Mycology in the Agriscience Classroom:
A Curriculum Based on Wild Foraged Mushroom Certification

Michigan State University
Agriculture, Food, and Natural Resources Education
Master of Arts Impact Project

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Abstract
The overarching goal of this impact project is to make mycology accessible to more agriscience educators and students. Lesson plans were prepared to link core competencies and science standards to the Wild-Foraged Mushroom certification. Incorporating mycology into the classroom has many benefits including discussions on food safety and regulation, the role of ecology, and taxonomic identification skills. Fungi also play many different roles in the ecosystem including decomposers, mutualists, and parasites. Lesson plans in three topic areas were produced: Mushroom identification and fungal ecology, mushroom growth and food safety, and mushrooms as a renewable resource. Examples of hands-on learning and connections to the Wild-Foraged Mushroom certification are provided. Looking at taxonomy, ecology, food science, and economics through the lens of mycology is an engaging way to motivate students while potentially helping them earn a certification.

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Chapter 1 Introduction

Fungi play many important ecological roles including parasites, decomposers, and mutualists, yet the field of mycology is often overlooked in science curricula. The overarching goal of this impact project is to bring fungi to the forefront of lesson plans designed for the agriscience classroom at the secondary level. This will include identifying macrofungi highlighted in the Midwestern American Mycological Information (2024) Wild-Foraged Mushroom Certification exam, which is overseen by the Michigan Department of Agriculture and Rural Development (2024). The Michigan Department of Education has approved this credential through the Perkins V legislation, which aims to increase certification opportunities for secondary education students through the Career to Pathways Grant (Michigan Department of Education, Perkins V 2024).

Purpose & Objectives

The primary objective of this impact project is to present lesson plans related to the Perkins V Core Competencies for the 03.0000 Natural Resources & Conservation CIP Code that are related to the Wild-Foraged Mushroom Certification (Michigan Department of Education Agriculture, Food & Natural Resources 2024). Twelve of the 17 competency codes can be addressed in relation to the certification and mycology. This includes all four Perkins Course Competencies. Lesson plans were also aligned with the Michigan K-12 Science Standards, which are based on the Next Generation Science Standards (Michigan Department of Education 2015). A secondary goal of this impact project is to prepare students for the Wild-Foraged Mushroom Certification class and exam. This will be achieved by focusing on mushroom identification, harvesting and storage, and poisonous look-alikes.

Need

The State of Michigan's Sixty by 30 goal aims to have 60% of working-age adults obtain a certification or college degree by 2030 (State of Michigan 2024). This will give Michigan residents more skills, knowledge, and opportunities to enhance their livelihoods. Wild-foraged mushrooms are now being sold more frequently at farmer's markets and online, which legally requires the Wild-Foraged Mushroom Certification in the State of Michigan (Michigan Department of Agriculture and Rural Development 2024). In Michigan, certified wild-foraged mushroom hunters earn $1,000 annually on average from morel sales alone, with more potential income from other mushroom species (Malone et al., 2022). Professional wild-foraged mushroom harvesters of various species have an income of 5% above average in rural populations in Finland (Cai et al., 2011). The Department of Education has approved the Wild-Foraged Mushroom Certification for the Natural Resources and Conservation CIP code as a certification for secondary students in the Agriculture, Food, & Natural Resources career pathway (Michigan Department of Education Agriculture, Food & Natural Resources 2024). Some of the online resources for mycological education, such as the North American Mycological Association (2024) or the Mycological Society of America (ND), provide links to ideas for lessons on fungi; however, these can be difficult to synthesize into a cohesive curriculum. An easily accessible curriculum related to mycology that meets the new Perkins V Competencies has not been developed. This impact project will meet this need by developing

mycology lessons aligned with both the Perkins V Competencies and the Wild-Foraged Mushroom Certification.

Chapter 2 Literature Review

Mycology has proven to be important in agriculture, food systems, and natural resources. Fungi are present in nearly every environment, which makes them accessible to study. In agriculture, we often focus on fungi as parasites or plant pathogens, but they can also be mutualists, such as mycorrhizal fungi. Understanding fungal interactions with our crop plants allows us to design strategies to enhance yields and lower costs, making farming more sustainable (Rambold et al., 2013). Fungi also produce many economically important secondary metabolites, including antibiotics and enzymes related to biofuel production.

Despite the economic and environmental relevance of fungi, mycology is not often a focus in educational settings (Rambold et al., 2013; Irga et al., 2020; Moore et al., 2005). Many secondary students have misconceptions related to the classification and ecological role of the kingdom of fungi, often confusing them with plants (Karakaya et al., 2023). Irga et al. (2020) reviewed the course offerings at eleven universities and found only one course focused on mycology, and this course was related to the field of medical mycology. Most curriculums incorporate an overview of mycology into a unit on botany or ecology, but very few offer dedicated classes on the topic. One barrier to including fungi in the curriculum may be that teachers need to become more familiar with how the fungal kingdom relates to the field of biology (Moore et al., 2005). Finding reputable sources for information related to fungi can be a challenge. It is important to be cautious about online information related to fungi, particularly when students are involved. Some social media posts may give out incorrect information or may be focused on psilocybin mushrooms and their psychedelic properties (Irga et al., 2020). This project aims to provide succinct lesson plans to address this gap in the curriculum and make mycology more accessible to all.

Many advances in DNA technology are now available to detect fungi in the environment, but mushrooms are accessible to everyone without the need for advanced laboratory equipment for identification. Martin and Watling (2016) suggest that teachers start by taking students into a nearby outdoor area for a foray (or field collection) of fungi, then bring samples indoors for spore prints and microscopy. Students learn proper documentation skills and how to make thorough observations during fieldwork (Martin & Watling, 2016). These are skills that can be applied to many different areas of science. It is important to demonstrate proper collection techniques by carefully digging up the mushroom, storing it in a separately labeled paper or foil container, and preserving it with refrigeration or drying (Martin & Watling, 2016). Michael Kuo presents a detailed guide to studying mushrooms on his website (mushroomexpert.com, 2024), but this may be too detailed for a simple introduction in class. The Fungi Foundation (www.ffungi.org, ND) has a protocol for students to observe, photograph, collect, and preserve mushrooms. This protocol includes a reference label card for record keeping. This website also offers a demonstration video on proper documentation during collection.

Following the foray, students can share their collections by displaying them in the classroom and organizing them based on their morphology or ecology (Martin & Watling, 2016). Morphological identification of fungi often requires background knowledge that is not easily accessible to the general public. Dichotomous keys, such as David Arora's Mushrooms Demystified (1986), may be considered the gold standard for mushroom identification, however, they are complicated by a lot of terminology for the beginner to use. The identification wheels presented in the Fungi of Temperate Europe (Læssøe & Petersen, 2019) provide a concise way to graphically view the key features of the groups and families with visual representations of essential features such as gill or spore shape. These wheel guides are freely available at mycokey.com. The keys presented at mushroomexpert.com (Kuo, 2024) are simple enough to be used effectively in the classroom with a small amount of background knowledge of morphological terminology. This website contains excellent information on identification with photos of key characteristics.

The diversity of fungi collected from a foray can be measured in different ways, including morphology and ecological roles. The MycoDiversity Game can incentivize students with a competition to see who can get the most diverse collection during a foray. It can also be adapted to discuss ecological clades of fungi (Hibbett, 2009). For more advanced students, this game can be used to show relations between taxa using phylogenetic trees while also studying morphological identification. One way to gamify a mushroom-collecting foray would be to have students compete to find as many different ecological roles as possible, such as litter decay, wood decay, mycorrhizal, lichen, and parasites (Hibbett, 2009). Fungi play many different roles in our ecosystems and easily lend themselves to discussions on ecological interactions between species. Something as simple as lichens growing on a rock may be a way to demonstrate the abstract idea of commensalism to students. Competition of belowground mycelium is nearly impossible to see, but the competition between two fungi on a Petri dish can be measured easily in a classroom. Martin and Watling (2016) describe how cultures of soil fungi or spores can be prepared for classroom use.

Giving students an outside audience to validate their work is essential in many models of teaching and learning (The Buck Institute; McKim et al., 2019; Crandall et al., 2022). Students can be assigned to a type of fungus and prepare a short presentation related to its identification and role in the ecosystem and everyday life. This will help students learn about fungal diversity and build leadership skills. Tom Volk's Fungus of the Month (2010) can be used to assign students a fungus related to their birth month and also includes fungi related to various holidays. Citizen or community science is one way students can enhance their identification skills and share their data with the global community. Online platforms, such as iNaturalist (inaturalist.org, ND), allow students to contribute data on mushroom identification in an area during a foray, which can help monitor the biodiversity of that area by crowdsourcing data (Irga et al., 2020). iNaturalist can also be used to confirm mushroom identification since mycologists across the world verify data. Making students aware of fungi, getting them in an outdoor environment, and allowing them to contribute in meaningful ways to the body of scientific knowledge will bolster student confidence and interest in mycology.

Chapter 3 Methods & Procedures

The curriculum has three focus topics: mushroom identification and ecology, mushroom growth and food safety, and mushrooms as renewable resources. Lesson plans related to each of these topic areas were developed. Each lesson is designed to take 2 to 3 hours. Mushroom identification and fungal ecology were combined into one larger lesson plan, taking approximately 4 hours, as both of these topics benefit from a mushroom-collecting foray. This lesson will introduce students to fungi and prepare them for the skills needed for the Wild-Foraged Mushroom Certification exam. Ancillary materials related to each lesson plan are linked in the appendices and printed in Appendix 4. This includes general directions for activities, links to Google Slides presentations, handouts, and links to helpful online resources.

Chapter 4 Results

Three lesson plans were written, each including a Google Slides lecture and one or more accompanying activities.

Appendix 1. Mushroom Identification & Fungal Ecology Lesson Plan
Appendix 2. Mushroom Growth & Food Safety Lesson Plan
Appendix 3. Mushrooms as a Renewable Resource Lesson Plan
Appendix 4. Ancillary Materials

Chapter 5 Reflection

The main objectives for this impact project were to design a curriculum related to the Perkins V Core Competencies and to prepare students for the Wild-Foraged Mushroom Certification exam. An underlying goal was to make mycology more accessible for educators and students. Mycology is a field that is notorious for being difficult to study. Albeit unintentional, there is some degree of gatekeeping in the mycological community. It was difficult to simplistically synthesize the copious amounts of information to describe, classify, and cultivate mushrooms. I have carefully balanced technical terms with more common language, kept lectures brief, and designed engaging student activities to build excitement around fungi. Countless other fungi-related topics can be applied in the agriscience classroom, such as mycofiltration and water quality, food, medicine and nutrition, biofuel production, and coarse woody debris and forestry.

I suggest three improvements to this curriculum: creating summative assessments, incorporating industry connections, and studying for the Wild-Foraged Mushroom Certification exam. The formative assessments in these lessons could be adapted to create summative assessments, but due to the introductory nature of the lesson plans I did not include official summative tests here. There are many ways to build connections with industry partners, such as visiting local mushroom farms or inviting guest lecturers into the classroom. Many Michigan-based companies are on the cutting edge of mycological research and are willing to share their knowledge. This includes Myconaut, which was recently awarded a grant to examine ways fungi can clean up water contamination, and Midnight Harvest, which is exploring ways to grow morel mushrooms in cultivation. The Michigan Mushroom Hunters Club also offers public forays where students and educators can learn from experts. Lastly, if students

aim to pass the Wild-Foraged Mushroom Certification exam, they should register and begin studying early. Passing the exam will require some studying outside of the classroom. Exams are offered throughout the year in various locations in Michigan, but Michigan State University typically hosts them in November and March. These are good target dates to keep in mind.

The field of mycology is often overlooked in science education, but fungi are becoming more and more prevalent in our culture. It is imperative that we teach students both the benefits and potential dangers of fungi. Using the identification lesson can be a great way to introduce students to the field of taxonomy with skills that can be applied to other living organisms. The lesson on food safety includes important points on cottage food law that can be applied to other products. The final lesson includes information on sustainability and renewable resources, which are something we all must consider as we seek solutions to problems on a local, national, and global scale. I hope these lesson plans will be easily accessible, flexible, and engaging enough that more educators feel comfortable including fungi in their curriculum.

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Appendix 1

Mushroom Identification & Fungal Ecology Lesson Plan

Scope and Sequence

This lesson was designed for high school students enrolled in an agriscience class. It is best done in the fall due to the higher diversity of mushrooms, but it could be done in the late spring. The mushroom foray could be used as a team building exercise early in the school year so that students work together while learning content related to identification skills and ecology.

The lesson includes an introductory lecture in a Google Slides format. This lecture covers basic terminology related to mushroom identification and fungal ecology. A handout from the Fungi Foundation on scientific collection protocols and an accompanying video are recommended before taking students outdoors for the foray. This background information and foray should take approximately 2 hours of class time. Fungal identification, scoring of the Mycodiversity Game, and reporting to iNaturalist should take an additional 2 hours of class time. The lesson includes some extension activities if more time can be dedicated to fungi in the curriculum or for students interested in learning more.

Core Competencies and Standards of Focus

A4. Identify and describe plants, wildlife, rocks/minerals, and soil.
B1. Keep accurate records by obtaining and analyzing data, and producing technical reports.
B2. Monitor and record soil and water quality, populations of plants, wildlife, and pathogens.
D1. Analyze and explain the nutrient cycles in relation to biotic and abiotic components within the environment.
D2. Analyze and explain how species interact in the environment, including native, exotic and invasive species, and human impact.

HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-LS2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
HS-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

Objectives

The objective of this lesson is to familiarize students with the kingdom of fungi. This includes basic mushroom identification and the various ecological roles that fungi play. Proper record-keeping skills for sample collection and documentation will also be learned.

Materials Needed and Suggested Resources
Required Materials: Student computers, copies of reference labels for collection, pens, wax paper or aluminum foil for collection

Google Slides Lecture on Mushroom ID & Fungal Ecology

Fungi Foundation Collection Protocol & Reference Labels

MycoKey Fungi of Temperate Europe Identification Wheels

Mushroom Expert Online Dichotomous Key

Simplified MycoDiversity Game Directions

Optional Materials: iNaturalist app with Seek, microscope, paper or glass slides for spore prints, student phones or cameras

Engagement Activities
Part 1 (2-3 hours)
A short video by National Geographic, "You didn't know mushrooms could do all this," can be played to get students' attention. Next, the Google Slides Lecture on Mushroom ID & Fungal Ecology is presented. This lecture can be broken up into different sections as needed, depending on the length of the class periods or topic of focus. This lecture should be available to students for future reference. The Fungi Foundation Collection Protocol should be discussed with students, and the video from their website can be played to show proper documentation. It is recommended that no more than one hour be spent on this background portion.

The second hour of class time is spent on the collection foray. Students should be cautioned about the dangers of poisonous mushrooms prior to the foray. Mushrooms should not be tasted under any circumstances, unless express permission is granted by the teacher. While handling mushrooms alone will not cause poisoning, some mushrooms are fatal if ingested. Additionally, students should be prepared with a safety talk including staying in groups, bringing water and first aid supplies, poison ivy identification, and knife skills. While a knife can be a helpful tool, it is not required. To prepare for the foray Reference Labels, pens, and wax paper or aluminum foil should be distributed to students. Students should be grouped in teams of 3-5. It is suggested that each student fill out their own reference label, and the group work together to find and collect one unique fungus sample per student during the foray. Students should be reminded to look for fungi of various textures and sizes during the collection foray. Teams will compete to find the most diverse fungal collection based on identification and ecological role.

Optionally, students can download the Seek app available through iNaturalist to aid in identification. Observations can be submitted to the iNaturalist database. To make a spore print (optional, but helpful for identification on day 2), mushrooms should be set out with the hymenium (gills or pores) facing down on paper or glass slides overnight in the classroom.

Part 2 (2 hours)
Identifications can be confirmed using reference materials such as Mushrooms Demystified, MycoKey Fungi of Temperate Europe Identification Wheels, or Mushroom Expert Online Dichotomous Key. The iNaturalist Seek app will not work as well on dried specimens and is sometimes lacking for fungal identification, so it should not be relied on as the only source of information for identification. Identification to order or family level is recommended before proceeding with the MycoDiversity Game. If spore prints were made, the color can help with identification. Spores can be made into a wet mount to view under the microscope. Approximately 1-1.5 hours should be spent on identification.

The Simplified MycoDiversity Game Directions include two versions of the game that can be played to see which team has the most diverse collection. Teams should score their collection based on the rules for the MorphoDiversity Game first, then the EcoDiversity Game second. Results and rankings can be shared with the class, and all students can view the combined collection. This should take 30 minutes to 1 hour.

Assessment
This lesson is designed as an introductory activity to the Kingdom Fungi; therefore, suggested assessments are formative rather than summative. Formative assessments could include examining student reference labels for completeness, the ability to use information presented on mushroom identification to correctly identify samples collected, the use of vocabulary to describe mushroom morphology, and correctly determining the ecological role of samples.

Differentiation (Support & Extension)
Before beginning this lesson, students may need to be introduced to dichotomous keys. If so, each student group could make a key based on the 3-5 fungi they collected. This artificial key should not include “not as above” answers and give distinctive characteristics for each fungus. This could be done as a warm-up activity before the foray the following day using teacher-collected specimens. This activity could also be done using the specimens collected during the foray instead of the MycoDiversity game.

It may be helpful for the teacher to demonstrate proper collection and documentation techniques in the field before students begin the foray independently with team members. Teachers should monitor the foray activities and help struggling students locate fungi as needed.

Using iNaturalist requires users to download an app and share their location, which may or may not be something students choose to do on their personal cell phones. The Seek app can be used separately from iNaturalist and does not require sharing personal information. It is suggested that the teacher submit some observations to iNaturalist to show students the citizen/community science process. These observations could be taken prior to the foray. The map of observations can be viewed as a class following the foray.

If time permits, the video Fantastic Fungi could be played and discussed. The student version of the video is accessible from the Fungi Foundation Education website. It also contains a curriculum that could be used to generate questions related to the video.

The full version of the MycoDiversity Game Directions includes many versions of the game that can be played to see which team has the most diverse collection. The basic game uses phylogenetic trees and requires identification to the genus level. This is suggested for more advanced students.

Appendix 2

Mushroom Growth & Food Safety Lesson Plan

Scope and Sequence

This lesson was designed for high school students enrolled in an agriscience class. It can be done anytime during the school year, including winter. It is suggested that mushroom grow kits, such as oyster mushrooms, be ordered a week or two in advance so that mushrooms are available for cooking and processing. It is not recommended that wild-foraged mushrooms be prepared in class without a certified expert to identify mushrooms and parental permission for liability purposes. This lesson would be best done following a lesson on mushroom identification and ecology (see Appendix 1).

The lesson includes an introductory lecture in a Google Slides format. This lecture is divided into two parts; general food safety and MDARD regulations for selling wild-foraged mushrooms, and common mushroom toxins. This background information, cooking mushrooms grown in class, and transferring mycelium to grow new mushrooms should take approximately 1-2 hours of class time.

Core Competencies and Standards of Focus

A1. Examine and summarize health, safety, and environmental regulations in AFNR organizations.
A2. Develop and practice plans to handle emergencies and common hazards.
C5. Describe how natural resources are harvested, processed, and turned into final products, and how this can be done sustainably.

HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Objectives

The objective of this lesson is to familiarize students with the Michigan modified food code as it relates to processing and selling wild-foraged mushrooms, common toxins found in wild mushrooms, and how to grow and cook cultivated mushrooms.

Materials Needed and Suggested Resources

Google slides lecture on Michigan mushroom sale laws and fungal toxins

Mushroom grow kit(s), toilet paper rolls, plastic bags, hot water (from pot or hotpot), extra trays or tote to handle hot material

Saucepan, heat source, butter or oil, utensils

Kahoot game review and student computers

Optional Materials: Pressure cooker, autoclave bags, straw or wood pellets for substrate, 70% rubbing alcohol, gloves, Martha tent

Engagement Activities
Students should help to prepare mushroom grow kits 1-2 weeks before the lesson. This involves soaking them overnight in water and then misting them daily. Two grow kits should be plenty to produce mushrooms for approximately 30 students to sample. This lesson should be done when the mushrooms have fully fruited. On the day of the lesson, the Google slides lecture on Michigan mushroom sale laws and fungal toxins is presented to the students. This lecture should take approximately 20-30 minutes. Discussion and questions should be encouraged at the teacher's discretion.

Students can help to process and cook the mushrooms by carefully slicing them from the block of substrate and cooking them in the saucepan with butter or oil (or the teacher can demonstrate this). All proper food safety protocols should be followed; the area should be disinfected with a food-safe cleaner, and hands should be washed. The difference between the cultivated mushrooms prepared here and wild-foraged mushrooms can be discussed. While mushrooms are cooking, the Kahoot game review can be played. Mushrooms must be thoroughly cooked for at least 15 to 20 minutes. Water should also be boiled at this time for mushroom cultivation using toilet paper (a hot pot works for this).

The substrate block from the mushroom kit can be broken up into smaller chunks either with a knife or by tearing pieces off with clean hands. Students can place a toilet paper roll in a plastic shopping bag, and then place the bag in or on a tote or tray. Hot water is poured into the bag to soak the toilet paper roll. The tote or tray helps students to move the bag around the room and not burn themselves. The toilet paper roll should be saturated without having extra water in the bag. A small handful of substrate from the mushroom grow kit will be added to the toilet paper roll once it is warm to the touch. The bag can then be tied shut and kept in a dark location. The bag should be checked once a week to view the white growth of mycelium and to check for contamination (usually green mold). Bags with contamination should be discarded. Setting up the new mushroom toilet paper growth bags will take approximately 20-30 minutes, depending on the size of the class. Cooked mushrooms can also be sampled during this time.

Assessment
This is designed as an introductory activity to the Michigan modified food code, mushroom toxins, and cooking and growing cultivated mushrooms. Therefore suggested assessments are formative rather than summative. Formative assessments could include class discussion and the ability of students to follow directions to process and grow fungus. The review Kahoot game is meant to be a formative assessment but could be adapted into a summative assessment.

Differentiation (Support & Extension)
Students should be encouraged to sample the mushrooms cooked as a class, but student allergies and mycophobia should be considered.

The optional list of materials includes supplies for students to grow mushrooms in a way that is more closely aligned to industry while still using accessible materials in the classroom. This is why a pressure cooker is suggested to sterilize bags and media instead of an autoclave. Keep in mind that the sterilization setting on a pressure cooker may take 1-2 hours, so substrate may need to be transferred the following day, or substrate bags can be sterilized in advance. Surfaces, tools, and gloves should be disinfected using 70% ethanol or isopropyl alcohol. These materials will cost more than the method using toilet paper, but is less likely to encounter contamination and may produce more yield. Students can continue growing new batches of mushrooms as long as the mycelium is not contaminated. Contamination will often look like green mold (*Trichoderma* spp.).

If the Kahoot game is made into a summative assessment, then accommodations should be made as necessary to support students with IEP or 504 plans.

Appendix 3

Mushrooms as a Renewable Resource Lesson Plan

Scope and Sequence

This lesson was designed for high school students enrolled in an agriscience class. This lesson is not weather-dependent and could easily be done in the winter months. It could be done independently of the lessons on mushroom ecology, identification, and growth (See Appendices 1 and 2).

The lesson includes a Google Slides presentation on laws and regulations related to the collection of wild mushrooms, how to forage sustainably, and how mushrooms are a renewable resource. The presentation ends with an introduction to life-cycle assessments for products. This introduction ties to the second portion of the lesson, in which students research a product made from fungal mycelium and compare it to a traditional product, listing the pros and cons in a life cycle analysis. The lecture and activity should take 1-2 hours of class time.

Core Competencies and Standards of Focus

C2. Analyze and describe laws related to natural resource management and protection.
C4. Analyze and explain how issues, trends, technologies, and public policies impact society, the economy, and the environment.
C6. Analyze and explain the pros and cons of renewable versus non-renewable energy products.
D3. Apply scientific principles to natural resource stewardship and management activities to enhance the quality of an ecosystem.

HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Objectives

The objectives for this lesson include familiarizing students with basic laws and best practices related to wild mushroom foraging, the concepts of sustainability and renewable versus non-renewable resources, and product life cycle assessments.

Materials Needed and Suggested Resources

Google Slides lecture on mushroom foraging laws and economics

Mushroom Product Life Cycle Analysis Worksheet

Student computers

Engagement Activities

To begin this lesson, students should brainstorm keywords related to sustainability or renewable resources. These keywords can be written down individually on scrap paper for 1-2 minutes, then shared aloud with the class and written on the whiteboard. These keywords should be referenced during the lecture. Next, the Google Slides lecture on mushroom foraging laws and economics can be presented to students. This lecture ends with an introduction to life cycle assessment for products. This portion of the lesson should take about 30 minutes.

Next, students should be split into small groups (3-5) to conduct research on the Mushroom Product Life Cycle Analysis Worksheet. Each group can be assigned a different product (building materials, packaging, or clothing). It should be made clear to students that life cycle assessments are very complex and require a lot of research by a company. Therefore, each student should thoroughly research the pros and cons of their products for each category of the life cycle analysis (resource recovery, manufacturing, packaging and distribution, use, and end of use). There is no single correct answer, but more information will help them present their results to the class. Students should be given 30 minutes to 1 hour to research their products and fill out the table on the worksheet. Students will then present their results to the whole class. This could be done verbally, using student worksheets under a document viewer, or with students writing out their pros and cons on the whiteboard. Student presentations should be given 30 minutes. This portion of the lesson will take 1 hour to 1.5 hours, depending on how much time is allocated for student research and the number of groups for presentations.

Assessment

This lesson was designed as an introductory activity to sustainable foraging, mushrooms as a renewable resource, and life cycle analyses of products. Assessments were designed to be formative rather than summative. Formative assessments could include class brainstorming of keywords and connections made during class discussion and lecture. The mushroom product life cycle analysis worksheet is meant to be a formative assessment but could be adapted into a summative assessment. As a formative assessment, it can be used to see how thoroughly students answer the questions and consider the pros and cons of each portion of the table. Some questions may be challenging to answer as some mushroom-based products are still being developed for commercial use. If it is made into a summative assessment, then clear expectations should be set for students.

Differentiation (Support & Extension)

Student grouping should be carefully considered for the active participation of all group members. Each group member could be assigned to one of the five life cycle assessment categories to help ensure equal distribution of group work. The teacher can assist struggling students by suggesting keywords to look for as they search for background information to fill out the table.

Additional products such as biofuels, nutritional supplements, or mycofiltration could be added to the life cycle analysis. These may be more challenging topics to research. An alternative way to assign groups could be to split the class and have half research the mushroom-based products and the other half research the traditional product. Results could then be compared in a debate-type format where each group defends their product type based on the five stages of the life cycle analysis.

Appendix 4

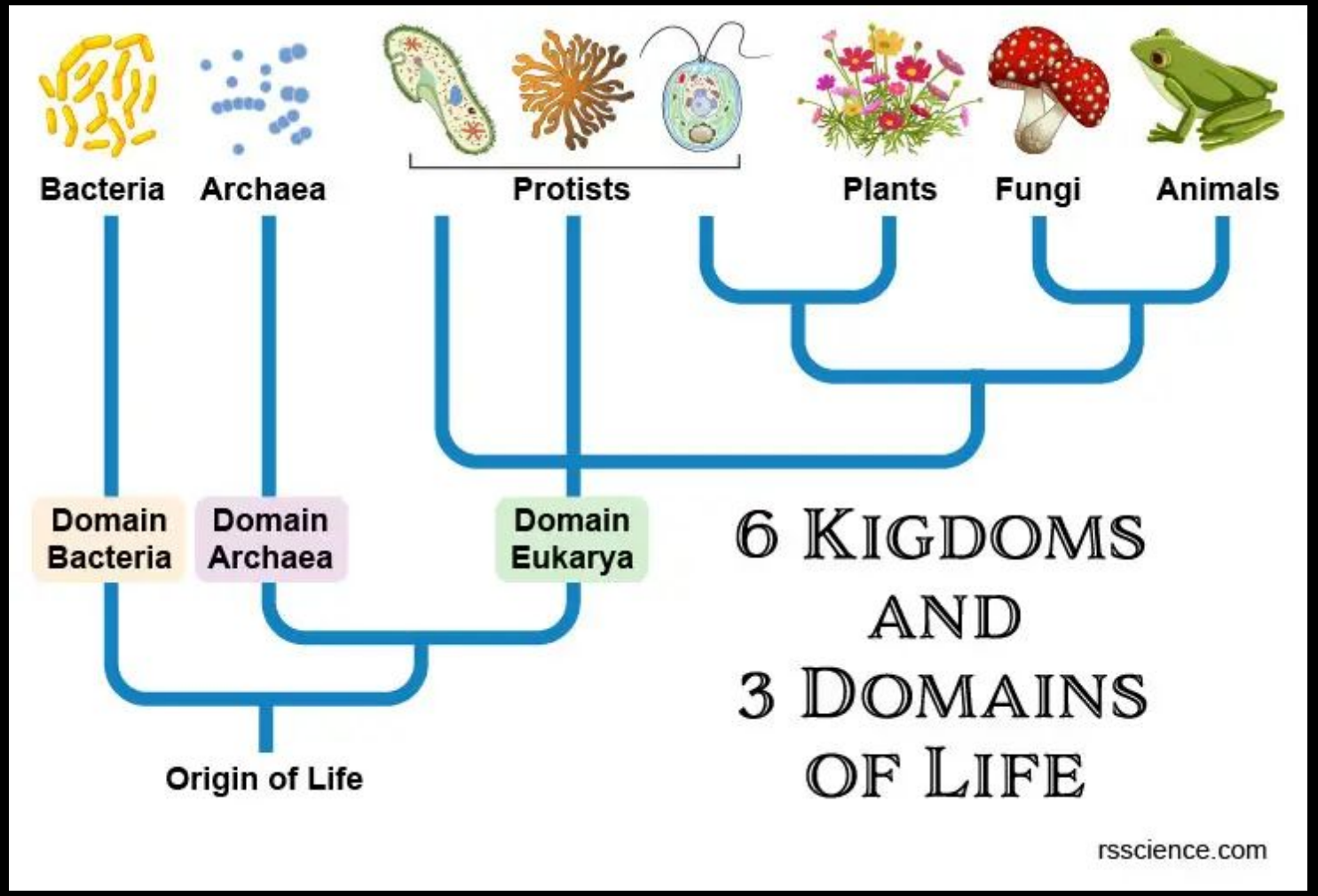
Ancillary Materials

This section contains all Google Slides lectures and worksheets in a PDF format.

Mushroom Identification and Fungal Ecology

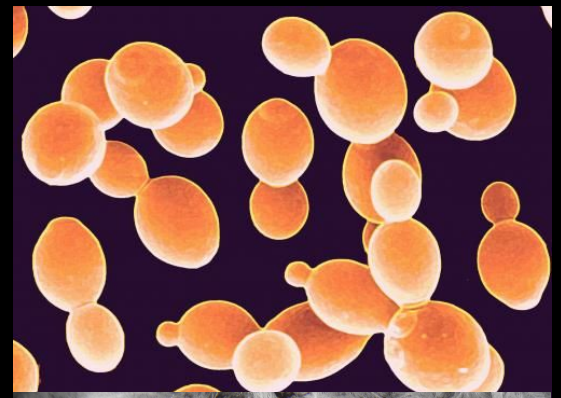
The Fungal Kingdom of Life

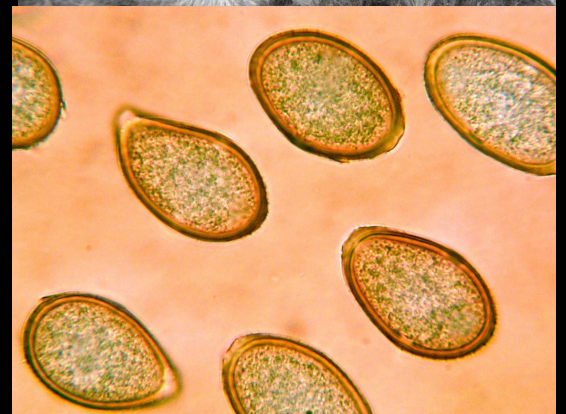
- Domain is Eukarya
  - Cells have nuclei
- More closely related to animals than plants
- Heterotrophs
  - Eat other organisms
  - Cellular respiration
    - Need oxygen
  - Many are decomposers
  - Wet conditions



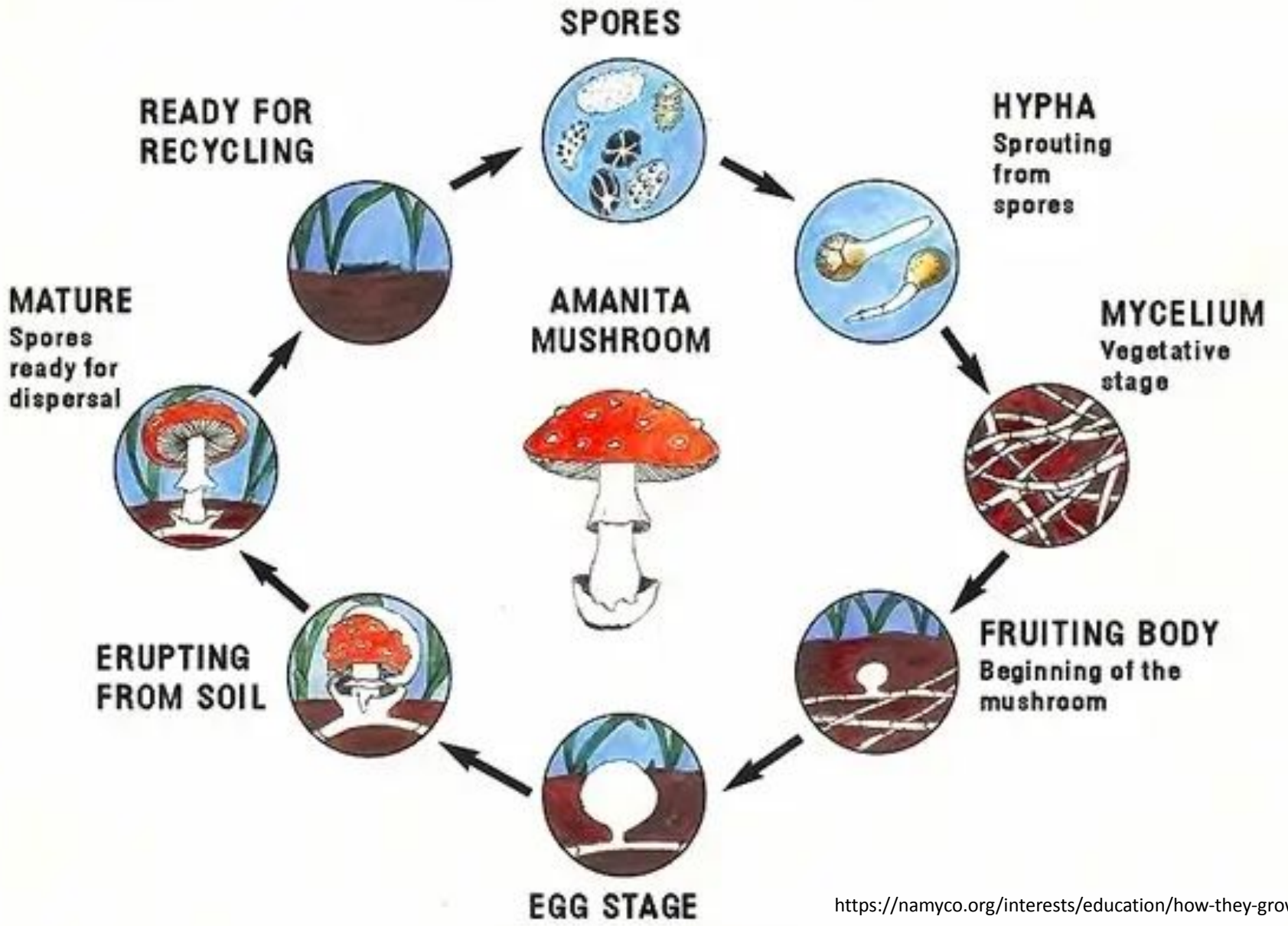
Fungal Growth Forms

- Some Single celled (yeasts)
- Most multi-celled with Hyphae/Mycelium
  - Looks like a web
- Some form mushrooms
  - AKA “Fruiting bodies”
  - Produce spores on hymenium
  - Mushrooms come in many shapes and sizes



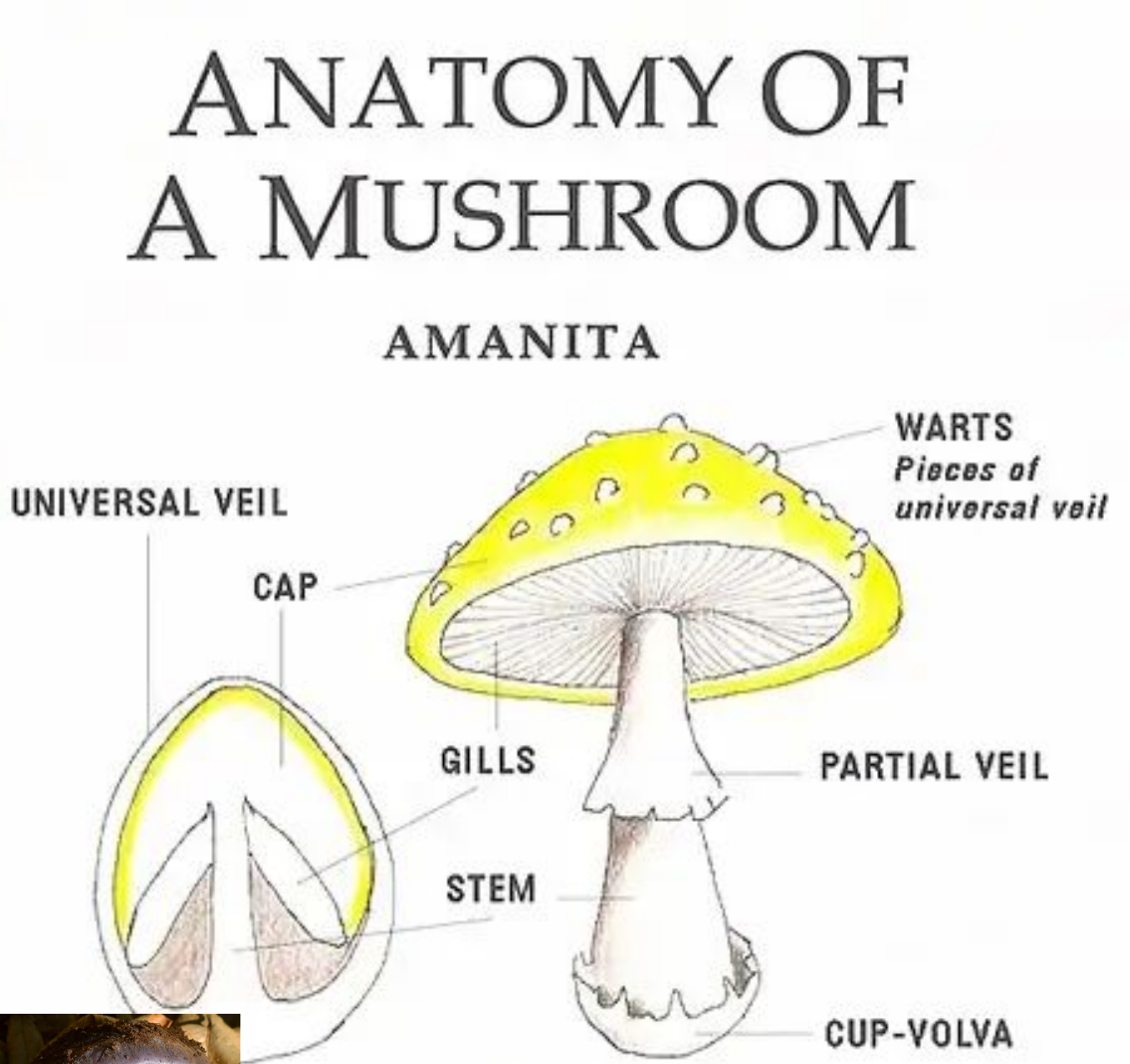


How Mushrooms Grow



https://namyco.org/interests/education/how-they-grow/

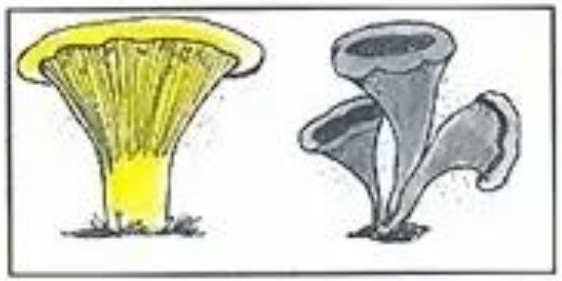
- Learning mushroom identification is challenging
- Some mushrooms don't have all parts of the anatomy
- Terminology can be confusing
  - Cap=Pileus
  - Stem=Stipe
  - Gills=Hymenium
    - Can be pores, ridges, or teeth
  - Universal veil may be present
    - Separates into many parts
      - Warts on top of cap
      - Annulus ring on stem
      - Cup below stem
  - Inner partial veil may form cortina
    - Covers hymenium in thin web before mushroom matures



https://namyco.org/interests/education/how-they-grow/

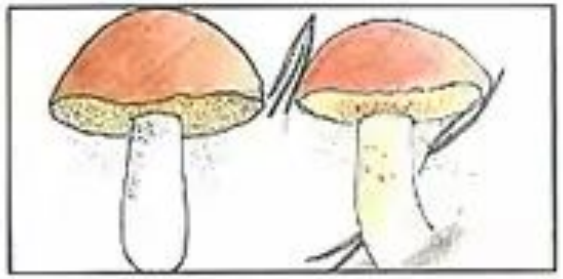
Different Shapes of Fungi
& where the spores are formed

CHANTERELLES

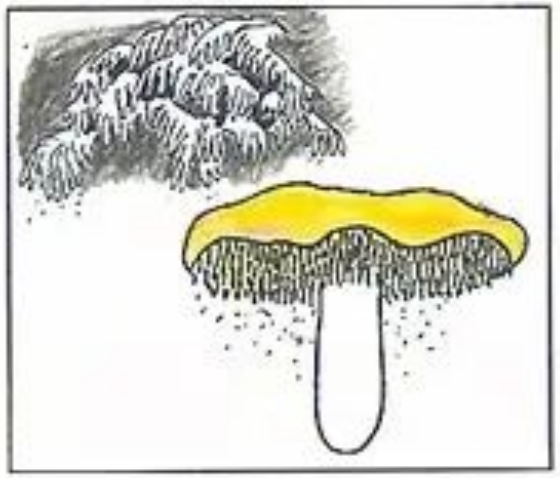


GILLED FUNGI

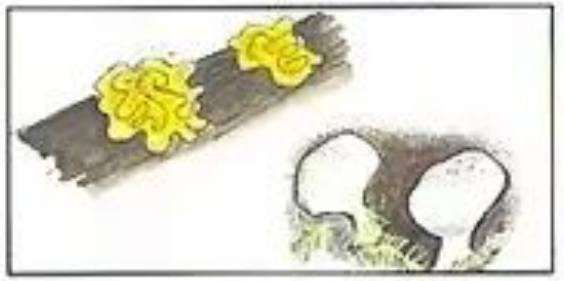
FUNGI WITH PORES



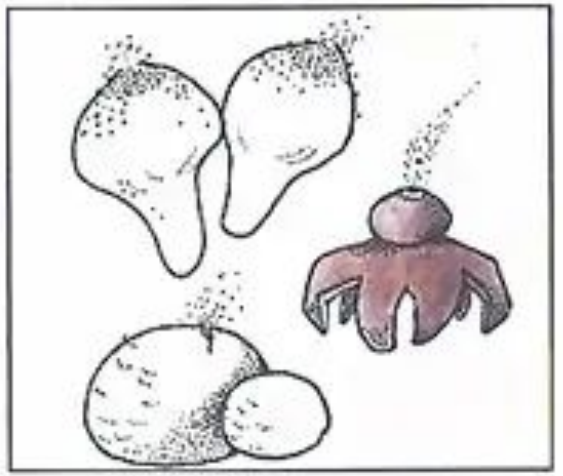
FUNGI WITH TEETH



JELLY FUNGI



PUFFBALLS

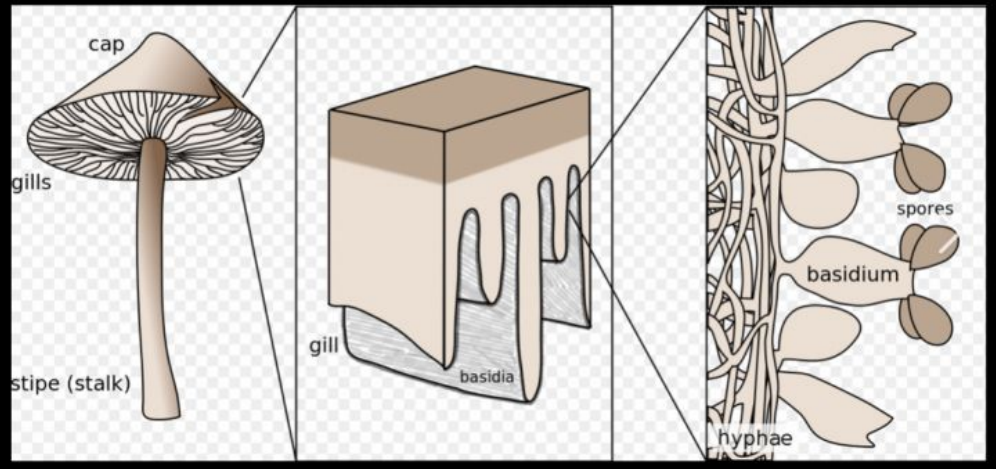


https://namyco.org/interests/education/how-they-grow/

Two Main Fungal Phyla (Groups)

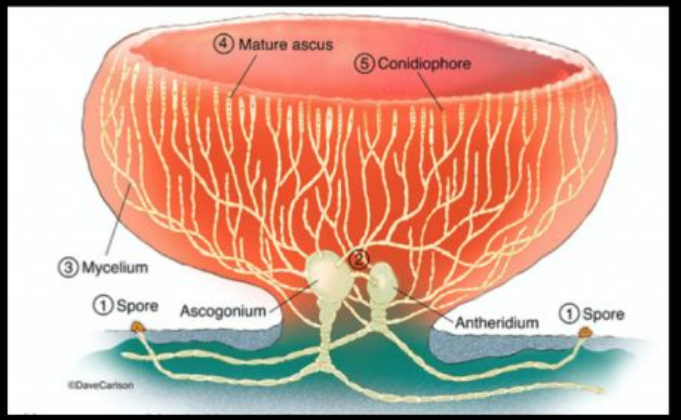
Basidiomycota

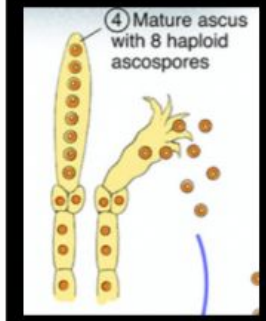
- Spore “droppers”
- Most of the fungal fruiting bodies that you see
- Spores are produced on gill (or equivalent) edges



Ascomycota

- Spore “shooters”
- The largest fungal phylla
- Includes flask fungi, lichens, yeasts and moulds
- Most commonly seen as cups, morels and truffles





Cup Fungi

Morels

Candlesnuff fungus

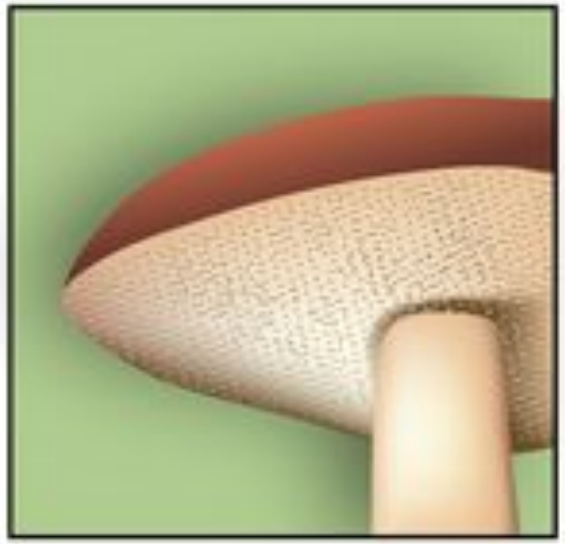
Truffles

https://gallowaywildfoods.com/an-introduction-to-fungi-foraging/

Wikimedia Commons

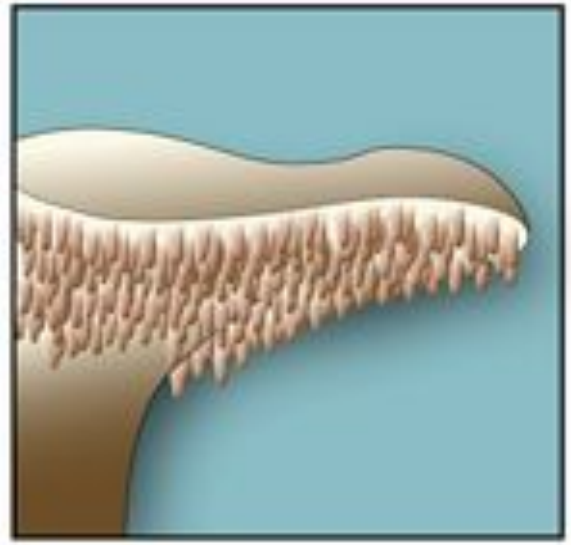
Spore-bearing surface under cap

Gills:
wide and thin sheet-like plates radiating from stem



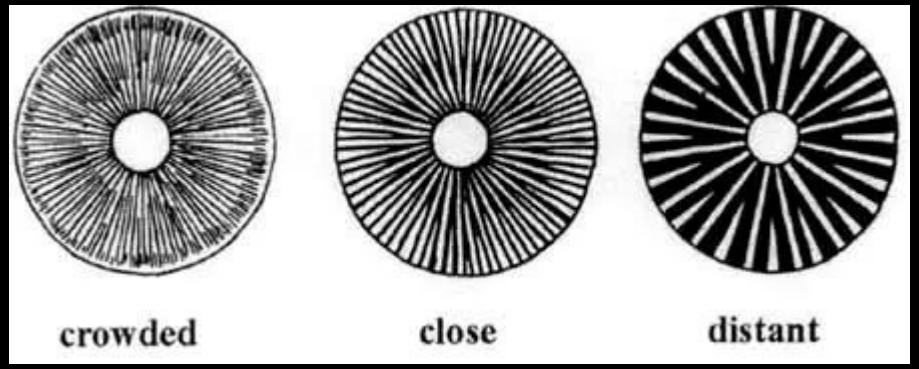
Pores:
many small tubes ending in a spongy surface

Ridges:
short, blunt elevated lines on stem and under cap



Teeth:
many small finger-like projections

- Spore prints
  - Show spore color & gill spacing →
  - Microscopic spore features



https://midwestmycology.org/identify/

Mushroom Spore Colours

- Only 7 basic spore colours
- Some genus include a range of spore colours
- Almost never blue, green or red

CREAM

- Funnels/Clitocybe
- Deceivers/Laccaria
- Toughshanks/Collybia
- Oysters/Pleurotus (sometimes white)

YELLOW

Some Chanterelles/ Cantharellus (varied)

WHITE

- Parasols/macrolepiota
- Amanita
- Brittlegills/Russula (some cream)
- Milkcaps/Lactarius
- Honey fungus
- Knights/Tricholoma

BROWN

- Boletes (occasionally olive green)
- Webcaps/Cortinarius (variable)
- Rustgills/Gymnopilus
- Poison Pies/Hebeloma
- Fibrecaps/Inocybe
- Scalycaps/Pholiota

DARK BROWN - PURPLE

- Tufts/Hypholoma (Dark brown)
- Mushrooms/Agaricus

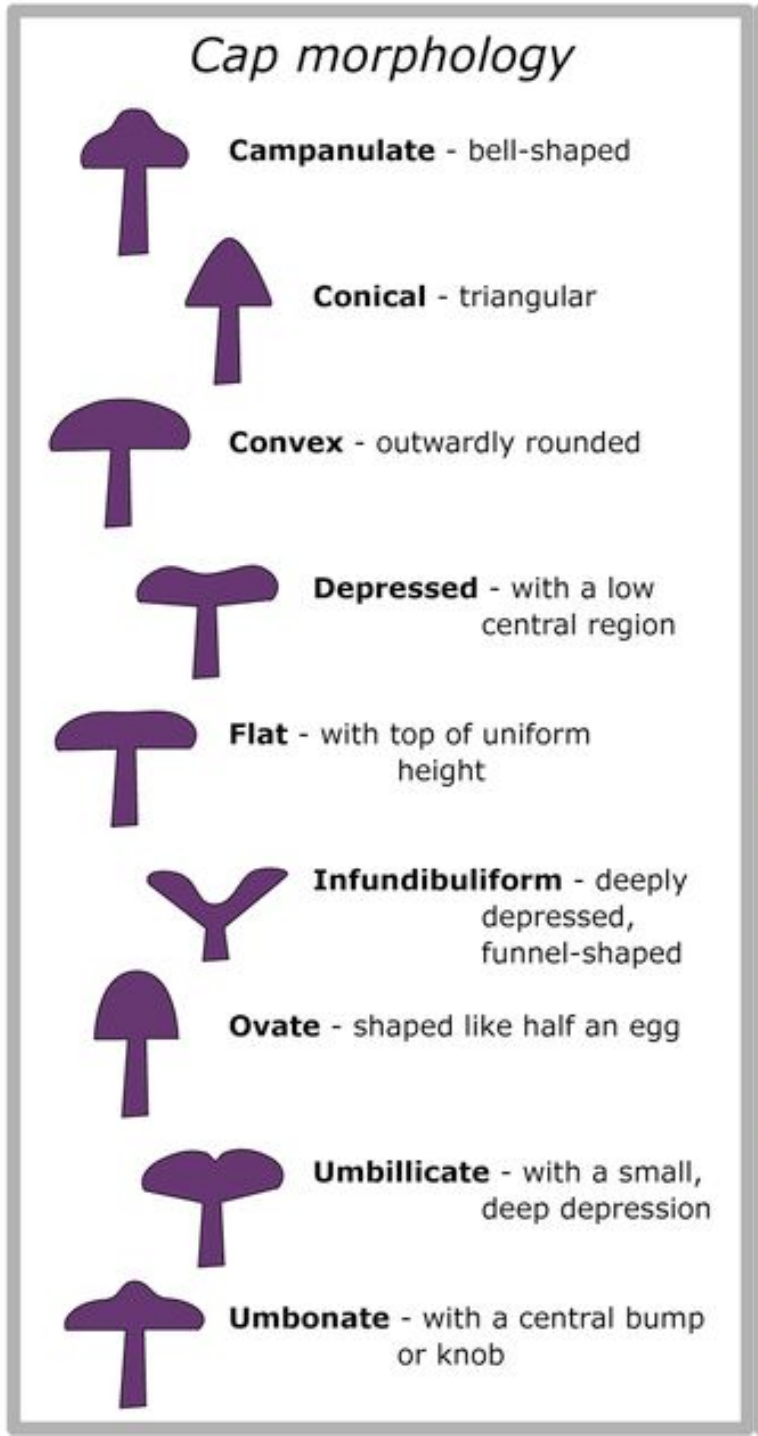
PINK

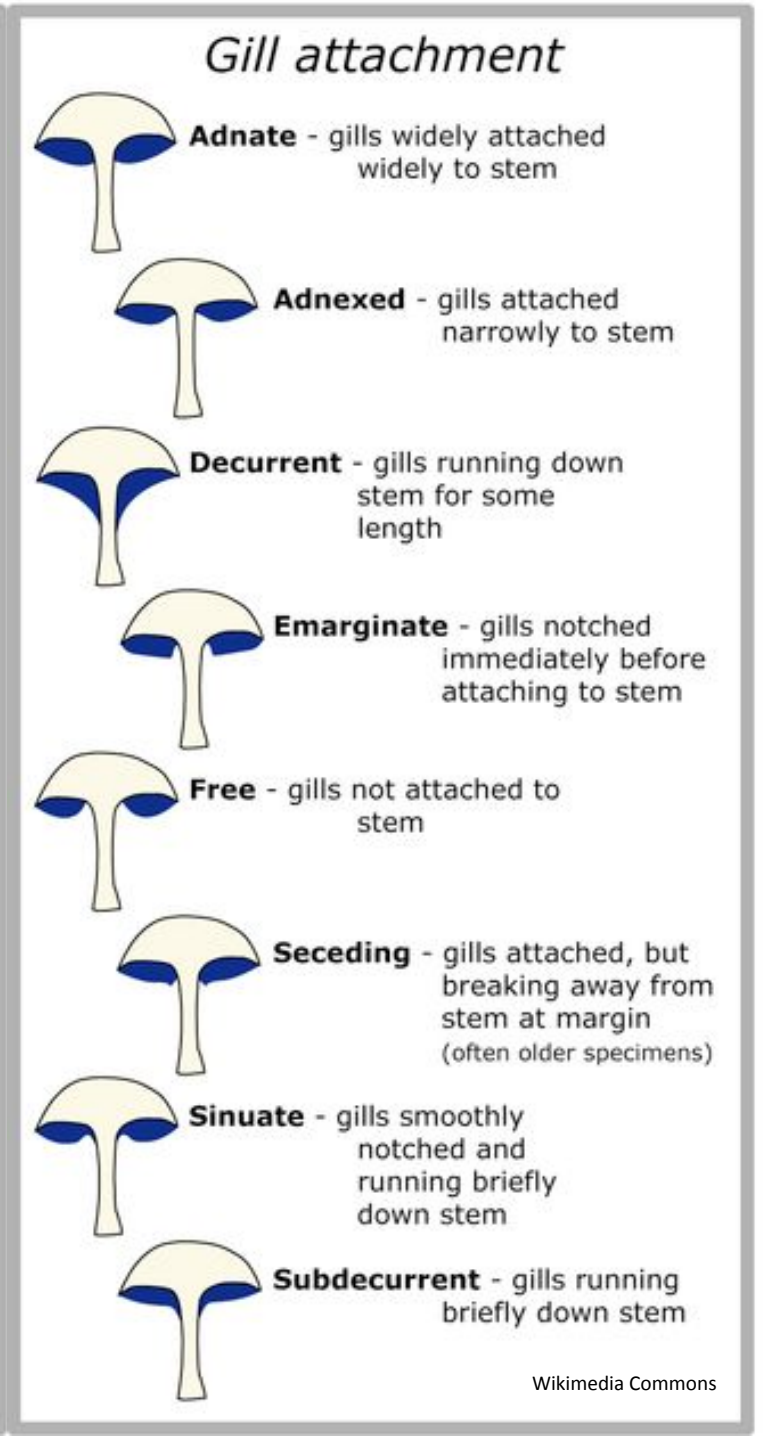
- Blewits/Lepista(Clitocybe)
- Pinkgills/Entoloma

BLACK

- Brittlestems/Psathyrella (or v dark brown)
- Inkcaps/Coprinopsis

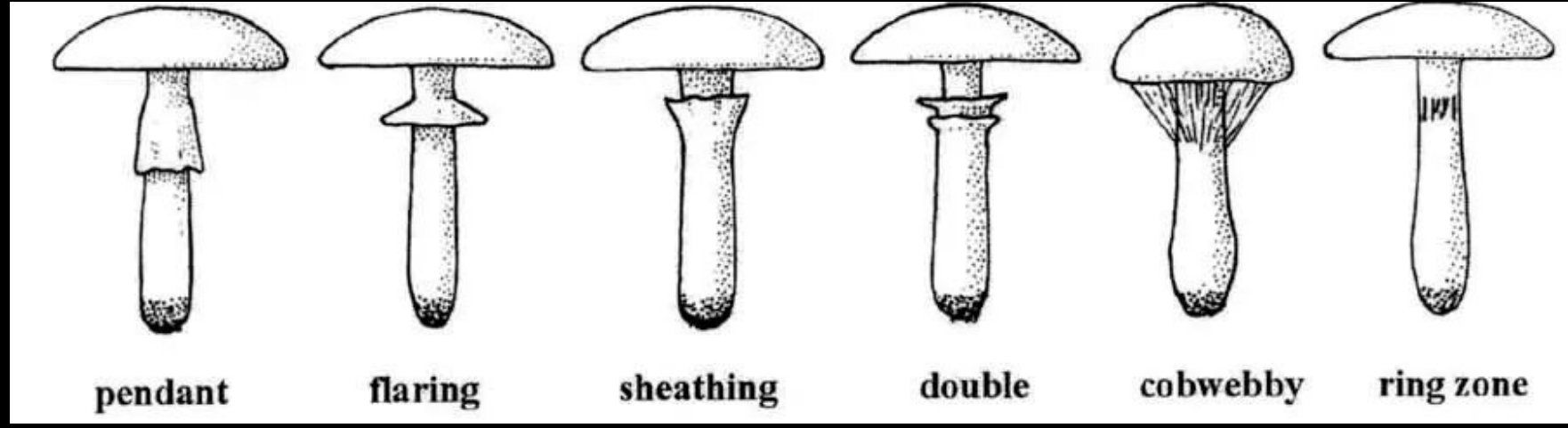
- Important features to note
  - Color
  - Texture on cap and stem
  - Smell
- Caps have many shapes
  - Can change with age
    - Usually flattens
- Gills attach to stem in different ways

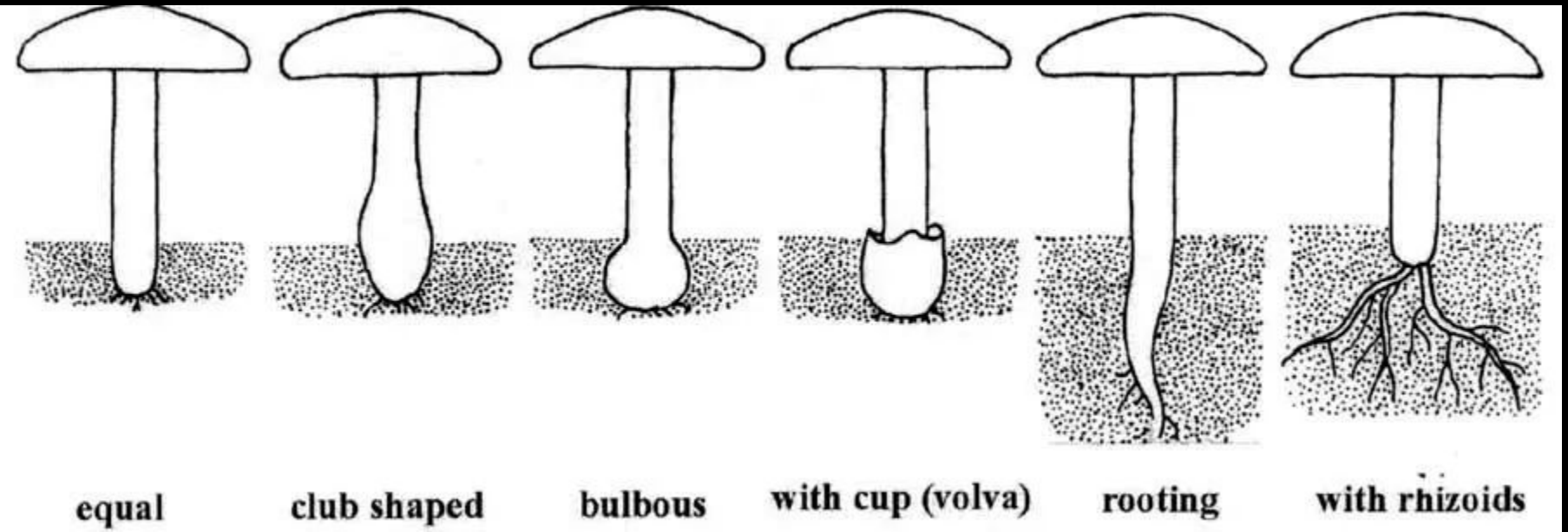




Veil Types →

- Veil might not be present
- Changes with age
  - Look around for older or younger specimens





←Stem Shape

- Important to dig up the base of the mushroom

Images: midwestmycology.org/identify/

Fungal Ecology

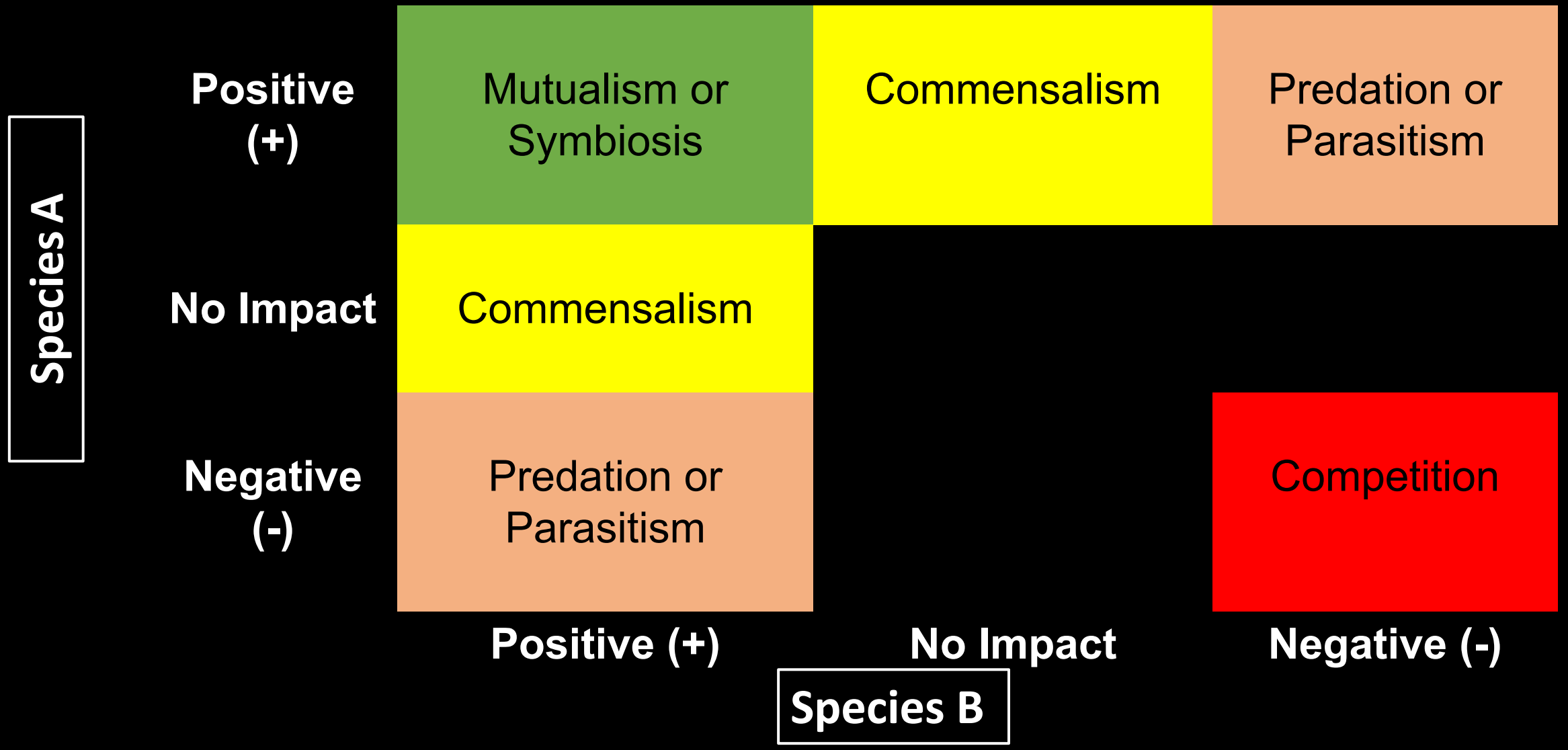
PARASITIC FUNGI

Mycorrhizal Partnership

SAPROPHYTIC FUNGI

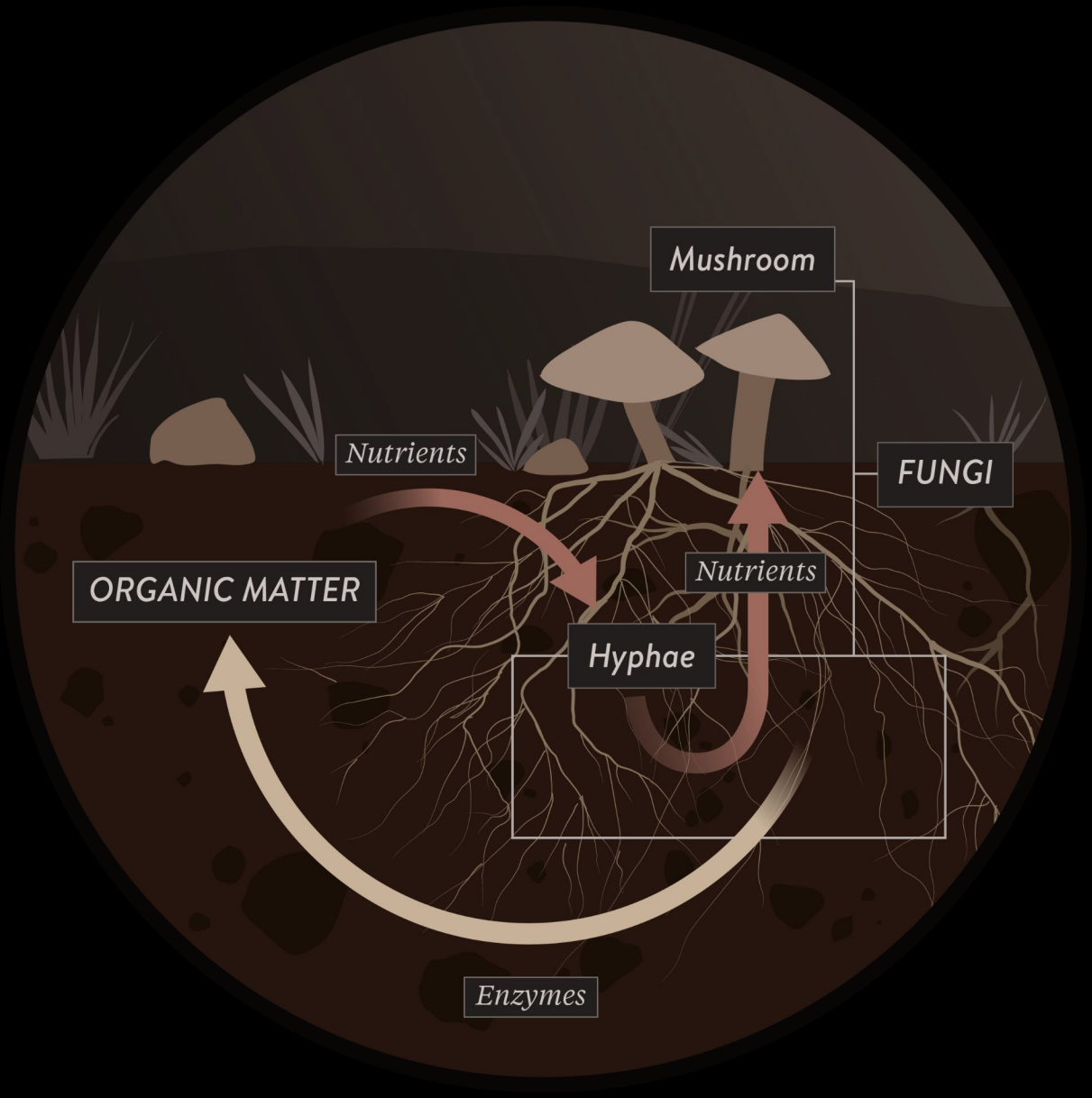
https://namyco.org/interests/education/how-they-grow

Types of Ecological Interactions



Mode of Metabolism: Decomposer

- Saprotrophs
  - Secrete enzymes into the environment to obtain food
- Make nutrients stored in dead plant and animal matter available for plants
- Recycle carbon and nutrients
- Can specialize on substrate
  - Leaf litter
  - Wood
  - Animals
  - Insect frass



https://www.bu.edu/articles/2016/soil-fungi/

Decomposer-Shiitake

- *Lentinula edodes*
- Usually grown on logs from deciduous trees
- Spawn Run 1-2 months
  - Longer for logs
  - Temps below 40 F can stop run, potentially kill mycelium
- World's second most cultivated mushroom

Decomposer-Burgundy Mushroom/Wine Cap

- *Stropharia rugosoannulata*
- Decomposer
  - wood chips, mulch
- Grows well with

  corn crops
- Kills nematodes

  with sharp ends of hyphae

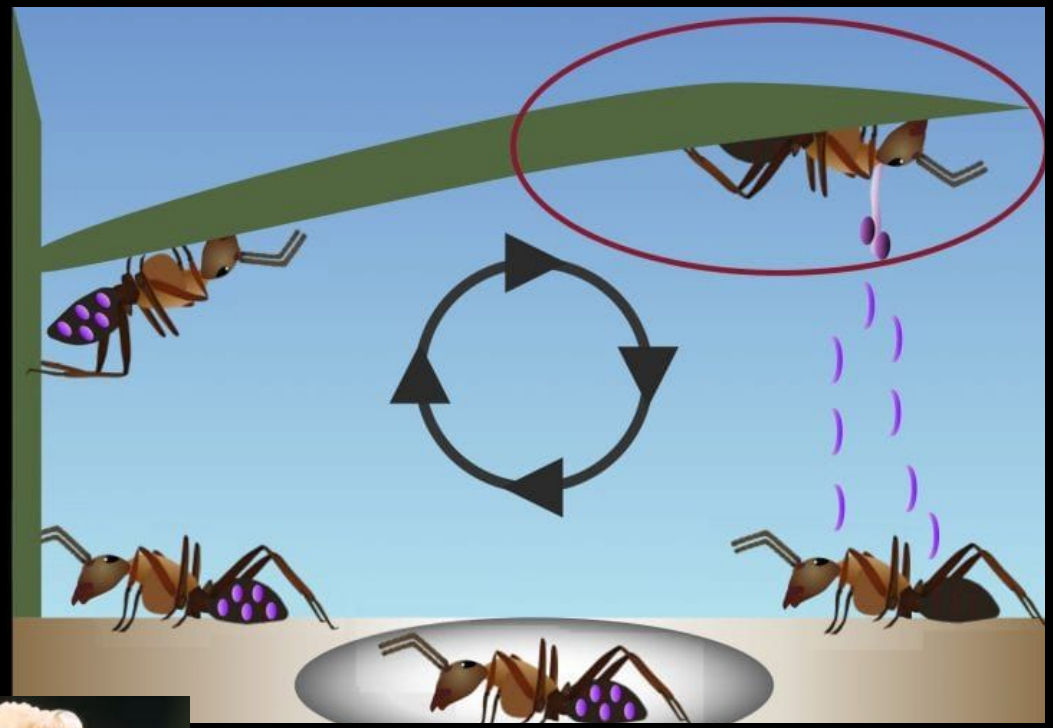
Invasive Species Golden Oyster Mushrooms

- *Pleurotus cintrinopileatus*
- Decomposers
- Short Spawn Run 2-3 wks
- Not native and may compete with native mushrooms for space and resources
- Escaped cultivation in early 2010's
- Other species used in mycoremediation
  - Clean up nutrients, oil spills, etc.
- All species catch nematodes and kill them with toxins

<https://www.youtube.com/watch?v=hWdmL8sGCB4

Mode of Metabolism-Pathogens & Parasites

- Can be specific to plants, animals, or other fungi
- Pathogens
  - May live independently of host organism
- Parasites
  - Must live in or on host organism
- Reduce the health of the host by taking nutrients
  - Discolored leaves
  - Slow growth
  - Small fruit or no fruit
  - May kill host



Ophiocordyceps fungal parasite infects “zombie” ants”

https://sciences.ucf.edu/biology/debekkerlab/research/

Pathogen-Armillaria white root rot disease

- *Armillaria spp.*
- Facultative pathogen kills trees
  - Devastating to orchards
  - Can also grow as a saprotroph on dead wood
- Largest living fungus covers over 3.4 square miles in Oregon
  - Michigan's humongous fungus in Crystal Falls is over 2,500 years old and 40 acres large
- Forms black rhizomorphs that can be found on nearby wood

Mycoparasite-Shrimp of the Woods

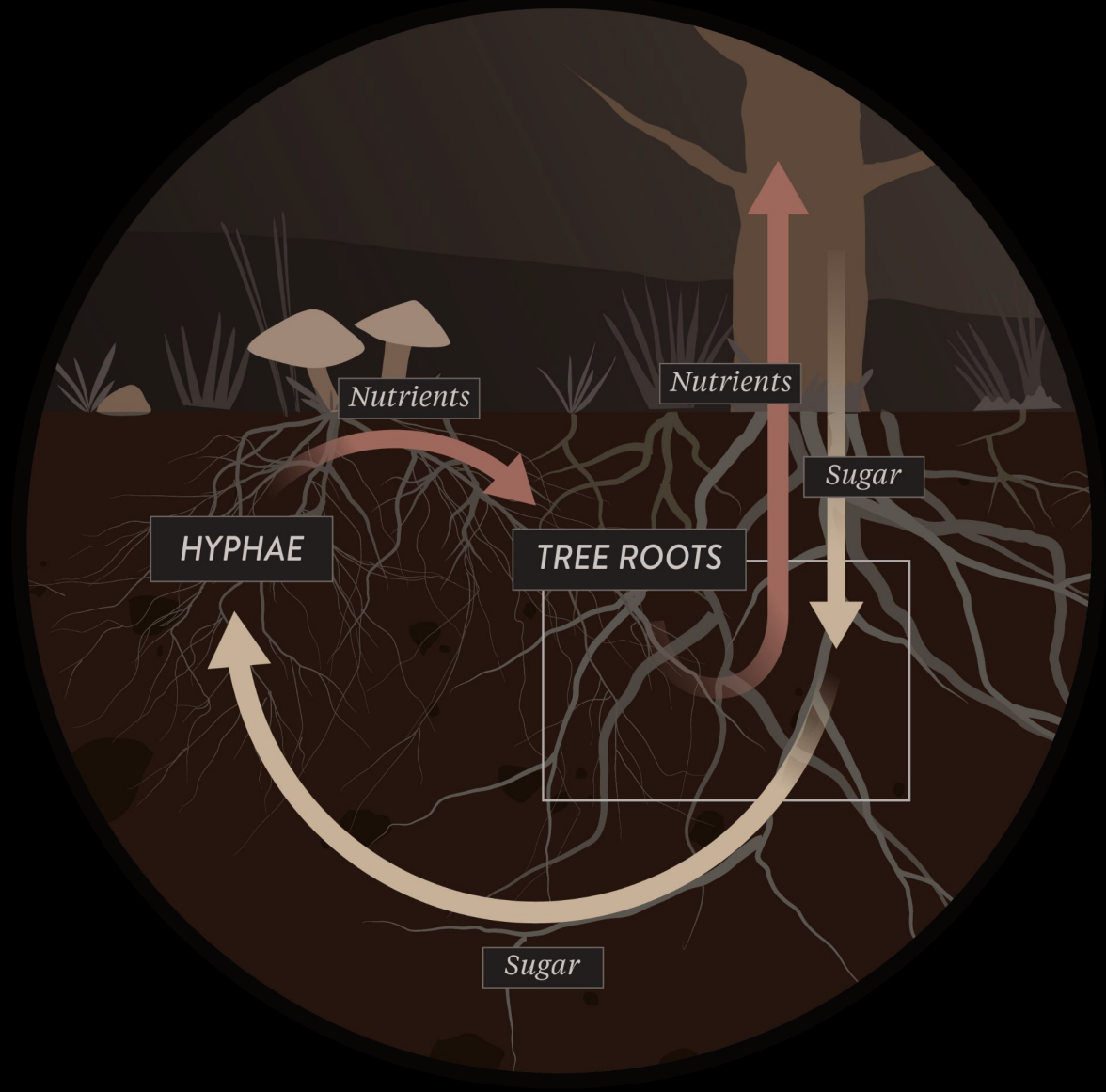
- *Entoloma arborvitum*
- Mycoparasite
  - Infects *Armillaria*
- Can also grow as a saprotroph on dead wood or leaf litter
- Aborted Entoloma is sought after edible, but Entoloma on its own is poison

Plant Parasite-Potato Blight

- *Phytophthora infestans*
- A “fungus” that attacks potatoes and tomatoes
  - Spores and hyphae grow on leaves and tubers
- Grows in wet, cool conditions
- $6 Billion in damage to crops each year

Mode of Metabolism: Mutualism

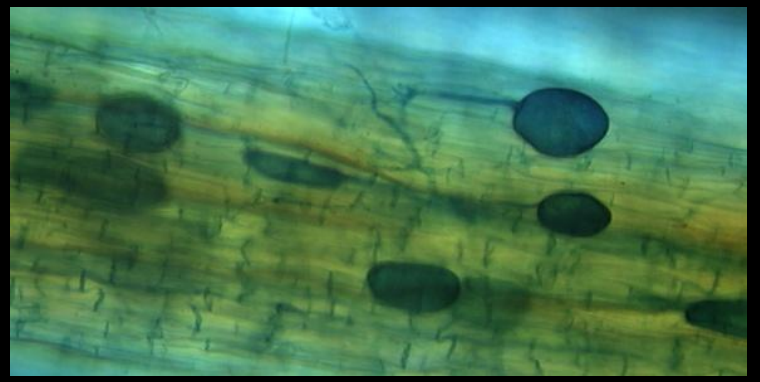
- Both plant and fungus benefit
- Mycorrhizal fungi
  - "Fungus Root"
  - Help plant take up nutrients in exchange for simple sugars from roots
  - Obligate symbionts
  - Two main types
    - Arbuscular
    - Ectomycorrhizal
- Endophytes live in or on leaves or roots
  - Help plant to secrete defense compounds

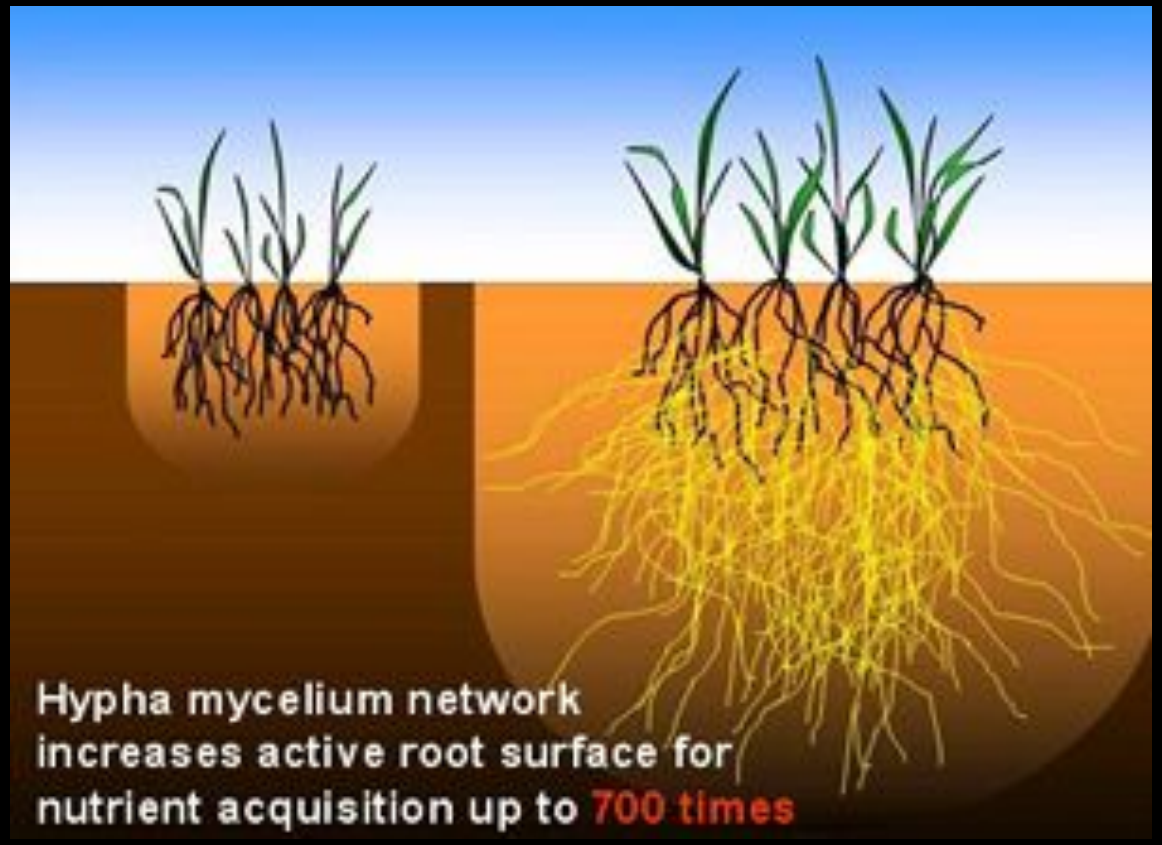


https://www.bu.edu/articles/2016/soil-fungi/

Arbuscular Mycorrhizal Fungi

- Associate with over 90% of plants
- Enhance plant nutrient uptake (P, Zn, Cu, etc)
- Protect from drought by taking up water
- Stimulate growth regulating substances (“hormones”)
- Don’t produce mushrooms





Ectomycorrhizal Fungi

- Associate with 30% of woody plants (trees)
  - Often used in pine and eucalyptus plantation establishment

- Obtain N resources for host
- Visible with the naked eye
- Some produce mushrooms

Mycorrhizal Mutualist-Truffles

- *Tuber spp.*
- Many species of oak rely on ectomycorrhizal mutualism
- Mushroom grows below ground (hypogenous)
- Produces smelly compounds to attract mammal for dispersal
  - Sought after for culinary purposes

Mycorrhizal Mutualist-Chanterelles

- *Cantharellus spp.*
- Mycorrhizal on conifers or hardwoods
- Mushroom yellow to orange with decurrent wrinkled gills
- Global trade >$1.5 Billion/year
  - Sought after for culinary purposes

Mycorrhizal Mutualist-Boletes

- *Boletus spp.*
- Most are mycorrhizal
- Mushroom spongy with pores on hymenium
- Many species are edible
  - Ceps or porcini
  - Red pored species or blue staining species should be avoided

Reference Sample Labels for Collection

2 cm

Collector: _____

Date ____ / ____ / ____ Sample n° _____

Species _____

Location _____

Coordinates _____

Altitude _____ / Substrate _____

2 cm

Collector: _____

Date ____ / ____ / ____ Sample n° _____

Species _____

Location _____

Coordinates _____

Altitude _____ / Substrate _____

2 cm

Collector: _____

Date ____ / ____ / ____ Sample n° _____

Species _____

Location _____

Coordinates _____

Altitude _____ / Substrate _____

2 cm

Collector: _____

Date ____ / ____ / ____ Sample n° _____

Species _____

Location _____

Coordinates _____

Altitude _____ / Substrate _____

MycoDiversity Game

The MorphoDiversity Game: The physical form, or morphology, of the mushroom fruiting body can be considered as a type of diversity. Add points according to the following guide. NOTE: each morphotype can only be scored once. For example, if you collect five agarics, you get only five extra points.

Morphotype	**Points Possible**	**Found (Y/N)**	**Points Awarded**
Agarics (with a cap and gills)	5		
Polypores (with pores)	5		
Toothed (with spines)	7		
Coralloid or Clavarioid (club shaped)	7		
Gasteroid (puffballs, stinkhorns, truffles, bird's nest fungi)	7		
Chanterelle like fungi (Craterellus, Polyozellus, Gomphus)	7		
Crust Fungi (corticoid smooth, poroid, or toothed spore surface)	10		
Jelly Fungi	10		
Cup Fungi (morels, earth tongues, discomycetes)	10		
Cyphelloid (hallow tube shape)	15		
Other (Sparassis)	20		
Total Points	113	XXXXXXXXXXXX	

These games were adapted from:

Hibbett, D. (2009). MycoDiversity: It's more than just the history of life, it's a game. Northeastern Mycological Federation workshop. https://hibbettlablog.wordpress.com/wp-content/uploads/2018/10/game-rules.pdf

The EcoDiversity Game: Fungi obtain their nutrition in diverse ways. Points are awarded for the various ecological clades of the fungi in your collection. You may need to consult with a professional mycologist (or your teacher) to determine how all your taxa make their living. Of course, in many cases, we don't know what the Fungi are doing! NOTE: Each ecological clade can only be scored once.

Ecological Clade	**Points Possible**	**Found (Y/N)**	**Points Awarded**
Litter-Decayer	5		
Wood-Decayer	5		
Mycorrhizal	5		
Lichen	5		
Plant Pathogen or Parasite	7		
Mycoparasite	10		
Insect Parasite or Mutualist	15		
Total Points	52	XXXXXXXXXXXXX	

These games were adapted from:

Hibbett, D. (2009). MycoDiversity: It's more than just the history of life, it's a game. Northeastern Mycological Federation workshop. https://hibbettlablog.wordpress.com/wp-content/uploads/2018/10/game-rules.pdf

Michigan Wild Foraged Mushroom Sale Laws

Certified Expert Identifier

- In order to legally collect and sell wild-foraged mushrooms anywhere in the United States, a person must be an expert in the identification of wild mushrooms (U.S. Public Health Service, F.D.A., 2009 Food Code, Michigan Modified Food Code 2012)
  - In Michigan certification is granted by MDARD in partnership with MAMI

- A seller must be recognized as an approved mushroom identification expert or employ a recognized mushroom identification expert.

- **Each individual mushroom** must be inspected and identified by the recognized expert. Only those identified as safe may be sold.

Midwest American Mycological Information

https://midwestmycology.org/selling-mushrooms/

Labeling and Record Keeping

- Every container used to **store** wild-foraged mushrooms must be labeled with latin and common name
- **Packaged** mushrooms may be identified by the common name only
  - Additional labeling; weight, name of seller, expert identifier, allergens
- Written records indicating the quantity, variety, expert identifier, and **buyer** of the mushrooms shall be retained by the seller for a period of not less than **two years.**
  - Available for MDARD examination upon request

Example Label

Scientific Name:_____
Common Name:_____
Net Weight (g):_____
Expert Identifier:_____
Seller:_____

Allergens: Contains Mushrooms
"Made in a home kitchen that has not been inspected by the Michigan Department of Agriculture & Rural Development"

https://www.michigan.gov/mdard/food-dairy/michigan-cottage-foods-information

Storage and Processing

- Protected from contamination in accordance with regulations associated with the handling and processing of foods intended for human consumption.

- Treated as a raw agricultural commodity under cottage food law
  - Refrigerate in paper bags until sale
  - Expert identifier can dry them

- Slicing or other processing of wild-foraged mushrooms must take place in an approved food kitchen licensed by MDARD or a local health department.

https://www.michigan.gov/mdard/food-dairy/michigan-cottage-foods-information

Mushroom Toxins

- There are at least 50 poisonous mushrooms that grow in Michigan
- Degree of toxicity ranges from stomach upset to death
- ***All*** mushrooms must be thoroughly cooked before consumption

Michigan State Extension guide to poisonous mushrooms and toxins →

https://shop.msu.edu/products/dont-pick-poison-when-gathering-mushrooms-for-food-in-mi

MICHIGAN STATE UNIVERSITY EXTENSION

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Major revision of E-1080, 1/02-5M-KMF/LAW, $3, for sale only

Extension Bulletin E-2777 (Replaces E-1080)
January 2002

Don't Pick Poison!

When Gathering Mushrooms for Food in Michigan

MICHIGAN STATE UNIVERSITY EXTENSION

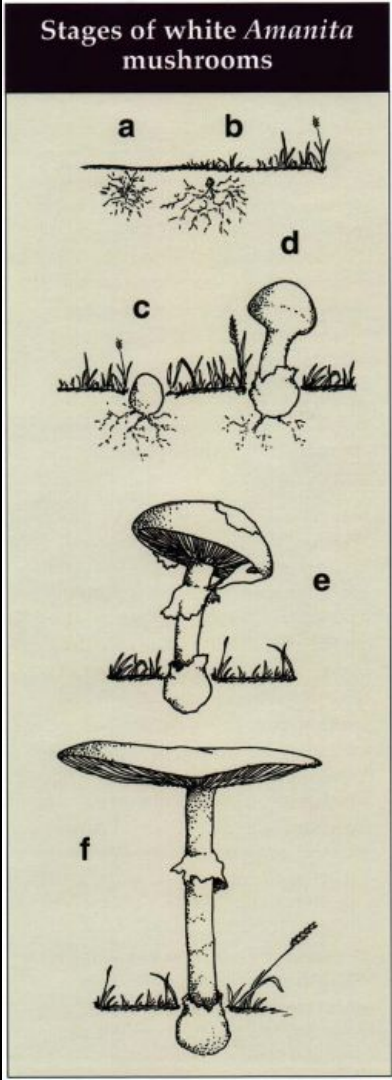
Tips on Eating Wild Mushrooms

Never eat mushrooms

1) You can’t clearly identify to species
2) Raw
3) That are old and decaying

When trying a new species

1) Collect by digging up base and make a spore print
2) Thorough cook and eat a small sample
3) Save some in fridge for ID
4) Don’t mix with other types



Amatoxins

Mushrooms: *Amanita, Galerina, Lepiota,* and *Conocybe*

Symptoms:
Stage 1) 6-36 hours after ingestion-severe stomach issues (vomiting & diarrhea)
Stage 2) Remission-you feel better
Stage 3) Coma and death-liver and kidney damage

No known treatment outside of liver transplant!

Look Alikes: Many. Avoid mushrooms with volva at base and annulus.

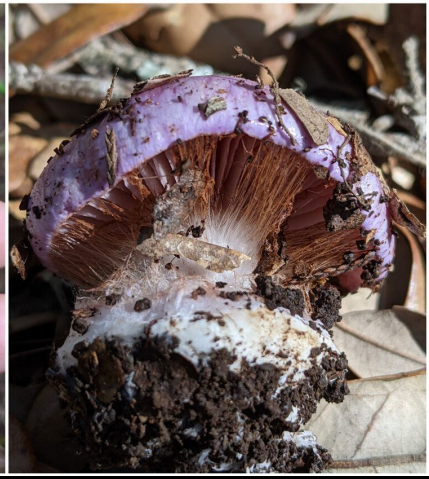
Conocybe filaris (Photo courtesy Mike Wood.)

Lepiota subincarnata

Amanita phalloides

Galerina marginata

Cortinarius Toxins

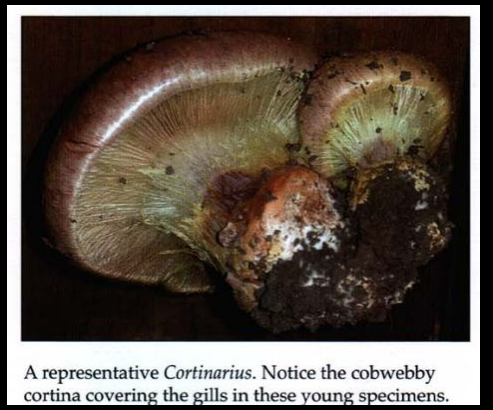


Mushrooms: *Cortinarius*

Symptoms:

- 3 days to 3 weeks for onset
- Vomiting, diarrhea, loss of appetite, headache, cold, eventual kidney failure
- Some patients recover
- No known treatment outside of kidney transplant!

Look Alikes: The blewit mushroom is also purple, but does not have a cortina and has a light spore print instead of rusty brown.



A representative *Cortinarius*. Notice the cobwebby cortina covering the gills in these young specimens.

Monomethylhydrazine

Mushrooms: *Gyromitra*

Symptoms:

- 6-8 hours for onset
- Stomach feels full
- Vomiting, diarrhea, headache, jaundice, eventual Kidney & liver failure
- Some patients recover, some die

Some people cook these by boiling first and not inhaling toxic vapors, but carcinogens in the mushroom can kill you over time.

Look Alikes: The morel is also an ascomycete, but has a pitted cap that attaches at base to stem. Even morels are toxic if not cooked!

Gyromitra esculenta

Coprine

Mushrooms: *Coprinus atramentarius* and *Clitocybe*

Symptoms:

- Occur when alcohol is ingested within 2 days of mushroom
- Flushed face, metallic taste, rapid heartbeat, tingling arms/legs
- Full recovery will occur
- Not truly a poison, but alcohol is

Some people eat *Coprinus* species (inky caps), but they autodigest, so must be cooked and eaten quickly.

Look Alikes: The shaggy mane (*Coprinus comatus*) is a bit larger, but may also contain coprine.

Psilocybin & Psilocin

Mushrooms: *Psilocybe, Stopharia, Panaeolus, Conocybe, Inocybe, Gymnopilus*

Symptoms:

- Onset is 20-60 minutes after ingestion
- Change of mood, fear, excitement, hallucinations, loss of coordination, rapid heart rate, fever, seizures

Some people seek out mushrooms containing these compounds and poison themselves with deadly toxins

Look Alikes: The honey mushroom (*Armillaria mellea*) has a white spore print. Other look alikes are not sought after as food.

(Photo courtesy Mike Wood.)

Gymnopilus spectabilis

(Photo courtesy Alexander Smith.)

Paneolus

Muscimol & Ibotenic Acid

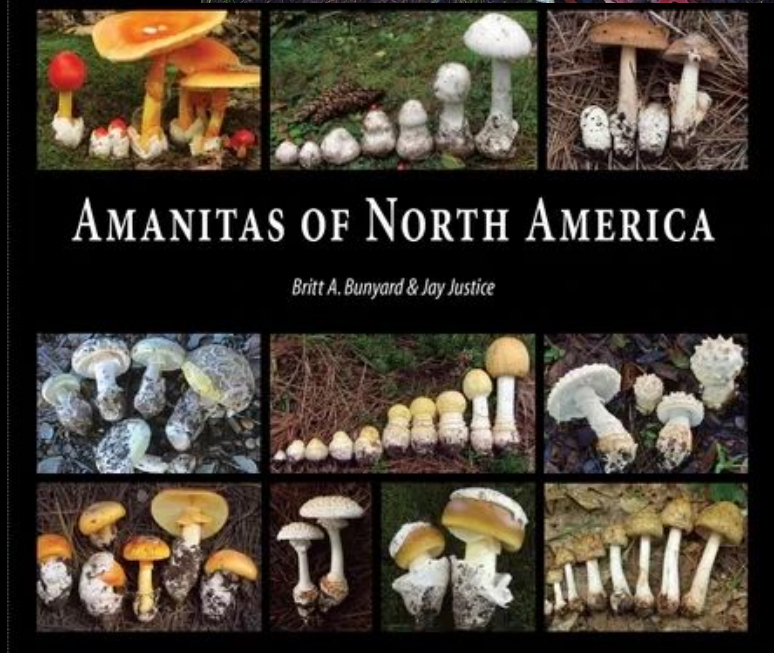
Mushrooms: *Amanita* spp.

Symptoms:

- Onset is 20-60 minutes after ingestion
- Stage 1-Sleepy
- Stage 2-Hyperactive, pronounced muscle spasms, hallucinations lasting 4 hours
- Stage 3-Deep sleep

Most recover, but fatal in 1-5% of cases.

Look Alikes: Look alikes are not sought after as food. *Amanita* should be avoided for collection.



Muscarine

Mushrooms: *Inocybe* and *Clitocybe*

Symptoms:

- Onset is 30 minutes to 2 hours after ingestion
- Salvation, perspiration, crying, involuntary urination and defecation, vomiting

Not fatal

Only fungal toxin with medical antidote available

Look Alikes: Look alikes are not sought after as food. May grow in lawns in fairy rings.

Conocybe filaris (Photo courtesy Mike Wood.)

Inocybe species (Photo courtesy Mike Wood.)

Other Toxins

Symptoms:

- Stomach upset in 30 minutes to 2 hours
- Not fatal

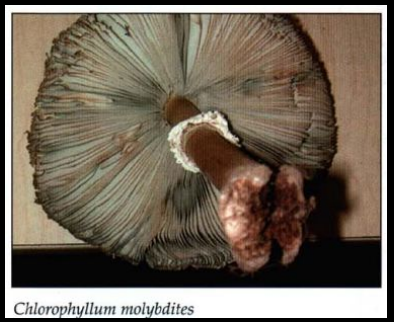
Omphalotus illudens

Jack O'lantern Mushroom
Bioluminescent

←Can be mistaken for *Armillaria*→


Entoloma abortivum. Aborted form on left.

Shrimp of the woods (left) can be eaten
Entoloma (right) poison


Chlorophyllum molybdites

The MSU mushroom
(white with green gills)


Lepiota (Leucoagaricus) naucina (Photo courtesy Tom Volk.)

Destroying Angel Look Alike


Boletus subtomentosus

Red-pored
blue-staining boletes


Laetiporus sulfureus


Paxillus involutus (Photo courtesy Mike Wood.)

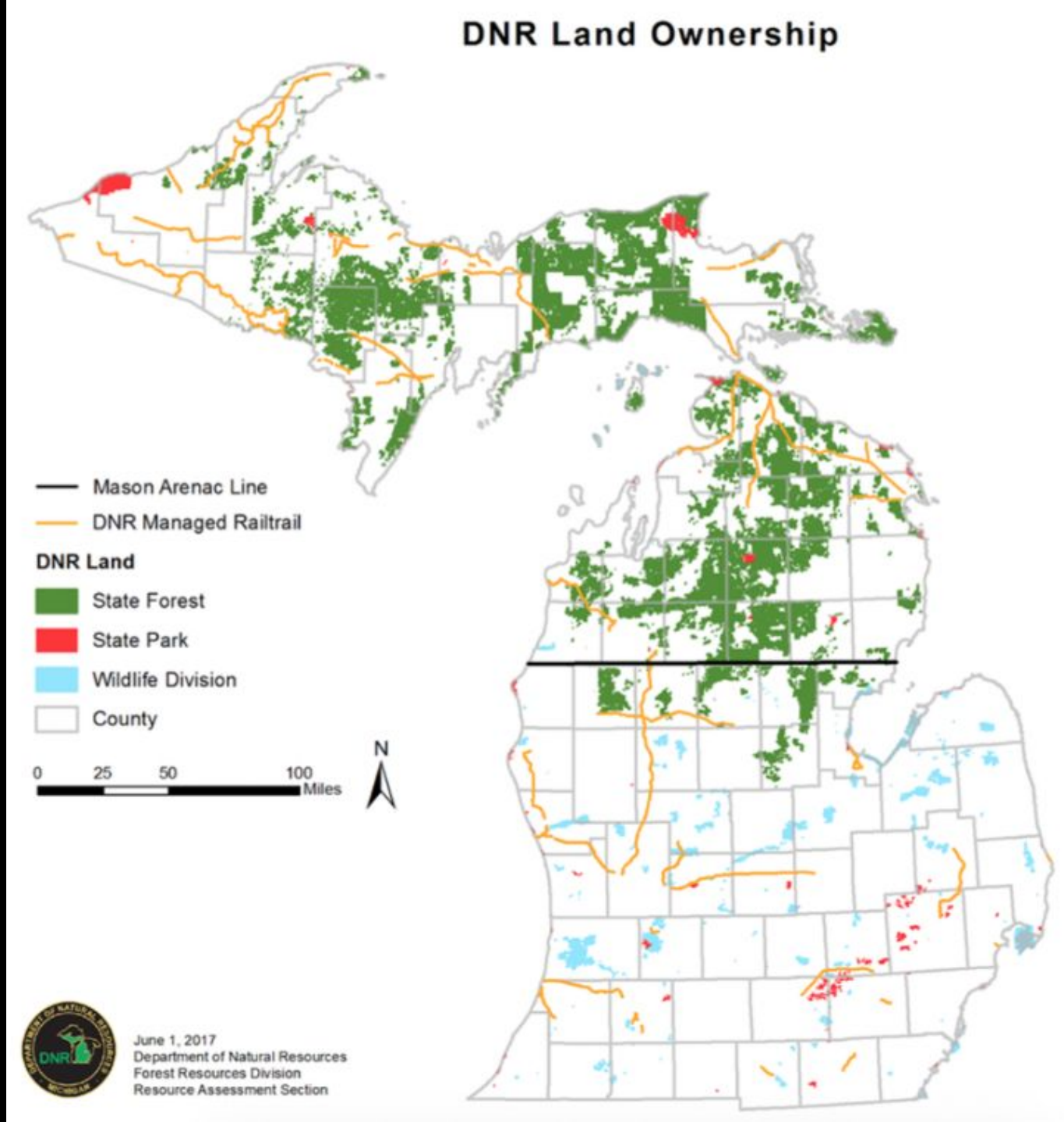
Can cause severe allergic reaction

Mushroom Foraging Laws and Economics

https://www.bridgemi.com/michigan-environment-watch/michigans-morel-mushroom-season-where-find-them-and-how-identify-them

Where to Collect Wild Mushrooms

- Land managed by the DNR
  - State Forests
  - Game and Recreation Areas
  - State Parks
- Collection for personal use not commercial



Where to Collect Wild Mushrooms

- National Forests managed by the USDA Forest Service
  - Hiawatha, Huron-Manistee, and Ottawa
  - Can get personal or commercial harvest permit
  - Permits vary each year
    - Check with each Region for updated rules and regulations

Where to NOT Collect Wild Mushrooms

- Private lands (without owner's permission)
- Prohibited in National Parks
- Local county and city parks each have their own rules

Safety While Foraging

- Check the weather and terrain maps
  - Wear appropriate clothing
- Let someone know where you are going
-
- Bring the 10 essentials

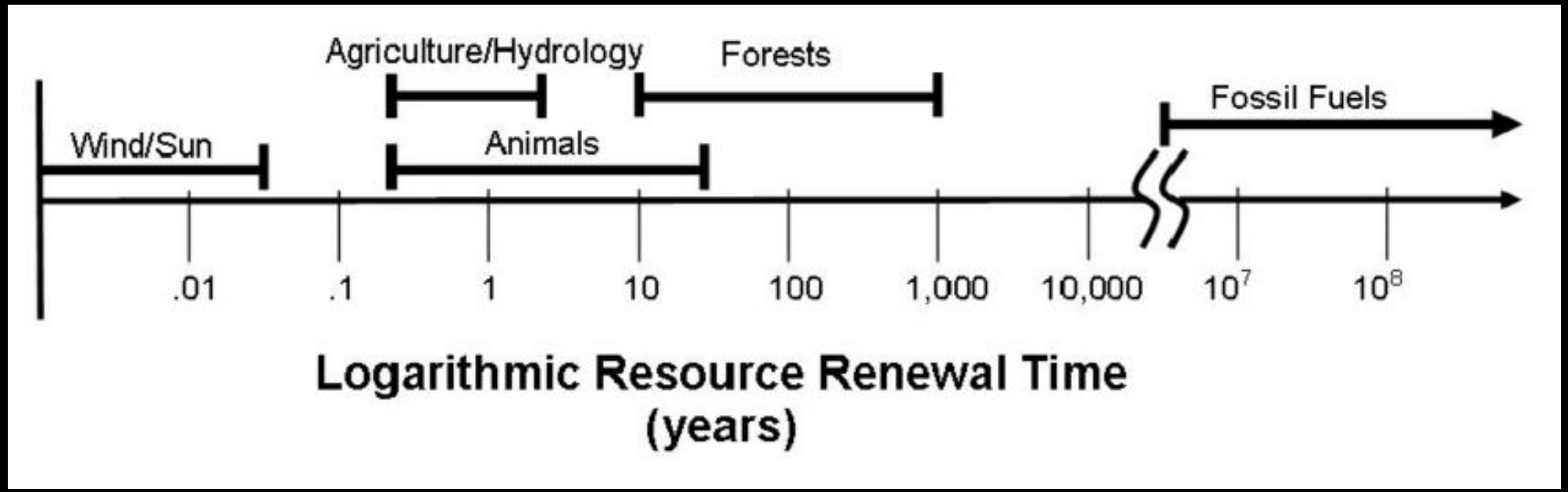
Sustainable Foraging

- Leave No Trace
- Avoid soil compaction and damage to habitat
- Don’t collect mushrooms that you can’t eat
  - Look for bugs and slugs
  - Remove soil with brush
  - Leave young and old mushrooms behind
- Avoid collecting in one area
- Use an open weave basket to spread spores

Mushrooms are a Renewable Resource

- Renewable resources are on a continuum

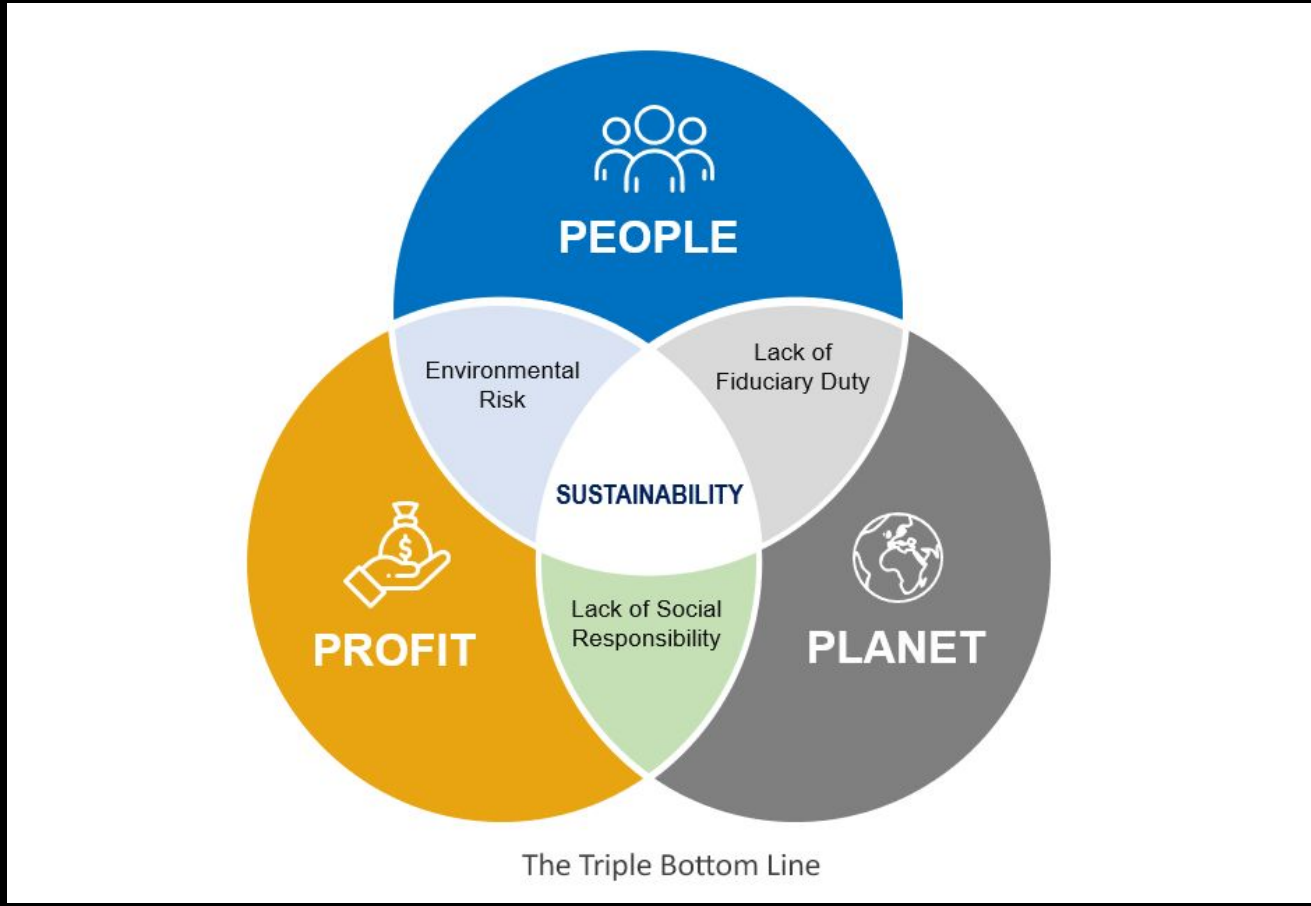
- Important to protect habitat
  - Avoid soil compaction and clear cutting
  - Keep coarse woody debris in place



Seager, Thomas & Cummings, Christopher & Theis, Thomas. (2005). Rethinking exergy efficiency in favor of exergy sustainability as a criteria for design. 2005 AIChE Annual Meeting Conference Proceedings.

Sustainability

- Being able to continue an action or process over time
- Meeting our own needs while not harming future generations

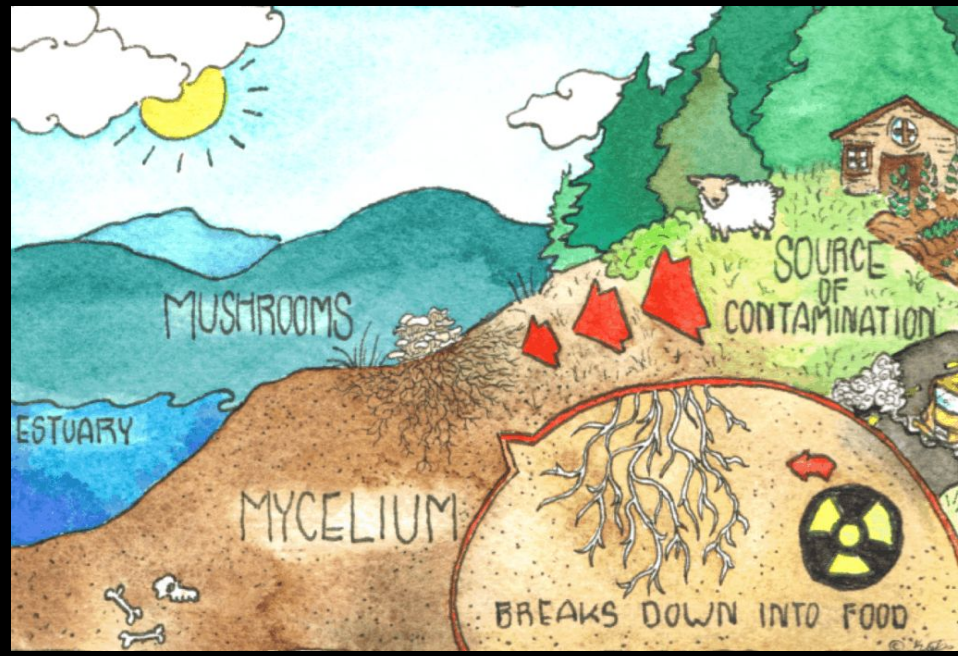


The Triple Bottom Line


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

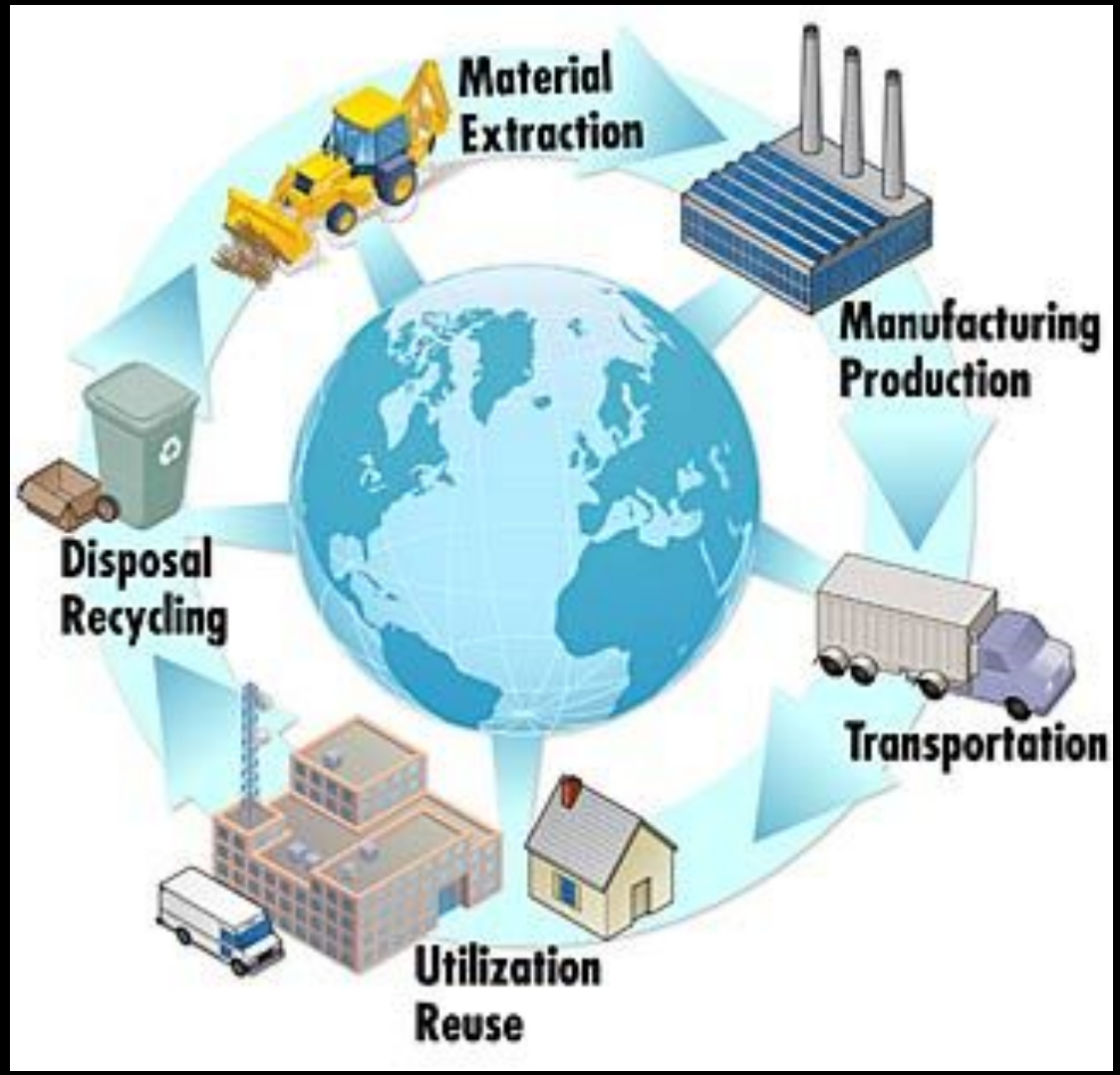
Sustainable Mushroom Products

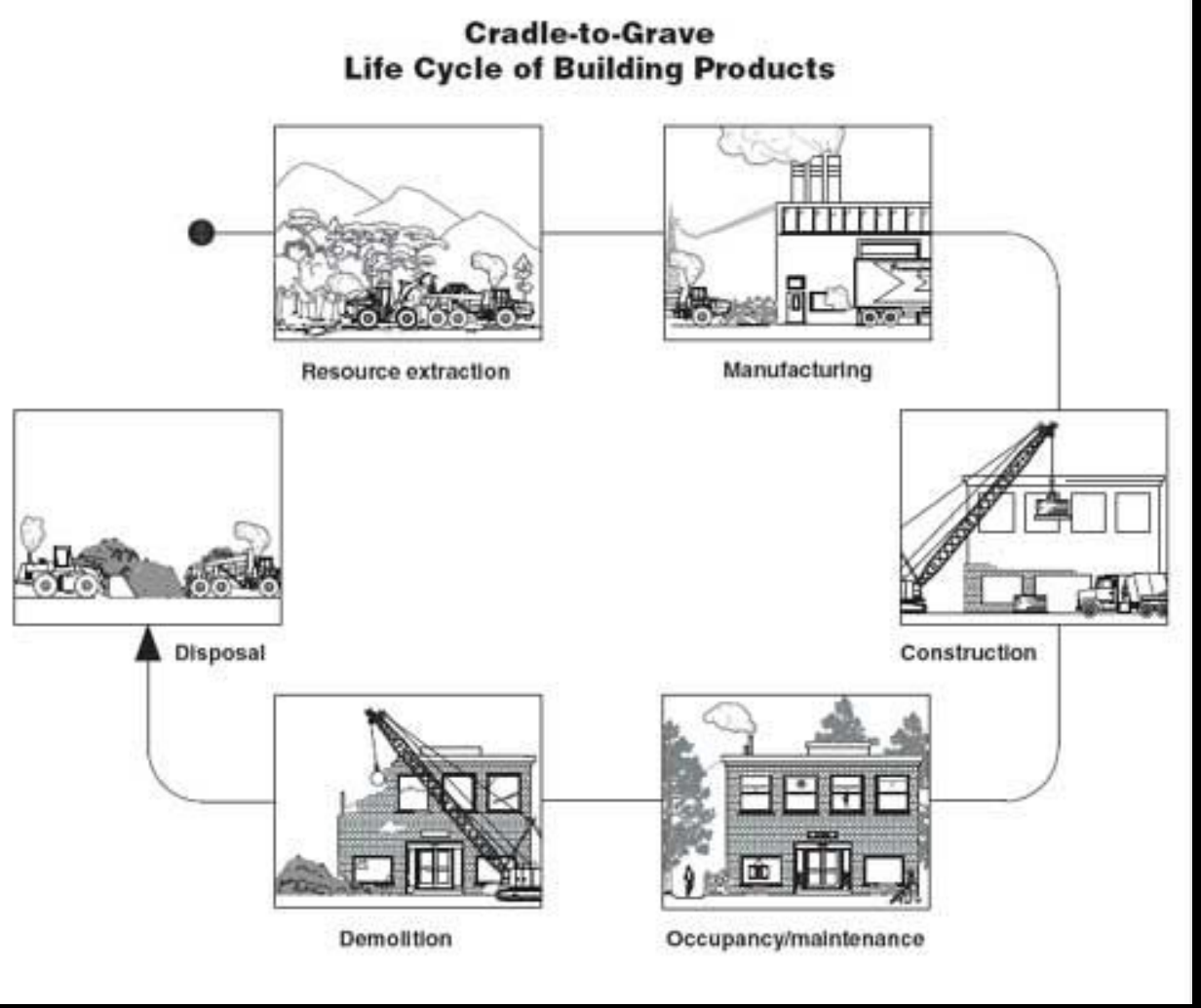
- Fungal mycelium can be used as a sustainable material
  - Buildings
  - Packaging
  - Clothing
- Fungi are used to produce biofuels
- Mycoremediation uses fungi as filters to clean up pollution



Life Cycle Analysis & Assessment

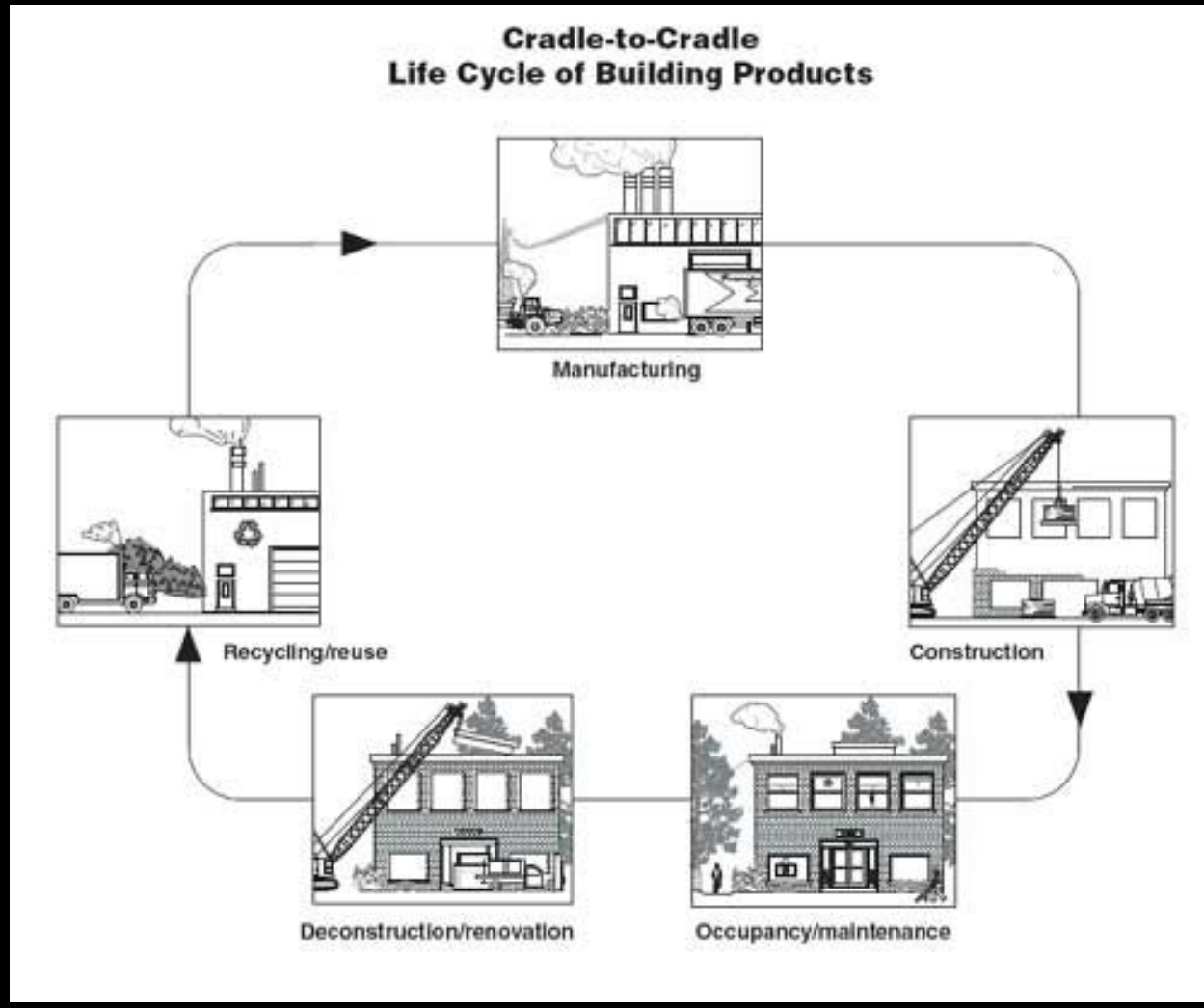
- Companies evaluate environmental costs and benefits to their products
- Complex analysis that requires careful documentation at each step
- Goal is to increase sustainability
  - Examine more than profits
    - Energy use
    - Water
    - Air
    - Land
    - Raw materials





Companies should consider all stages of the product life cycle

Sustainability increases when materials can be recycled



https://www.fs.usda.gov/t-d/pubs/htmlpubs/htm08732839/page02.htm

Assignment

- Pick one fungal mycelial product and compare it to traditional products
  - Building materials
  - Packaging materials
  - Fabric
- Research the pros and cons of the life cycle analysis at each step
- Be prepared to present your findings to the class

https://www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca

Mushroom Product Life Cycle Analysis

Pick a product made from mushrooms (fungal mycelium) and compare it to a traditional material citing the pros and cons of a life cycle assessment.

Examples might include mycelial building materials vs. lumber, mycelial packaging vs. styrofoam, or fungal leather vs. other clothing materials.

Be prepared to discuss your results as a class. Questions to consider are given to guide you in making your list of pros and cons.

Image: https://www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca

Mushroom Product Life Cycle Analysis

Product Type (Circle One): Building Materials, Packaging Materials, Clothing

	Mushroom Material	Traditional Material
Resource Recovery (How is the raw material extracted? How renewable is it? How long does it take to grow?)		
Manufacturing (What kind of processing is needed for the raw material to become the final product? Is the raw material shaped or cut? Is it treated with chemicals?)		
Packaging and Distribution (How heavy is the final product? How far would it need to be shipped? Does it hold up well to transportation?)		
Use (How strong is the product? How long will it last?)		
End of Use (Can the product be recycled? How well does it decompose?)		