the fungus's complex interaction with its fly host. The process begins when fungal conidia penetrate the fly's cuticle, marking the entry of the fungus into the host's body. Initially, the infected fly exhibits normal behavior while the fungus spreads internally, targeting the fly's fat body for nutrient absorption. Over time, as the fungus continues to develop, the fly's locomotor activity decreases, signaling the onset of behavioral manipulation. This manipulation culminates in a behavior known as "summiting," where the fly climbs to an elevated position. At this point, the fungus utilizes the host's vital organs to complete its life cycle, ultimately ejecting conidia into the environment to infect new hosts. This cyclical process underscores the sophisticated evolutionary adaptations of Entomophthora muscae, enabling it to efficiently propagate through its host population. [3]



Biochemical Mechanisms behind “Summit Disease”

The fungus begins its invasion by penetrating the fly's exoskeleton and spreading throughout the host's body, particularly targeting the fat of the fly, which is crucial for energy storage. As the infection progresses, this fungus releases many biochemical signals that manipulate the fly's central nervous system, altering its behavior. [5]

One biochemical factor involved is the production of fungal metabolites that interfere with the fly's neurotransmitters. These metabolites may mimic or disrupt the normal signaling pathways that control the fly's motor functions and behavior. These fungal chemicals could influence dopamine and serotonin levels, which are critical for regulating mood, movement, and other behaviors in insects. The result is a gradual reduction in the fly's ability to move normally, leading to the characteristic sluggishness seen in the later stages of infection.

As the infection progresses, the fungus induces the fly to climb to an elevated position, which is a behavior crucial for the next stage of the fungal life cycle. [4] The exact molecular triggers for this climbing behavior are not known, but it is hypothesized that E. muscae manipulates the fly's circadian rhythms and stress responses. By hijacking the neural circuits that control these behaviors, the fungus ensures that the fly moves to a high point before dying. [5]

Evolutionary Advantage for the Fungus

The summiting behavior offers a significant evolutionary advantage for *Entomophthora muscae*. By causing the fly to die in an elevated position, the fungus ensures that its spores are released into the air from a height, increasing the likelihood that they will be carried by the wind to new potential hosts. This high dispersal efficiency allows the fungus to spread rapidly through fly populations, maximizing its reproductive success.

Furthermore, by manipulating the fly to climb to an exposed position, the fungus makes it easier for the spores to be picked up by other flies that come into contact with the dead host. This behavior increases the chances of spore transmission, ensuring the continuation of the fungal life cycle.

Conclusion

In conclusion, the interaction between *Entomophthora muscae* and its fly hosts reveals just how clever and complex parasitic organisms can be in their quest to survive and spread. The fungus uses specific chemical signals to alter the fly's behavior, leading to a condition known as summit disease. This behavior is not random, but rather a strategic move by the fungus to ensure that its spores are released in a way that maximizes their chances of finding new hosts. By making the fly climb to a high point before it dies, the fungus greatly increases its ability to spread and continue its life cycle. Understanding these mechanisms gives us valuable insight into how parasites and their hosts interact, and why these relationships persist over time. The study of *E. muscae* provides important knowledge about how pathogens can control and manipulate the behavior of their hosts to their own advantage, helping us better understand the role of parasitism in the natural world.

Works Cited

[1] “Entomophthora muscae,” *Wisconsin Horticulture*. https://hort.extension.wisc.edu/articles/entomophthora-muscae/

[2] “- YouTube,” *Youtube*, 2024. https://youtu.be/C2Jw5ib-s_I?si=xTzi96qiYip4EiGj (accessed Aug. 09, 2024).

[3] H. Hodge, T. Van Leeuwen, and F. Jensen, "Evolutionary Ecology of an Obligate and Behaviorally Manipulating Insect-Pathogenic Fungus *Entomophthora muscae*," *ResearchGate*, 2023. [Online]. Available: https://www.researchgate.net/publication/368971394_Evolutionary_ecology_of_an_obligate_and_behaviorally_manipulating_insect-_pathogenic_fungus_Entomophthora_muscae. (Accessed: Aug. 9, 2024).

[4] gazetteterrymurphy, “‘The Last of Us,’ fruit fly edition,” *Harvard Gazette*, Apr. 18, 2023. https://news.harvard.edu/gazette/story/2023/04/how-a-mind-controlling-fungal-parasite-turns-insects-into-zombies/

[5] C. Elya, A. Lok, and D. S. Eisen, "Behavioral hijacking by the entomopathogenic fungus *Entomophthora muscae*," *Journal of Invertebrate Pathology*, vol. 174, pp. 107405, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S002220112030104X. (Accessed: Aug. 9, 2024).