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A Summary of Pathogenic and Parasitic Fungi: Their Roles as Crucial Organisms

Parasitic and pathogenic fungi play interesting roles as organisms within their ecosystems. Fungi in general have provided a multitude of services such as being decomposers of dead material, commodified as delicacies for certain cuisines, used recreationally for their hallucinogenic properties, or valued for their medical purposes. Their value and connotation, whether they are deemed as good or bad, can be decided by the person who studies them. Are parasitic and pathogenic fungi "bad" because they do not engage in a mutualistic relationship with their hosts, and use them for their own benefit? Comprised of a series of illustrations that alphabetize the fungi studied, this project is designed to portray information on how parasitic fungi function, using specific examples. Only depicting letters A,B and C, the illustrations will show three different types of parasitic fungi and how they infect their hosts.

Why study parasitic and pathogenic fungi? In general, fungi have become major earth inhabitants alongside humans, because the ideal temperature for mammals to survive, which is about 37º C, allowed for a natural resistance against their pathogens [1]. Humans then are naturally resistant to fungal diseases, but other animals whose core temperatures are lower than 37º C are at risk to fungal infection [1]. Thus, they are capable of living alongside humans without posing as a major threat. Most non-poisonous fungi are used as a suitable source of food for humans and other organisms, due to the fact that non-lethal mushrooms far outnumber poisonous ones [3]. However, aside to how humans are able to interact with fungi, they play vastly different roles against other animals. Their abundance in diversity allowed for various types of characteristics within their ecosystems— such as taking mutualistic or parasitic relationships with their hosts. Ecologically, parasitic fungi prey on their host in order to reproduce, as a way of killing and maintaining population numbers.

The "A" page of this alphabet book will detail the life cycle of parasitic fungi, using the two species, *Rhizosiphon crassum* and *Rhizosiphon akinetum,* as examples. It is titled "A is for *Anabaena macrospora,"* because that is the species that the two fungi infect. The illustration is broken down to show each stage: encystment, the penetration of the zoospore into the host cell; porsporangium, where the contents of the spore are released into the cell until the stage expansion, where asexual reproduction occurs followed by the budding and maturing stages [2]. It is important to show these steps because this life cycle affects other living organisms as well, such as the bloom of *Anabaena macrospora*, a species of cyanobacteria living in aquatic ecosystems [2]. Even at a small level, fungi have profound effects on organisms. This illustration is specifically designed to give insight to the life cycle of certain pathogenic fungi. Portraying each step of the life cycle through digital painting, using bright colors to allude to bioluminescence. Each illustrated step is then accompanied with the description of the life cycle. Using digital techniques, the illustration will look bioluminescent— like an glow in the dark image. This will allude to how some parasitic and pathogenic fungi are studied through

bioluminescent imaging, where DNA is genetically altered to to stabilize an outside substance called the luciferase gene [5]. Structured like a narrative, where the steps of the life cycle are illustratively laid out, the audience can visually learn how this fungi's specific role within the ecosystem takes place— the mechanisms to power a parasitic relationship.

The "B" page is titled "B is for *Batrachochytrium dendrobatidis,"* the cythrid fungi. It is a parasitic fungi that infects most vertebrates, particularly amphibians, where infected tadpole victims may lose mouthpart structures. [6]. Other side effects are excessive skin shedding, lethargy, loss of reflexes and death [6]. This illustration is depicted through frogs, and the different phases the fungi infect the frog. The first step depicts a healthy frog upon a rock, where the zoospores of the fungi initially infect the frog. This is due to how infection can be caused by direct contact with animals, or contact through contaminated water are common modes of transmission. [7]. The second frog depicts the developed infection, where the fungi asexually reproduced and grew deep within the skin [7]. The third frog is illustrated as dead, where the cycle ends for the amphibian but continues to the fungi as it finds a new host.

The final, "C" page is titled "C is for Chinese Caterpillar Fungi." It depicts the ecological cycle of the Nepalese parasitic fungi, *Ophiocordyceps sinesis*. This forms a complex with the caterpillar of the ghost moth species, and are an expensive delicacy harvested by poor communities [4]. They play a pivotal role within Nepal's local economy, as poor locals are used to harvest the fungi, and are prized for their medicinal properties [4]. This page illustrates how the moth, belonging to the family Hepialidae, lay its larvae and the spores of the the parasitic fungi infect it [8]. The fungi allows the caterpillar's exoskeleton to withstand the winter, and uses the host for nutrition until the fall of the next year, where the grown fungi's fruiting body emerges from the ground [8]. Then, the illustration portrays how human's harvest the complex fungi and use it for medicine. Unlike the other two illustrations, which show parasitic fungal infections on a microscopic level or how fungi infects one species, this illustration portrays human interaction with the fungi.

Essentially, this alphabet books is a series of illustrations aimed to detail the parasitic relationship through certain types of fungi. All three pages are graphs that portray the flow of how certain species of fungi essentially live through parasitism. Ideally, it could serve as an educational tool to younger audiences to reveal the complexities of parasitic and pathogenic fungi. It can serve as a supplement to their textbook readings. It also is a parody on children's books and media itself, since parasitic fungi as a topic involves the deaths of creatures. A life cycle that naturally occurs within nature that seems more macabre, like parasitic fungi, becomes a strange juxtaposition with children's media. Without pursuing mycology itself, the study of fungi seems very surface level, despite their huge presence among the earth. The audience is supposed to get a better understanding about parasitic and pathogenic fungi, and how they affect other organisms and even human activity. Ultimately, it is up to the viewer to decide if the connotation towards parasitic and pathogenic fungi is positive or negative. Would a benefit to humans qualify them as good? Would their method of living, which is to infect other hosts to kill them, make them bad? Either way, this broad type of fungi within their kingdom provide crucial functions within their ecosystems— whether it is viewed as positive or negative is up to the viewer, but it is interesting and profound to learn and explore.

Bibliography

[1] Casadevall, Arturo. 2012. Fungi and the Rise of Animals. *PLoS Pathog* 8:e1002808

Mammals have appeared dominant over reptiles as terrestrial bodies since the extinction of dinosaurs. Likewise, fungi began to thrive when earth became a huge compost site post the massive extinction. Most mammals carry a natural resistance to certain general and pathogenic fungi, while reptiles do not, affecting their dominance as a terrestrial race post Cretaceous. The author hypothesizes that more fungi will evolve to become climate-tolerant, and even become more pathogenic.

[2] Gerphagnon, Mélanie, Latour, Delphine, Colombet, Jonathan, Sime-Ngando, Télesphore. 2013. Fungal Parasitism: Life Cycle, Dynamics and Impact on Cyanobacterial Blooms. *PLoS One* 8:e60894.

Scientists studied the bloom of a specific species of cyanobacteria, *Anabaena macrospora* at a French Lake, to understand chytrid parasitism. They found two types of parasitic fungi associated and were able to find out their life cycles, which happens in stages, are relatively similar. They projected an accelerated decrease in cyanobacterias blooms from one observation, since chytrid infection affects filaments and influences cyanobacteria sizes, ultimately killing the host.

[3] Gray, William Dudley. 1970. *The Use of Fungi as Food and in Food Processing*. Cleveland, OH. CRC Press.

This book details different types of mushroom and fungi, as they are classified as edible, poisonous and even hallucinogenic. The chemistry in how they are classified as poisonous are revealed. Their role is discussed as being the start of some food chains, being prized delicacies and used as a source of food for animals and humans.

[4] Shrestha, Uttam Babu and Bawa, Kamaljit S. 2014. Impact of Climate Change on Potential Distribution of Chinese Caterpillar Fungus (Ophiocordyceps sinuses) in Nepal Himalaya. *PloS One* 9:e106405.

The expensive Chinese Caterpillar Fungus, *Ophiocordyceps sinensis* is a complex formed by the parasitic relationship with fungi and the caterpillar from a ghost moth species. They inhabit the Himalayas as part of the rich biodiversity and are affected by the temperature increase and soon to-be increasing precipitation during the summer, more in the winter. Scientists studied the future distribution of this species using three greenhouse gas concentration trajectories for three different time periods, and modeled the data through computers. The results show an extended distribution of the species, but not necessarily an increase in population. This species was especially studied since they are expensive, but harvested by poor communities, playing a pivotal role within their local economy as well as human activity playing a role in their survival.

[5] Papon, Nicholas, Courdavault, Vincent, Lanoue, Arnaud, Clastre, Marc, Brock, Matthias. 2014. Illuminating Fungal Infections with Bioluminescence. *PLoS Pathog* 10:e1004179.

Bioluminescent imaging is a process used by scientists to find infections within organisms. This type of research is applied to finding tumor cells within the human body, disease causing agents and even fungi. However, some hyphae proved to be impermeable to the substance used to conduct bioluminescent imaging. However, this can provide some clues to vaccines towards fungal diseases, and other medical advantages.

[6] Xie, Giselle Yang, Olson, Deanna H., Blaustein, Andrew R. 2016. Projecting the Global Distribution of the Emerging Amphibian Fungal Pathogen, *Batrachochytrium dendrobatidis*, Based on IPCC Climate Futures. *PLoS One* 11:e0160746.

This article studies how the infectious amphibian chytrid fungus— a pathogen known to infect and disrupt their populations, is affected and distributed because of climate change. Climate change might be affecting the processes in which fungi neutralize amphibian species. they created a model, estimating the future distribution of this species, gathering climate variables from different forests. Occurrence for this species is predictably low near the equator, but not for coastal regions or mountainous areas, because what is defined their occurrence was temperature. Their projections are to help estimate other vulnerable species and to understand other disturbances within the area.

[7] Kolby, Jonathon E., Ramirez, Sara D., Berger, Lee, Richards-Hrdlicka, Kathryn L., Jocque, Merlijin, Skeratt, Lee F. 2015. Terrestrial Dispersal and Potential Environmental Transmission of the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*). *PLoS One* 10:e0125386.

This was a study on the infectious fungi *Batrachochytrium dendrobatidis*, because of its threat towards the worldwide amphibian biodiversity and population. The spread of the fungi throughout Central and South America is associated with dramatic decreases in amphibian populations. They investigated Honduras, taking samples from leaves and water. Their efforts were to trace high transmission zones of *Bd* and correlating it with the population decreases.

[8] Quan, Qing-Mei, Chen, Ling-Ling, Wang, Xi, Li, Shan, Yan, Xiao-Ling, Zhu, Yun-Guo, Wang, Mu, Cheng, Zhou. 2014. Genetic Diversity and Distribution Patterns of Host Insects of Caterpillar Fungus *Ophiocordyceps sinensis* in the Qinghai-Tibet Plateau. *PLoS One* 9:e92293.

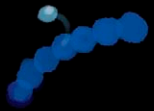
Ophiocordyceps sinensis are prized in China for their medical properties, where the complex's survival is dependent on the host— which raises concerns for their conservation. This was a study on the genetic diversity of the different possible hosts of the fungi. Their results yielded high for the Haplotype diversity of the host insects, which means their conservation can yield higher fitness during environmental changes.

THE ABC'S OF PARASITIC FUNGI

ERIKA PAJARILLO

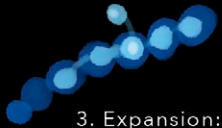
A is for *Anabaena macrospora*

the infected cyanobacteria



1. Encystment:
Zoospore of fungi
Rhizosiphon crassum or
Rhizosiphon akinetum
infects host.

2. Porsporangium:
Contents of spore
are released into cell.



3. Expansion:
Asexual expansion
of fungi within host.

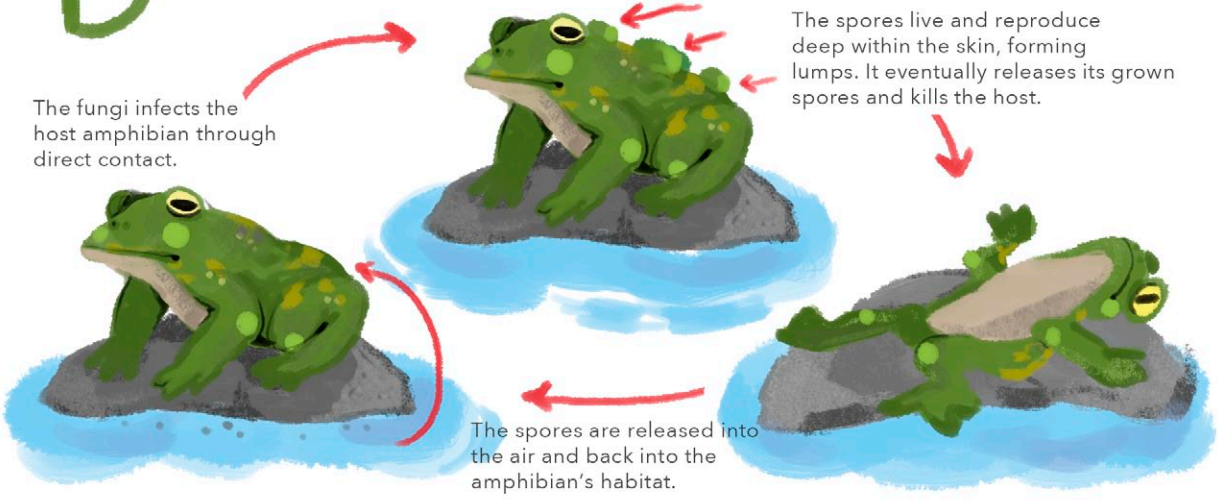
4. Budding:
A bud emerges
containing new fungi.

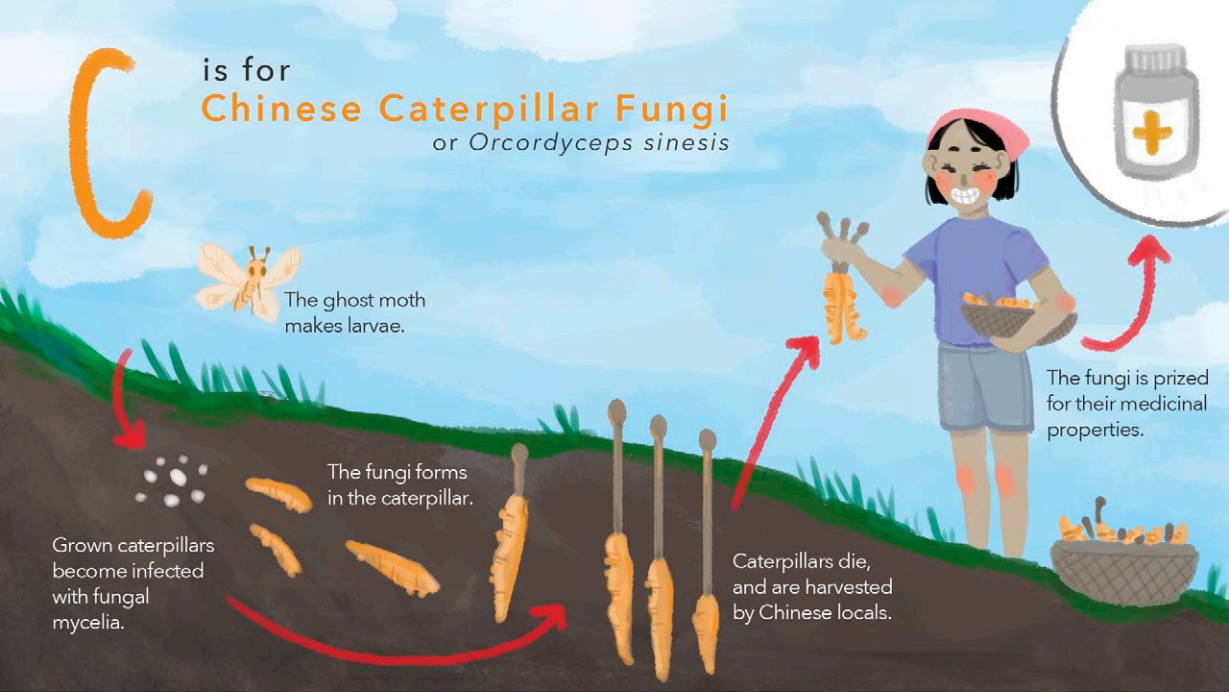
5. Maturation:
Bud fills with mature
sporangia.

6. Empty Stage:
Zoospores release
from bud.

B is for *Batrachochytrium dendrobatidis*

the wild amphibian killer fungi




C is for
Chinese Caterpillar Fungi
or Orcordyceps sinesis
The ghost moth makes larvae.
Grown caterpillars become infected with fungal mycelia.
The fungi forms in the caterpillar.
Caterpillars die, and are harvested by Chinese locals.
The fungi is prized for their medicinal properties.