Fungi with a Fun Guy: Feasts, Famines and the Fungus among Us

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Session Goals:

1. Investigate how fungi impact our food system
    a. Visualize fungal structures used to decay plants or produce spores
    b. Examine the effects of plant pathogenic fungi through history to present
    c. Explore ways that we use fungi to modify foods
    d. Relate fungal saprotrophy to sustainable food production and bioremediation
    e. Discuss mutualistic associations between fungi and plants

Pre-session trivia:

1. **Plants reproduce using seeds, whereas fungi reproduce via _____.**
    a. **Spores** – Each of the millions to billions of spores produced by fungi are capable of starting a new colony elsewhere.
2. **An apple is to an apple tree as _____ are to some fungi.**
    a. **Mushrooms or conks** – Mushrooms and conks are fruiting bodies produced by some fungi. These sporocarps (meaning 'spore fruits') are important for disseminating spores. If you see a mushroom or conk in nature, most of the fungus that is producing it exists in the tree or soil that it is emerging from. Most fungi (think molds) never grow mushrooms or conks, but produce their spores in or on microscopic structures.
3. **Of the 1.5-5.1 million fungi that are estimated to exist, we have described approximately how many?**
    a. 50,000
    b. 100,000
    c. 500,000
    d. 1,000,000

    a) **100,000** – This means that mycologists have only described ~2-7% of all fungi. In other words, we (including future mycologists) have a lot more work to do! But why are these fungi so hard to find and describe? Many fungi that exist in nature cannot be grown in laboratory settings. We often only know that certain fungi are present due to relatively recent advances in detection methods that directly test for DNA. Unfortunately, fungi for which a specimen cannot be collected and deposited in a culture collection are not allowed to be considered species. Some mycologists believe that this system is antiquated in light of the rapid progress in molecular biology.
4. **Fungi are most closely related to which group of organisms listed below?**
    a. Plants
    b. Bacteria
    c. Archaea
    d. Animals

a) Animals – Fungi actually share a recent (evolutionarily speaking) common ancestor with animals known as the Opisthokonta. Indeed, one of the primary cell wall constituents of fungi is chitin, the same compound that is found in the exoskeletons of insects and crustaceans. The many similarities that fungi share with humans make fungal-caused diseases especially difficult to treat.

5. **Fungi are important because _____.**
    a. **they cause the majority of plant diseases**
    b. **they produce secondary metabolites that can be used for medicine (e.g. penicillin)**
    c. **they are the primary decomposers of woody material**
    d. **they form mutualistic relationships with nearly all plants**
    e. **they are used to modify foods and some produce delicious and healthy mushrooms**
    f. **they can be used to degrade pollutants that threaten human and environmental health**
    g. **All of the above**

a) **All of the above** – This is the obvious answer, but very few people realize how important fungi are in nature or for biotechnological applications. Most people only think about fungi when their food is moldy or they see some mushrooms, but fungi are nearly everywhere playing important roles that often go unnoticed. There are fungal spores in every breath you take. Fungi are on you and in you effecting your immune system. Fungi are in and on every plant around you protecting them from diseases and helping them access nutrients and water. The soil beneath your feet is packed full of fungi. Wood-decaying fungi are critical for forest health, but also cause more than one trillion dollars in damage each year. The same enzymes that fungi use to decay wood can be used to degrade diesel fuel, pesticides, dyes and explosives such as TNT. Fungi have been at the heart of devastating famines. Fungi have even shaped culture (the English used to drink coffee instead of tea). Perhaps most importantly, we would not have beer, wine, fluffy bread, salami, several cheeses, soy sauce or mushrooms without fungi either!

Activities

Activity #1 – Visualize fungal structures

Desired Learning outcomes:

1. Comprehend how and why fungi rot our fruits, vegetables and other foods
2. Differentiate structures that fungi use to disseminate spores and reproduce

Materials:

1. Dissecting scopes
2. Strawberries being colonized by a fungus
3. Mushrooms and other fruiting bodies
4. Sections of mushroom gills and pores
5. Fungi in pure culture in Petri dishes

Lesson:

Visualize different structures produced by fungi to explore how they are used in nature and how they impact our food system.

Set up mushrooms and conks, or sections thereof, and fungi in Petri dishes on the table for people to place under one of the dissecting scopes. Point out the different structures used by basidiomycete fungi to produce spores i.e. pores, gills, teeth, etc., as visitors visualize the specimens. Also note the vegetative part of fungi growing in pure culture to explain how fungi access nutrient

Focus a second dissecting scope on a strawberry that is being colonized by a fungus. Note that the fuzzy looking threads are hyphae that constitute mycelium and that they are releasing enzymes to break down and absorb nutrients from the strawberry. Use discussion of the rotting strawberry as a segue to explore how fungi act as plant pathogenic agents.

Activity #2 – Famous fungal famines

Desired Learning outcomes:

1. Understand that fungi are the primary agents of plant diseases
2. Interpret how plant diseases have affected humans in the past and present
3. Analyze how farming practices promote or discourage plant diseases
4. Summarize research approaches used by scientists aimed toward reducing the negative impacts of plant disease

Materials:

1. Information sheets about the Irish potato famine, the Bengal famine and coffee rust
2. Diseased leaf samples
3. Hand lenses
4. UMN Plant Disease Clinic brochures

Lesson:

Use examples of famines throughout history to illustrate that fungi cause about 70% of plant diseases and can have serious impacts on agricultural productivity.

Set up examples of diseased leaves on the table. Show that fungi cause diverse symptoms on plants and explain that all plants are susceptible to some sort of disease.

Highlight the UMN Plant Disease Clinic and examples of research happening at UMN and elsewhere aimed toward reducing the impacts of plant disease through breeding for resistance, and improving agricultural practices and control measures.

Analyze the pros and cons of our agricultural system related to how they promote or discourage plant disease.

Activity #3 – Fungal pets

Desired Learning outcomes:

1. Demonstrate that we use diverse fungi in different ways to modify a variety of foods.
2. Emphasize that fungi use spores to reproduce
3. Create a living art project that will grow and illustrate a fungal lifecycle

Materials:

1. Fungal-modified foods including a loaf of bread, a bottle of soy sauce, salami, brie and blue cheese
2. Toothpicks
3. Petri dishes with potato dextrose agar media (1 per visitor)
4. An active yeast culture in an Erlenmeyer flask fitted with an airlock

Lesson:

Place fungal-modified foods on the table. Discuss how different fungi are used to modify popular food items that people don't generally associate fungi with

Have visitors (mostly kids) dip a toothpick in the blue part of blue cheese and use it to draw a design on a Petri dish. Explain that the blue stuff in cheese are millions of fungal spores and that those fungal spores will germinate in the plate and grow following the pattern that they were drawn in. Discuss how the whitish mycelium will first grow out to collect nutrients and that the culture will start turning blue as the fungus begins to produce spores.

Use the yeast culture and bread to explain how yeast ferment sugar to produce carbon dioxide that makes bread rise and ethanol that is in beer, wine and maybe even their car.

Activity #4 – A plant's trash is a fungus' treasure

Desired Learning outcomes:

1. Understand how fungi impact biogeochemical cycles acting as saprotrophs
2. Synthesize knowledge of the saprotrophic lifestyle to summarize how fungi can fit into a sustainable food system
3. Extend information known about the role of fungi in nature to give examples of how their natural abilities can be used for biotechnological purposes

Materials:

1. Information sheets about mushroom substrates and different kinds of mushrooms
2. Shiitake log
3. Spawn jars at different colonization stages
4. Examples of degraded wood and sound wood

Lesson:

Use the information sheets that depict many substrates to explain that fungi can grow on almost any agricultural byproduct that one can think of. Extend that information to illustrate how mushroom production can be incorporated into farming system to reduce waste. Further explain that fungi do not photosynthesize and can be grown in many urban area or other areas where plant production is difficult.

Use the shiitake log and spawn jar to show how some fungi colonize plant material to produce large mushrooms. Explain that basidiomycete fungi are the only organisms that can directly degrade wood and use examples of white-rot, brown-rot and sound wood to show the different ways that wood is decayed.

Extend the information given about wood decay to how the enzymes that fungi use to decay wood can also be used to remediate a variety of contaminants that threaten human and environmental health. Share examples of research in this area.

Activity #5 – Mutual agreement

Desired Learning outcomes:

1. Extend information about fungal lifestyles to the world around us
2. Analyze the range of interactions that fungi have with plants
3. Relate knowledge of mutualisms to the current food system

Materials:

1. Information sheet about mycorrhizae
2. Surrounding trees

Lesson:
Use the information sheet to illustrate how mycorrhizae form mutualisms with more than 80% of plants and compare this information to the relationships that fungal pathogens have with plants. Use pictures to show how mycorrhizae increase the potential surface area of roots and improve plant growth. Explore how we might use mycorrhizae and other beneficial organism in agricultural systems to decrease the need for chemical fertilizers

Point to the trees around the area and explain that every tree that has ever been tested is full of fungi on the inside and out acting in a range of different ways e.g. some may be latent pathogens while others may be true endophytes.

Optional Handouts

See attached

Links to references or background materials

Recommended age range

All ages

Recommended citation for this lesson plan:
Jackson, L. 2016. Fungi with a Fun Guy: Feasts, Famines, and the Fungus Among Us. marketsci.org

Bengal Famine of 1943

1.5-4 Million Died

Cochliobolus miyabeanus
(Brown spot of rice)

Irish Potato Famine

~1 Million Died

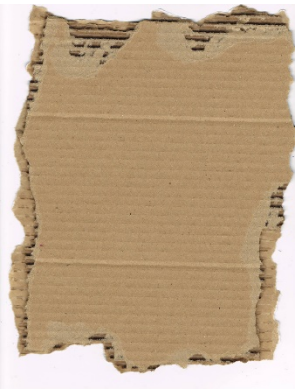
Phytophthora infestans
(Late blight of potato)

What do these items have in common?








Common Edible Mushrooms













Mycorrhizae