The fungus FILES

AN EDUCATOR'S GUIDE TO FUNGI
K-6

SECOND EDITION

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With sincere appreciation,

terraBrie Stewart, B.Sc.

TD Friends of the Environment Foundation

ANPC Alberta Native Plant Council

NATURE ALBERTA

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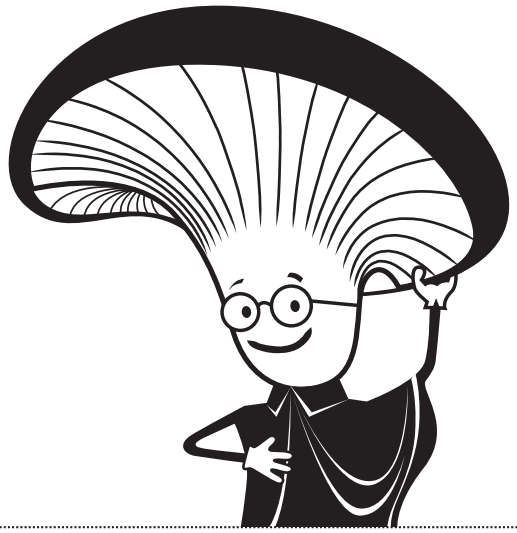


Introduction

Throughout history, fungi have been regarded with great suspicion. The ancients, wary of mushrooms that appeared like magic after a heavy rain, called them '*a callosity of the earth*', '*earthly excrescences*', and '*the evil ferment of the earth*'. In spite of leaving a bad first impression, these peculiar entities are subjects of great curiosity. The strange talents of fungi include the ability to luminesce; their greater similarities to insects than to plants; and the tendency to grow in fantastical fairy rings. These are only a few ways these bedazzling organisms can launch a child's imagination into overdrive. However, what is truly relevant about fungi is the way that they encourage ecological thinking by illustrating the delicate interconnectedness of all living and non-living things.

GETTING STARTED

Here are a few recommendations to consider in preparation for the activities presented in this guide:

- **DO** become acquainted with the whole guide, as many activities are complementary.
- **DO** collect a variety of mushroom picture books and field guides and/or posters before commencing fungal studies. There is a great series of posters created by David Arora available for sale online (see Suggested Resources and Sources, page 91)
- **DO** familiarize yourself with basic fungal vocabulary; a glossary can be found at the end of this guide. For example, "fungus" and "mushroom" are often used interchangeably but you need to recognize that there is a distinction: **mushroom** generally refers to just the fruiting body or reproductive part of the organism whereas the term **fungus** encompasses the entire organism. Similarly, **hyphae** (sg. hypha) are the threads that make up the fungal body; collectively, the hyphae are called the **mycelium** (pl. mycelia).
- **DO NOT** be intimidated by the depth of the background information. It is simply meant to provide a comprehensive overview of the Kingdom Fungi and certainly not all of the information is necessary to provide a stimulating introduction to your students.

FORMAT

This educator's guide explores the world of fungi through worksheet activities, hands-on activities, and classroom demonstrations. It is divided into five sections, each containing a set of activities relating to the main topic.

INTRODUCTION

An overview of topics discussed in the guide are presented in the introduction-- this includes what constitutes the fungal kingdom; the diversity of forms; and their ecological roles. Students will also become aware of just how prevalent (though hidden!) fungi are in their everyday environments.

BIOLOGY AND CLASSIFICATION

In this chapter, students will learn what separates the fungi from the plants and the animals; the basics of anatomy; and the use of dichotomous keys for identification purposes.

REPRODUCTION AND DEVELOPMENT

The purpose of this chapter is to develop an appreciation of fungal life cycles. The non-fleshy fungi, in particular moulds and yeasts, will be explored in detail. Students are also introduced to some of the unique ways fungi disperse their spores into the environment.

ADAPTATION AND ENVIRONMENT

This chapter emphasizes the concept of mycorrhizas and other symbiotic relationships. To a lesser degree, the role of fungi in nutrient recycling and soil creation are also addressed.

FUNGUS AMONG US

This chapter examines our relationship with fungi throughout the centuries, which includes topics such as folklore and mythology. A major activity gets students outside for a mushroom hunt. In doing this, students will also become familiar with field guides as tools for mushroom identification. Finally, the ecological impacts of a variety of human activities are discussed.

The activities will be divided into

- ***Objective***: States the theme and objective of the activity.
- ***Grades****:* Grade level of the approximate target audience.
- ***Type of Activity***: Teacher read/comprehension, Crosswords, Observation puzzle, etc.
- ***Materials****:* Materials required to complete the activity.
- ***Vocabulary****:* Specific terminology students may not be familiar with; it is a good idea to review these words before starting the activity. Definitions for these words can be found in the glossary.
- ***Background Information***: This section provides additional information that prepares the educator for questions that may arise. More complete background text can be found at the beginning of each section.
- ***Teacher Instructions***: Step by step instructions that guide the educator through the activity.
- ***Extensions****:* Suggested ways to expand upon the presented activities.

Although a list of discussion topics does not always accompany the activities, it is recommended before starting an exercise that the students are given a chance to express themselves by either asking questions or sharing relevant experiences on subject matter pertaining to the activity.

Fungi—The Hidden Kingdom

Activity 0.1

OBJECTIVE
- To provide students with basic knowledge about fungi

BACKGROUND INFORMATION
The following text provides an introduction to the fungi. It is written with the intention of sparking curiosity about this fascinating biological kingdom.

TEACHER INSTRUCTIONS
1. With your class, brainstorm everything you know about fungi.
2. For younger students, hand out the question sheet before you begin the teacher read and have them follow along and answer the questions as you read.
3. For older students, inform them that they will be given a brainteaser quiz (that is not for evaluation) after you finish reading the text.
4. The class can work on the questions with partners or in groups and then go over the answers as a class. Discuss any particularly interesting facts and encourage further independent research.

K-3 ADAPTATION
1. To introduce younger students to fungi, you can make a KWL chart either as a class or individually. A KWL chart is divided into three parts. The first tells what a student KNOWS (K) about a subject before it is studied in class. The second part tells what the student WANTS (W) to know about that subject. The third part tells what the child LEARNED (L) after studying that subject.
2. Share some of the fascinating fungal facts presented in the "Fungi—The Hidden Kingdom" text with your students.

COMPREHENSION QUIZ ANSWER KEY
A.1.**F**; 2.**T**; 3.**F**; 4.**T**; 5.**T**; 6.**F**; 7.**T**
B. **wheat**
C. **1 500 000**
D. **tin cans**
E. **roots**
F. **all of these**;
G. **Irish potato famine**
H. **recycling**
I. **mowing the lawn**

GRADES
4-6 with a K-3 adaptation

TYPE OF ACTIVITY
Teacher read/comprehension

MATERIALS
- copies of page 11
- pencils

VOCABULARY
bioremediation
chitin
fungi
habitat
hyphae
kingdom
lichens
moulds
mushrooms
mycelium
mycorrhizas
nematodes
parasitic fungi
photosynthesis
protozoan
rusts and smuts
saprophytic fungi
seed
spore
symbiotic fungi
yeasts

Fungi—The Hidden Kingdom

Have you ever played the question game "Animal, Mineral or Vegetable"? If so, choosing a mushroom as the answer would be sure to confuse people Most people think of mushrooms as vegetables but this is really not true! These tricky organisms are actually **fungi** (**fungus** sing.) and are as different from plants as plants are from animals—in fact they are actually more like us than they are like cucumbers!

MUSHROOM, FUNGI...WHAT'S THE DIFFERENCE?

Before we really start to talk about fungi, we should set something straight. There is far more to fungi than just mushrooms. The word "fungi" is used to describe a classification or **kingdom** of organisms (plants and animals each have their own kingdom). Members of the Kingdom Fungi are not able to make their own food. A mushroom is only a very small part of a much bigger organism, the fungal body or **mycelium**. The mushroom is the fruit of a fungus much like an apple is the fruit of an apple tree. Fungi also love to play hide and seek and they often hide underground. This is one reason why fungi have been called "the hidden kingdom".

There are many type of fungi that do not produce mushrooms. Fungi also include **yeasts** (that make bread light and fluffy), **moulds** (that we find on old bread and on fruits and vegetables), **rusts and smuts** (that cause damage to agricultural crops) as well as many other forms that give us medicines or cause us discomforts like athlete's foot and ringworm.

DID YOU KNOW...

that for every person on earth there are approximately 2 tonnes of fungi? That means for every person in your class there is a hippopotamus' weight worth of fungi! Experts estimate that there may be as many as 1.5 million species of fungi. However, only a small fraction have been described and even fewer of these produce mushrooms. This means there are more fungi than most other types of organism -- and fungi aren't spring chickens either! The oldest fossil fungus found dates back 545 million years old, which is a long time before flowering plants appeared on the earth.

FOLKLORE FANCY

Fungi have also been a source of mystery and folklore for thousands of years. Many ancient people believed that mushrooms were formed when bolts of lightning hit the ground. Other people thought they were created by witches or evil spirits and you could catch a disease just by touching them! Others believed that "fairy rings", which are the places where mushrooms grow in circles, were dangerous places where elves danced, toads met, or the devil set his churn at night. These ideas all seemed to come from the ability of mushrooms to "appear out of nowhere", usually after a rainstorm. We now understand that the fungus was there all along and the moisture of rain encouraged the mycelium to produce its fruit.

SURPRISE! MUSHROOMS ARE NOT PLANTS!

Until fairly recently scientists considered fungi to be a type of non-flowering plant, but there are three main differences between plants and fungi. First, plants are able to make their own food using sunlight through a process called **photosynthesis** whereas fungi need to get their food from another source. There are three main ways that they can do this: they can get their nutrition by breaking down dead material like leaves and wood; these fungi are called **saprobic** fungi. They can also get their energy from another living thing like an insect, plant or animal. This type of fungus is what causes diseases such as athlete's foot and they are called **parasitic** fungi. Finally, fungi can get their food by cooperating with other species such as trees or **algae**. These are called **symbiotic** fungi and are very common. You might recognize **lichens** as one type of symbiotic fungi; you can find lichens growing on bark, and very extreme places such as in the Arctic or even on rocks.

There is another big difference between plants and fungi. Plants reproduce using **seeds**. Seeds contain many cells which make up an embryonic plant plus a food supply. This means that when a seed lands in a good **habitat**, it can use its own "packed lunch" as energy to begin to grow. Fungi reproduce using **spores**. Spores are different from seeds because they are often only a single cell and do not contain much stored energy. This means they need to land on a good food source (like that fruit that has been on the counter too long) before it can start to grow. Once the spore sprouts or germinates, it grows into tiny threads called **hyphae**. Once these threads get numerous enough, they will collectively be called the **mycelium**. A mushroom is actually made up of a whole bunch of tightly packed hyphae.

Finally, plants have cell walls made of cellulose whereas fungi have cells walls made of **chitin**. Chitin is the hardest biologically made substance on Earth. Chitin also forms the hard shells of many insects. It also protects spores from harm before it is time for them to start to grow. Some scientists suspect that mushroom spores are capable of space travel; a few even believe that some fungi found on Earth originally came from outer space! What do you think about this idea?

MORE THAN JUST A MUSHROOM?

As you might have already guessed, there is a much bigger variety of mushrooms out there than the little umbrella-shaped ones you see at the grocery store. Mushrooms can look like a mini bird's nest, coral from the ocean floor, an octopus, balls of lace, little brown brains, orange peels, shelves on a tree trunk, or even like big white soccer balls. They come in virtually every colour of the rainbow too. Some fungi even have the ability to glow-in-the dark! Imagine that!

I bet you are surprised to learn that there also predatory fungi that trap small worms called **nematodes**. The fungi will set a variety of booby-traps or snares and then at the right moment, SNAP the worm is trapped and the fungus begins to digest the worm from the inside until all that remains is the skin.

FUNGUS HUMONGOUS

Would you believe that some mushrooms called Giant Puffballs have been known to grow so big as to be mistaken for sheep? In Michigan, USA, another type of fungus mycelium was found to cover an area equal to 212 football fields and weigh as much as a blue whale. Not only is this fungus thought to be among the largest living organisms on earth, but it is also believed to be 1500 years old!

FUNGI AROUND THE WORLD AND ACROSS TIME

Fungi are found all over the world in fields and forests, hot deserts and dry Arctic lands—they have even been found on Antarctica. In many countries, mushroom hunting is a national pastime and wild mushrooms are considered a delicacy or excellent source of natural medicine. The prehistoric Iceman "Ötzi", who is thought to have lived 5000-5500 years ago, had two different types of fungi with him; one was a type of fungus used to help get a fire started, and the other was threaded onto a leather thong and is believed to have been used medicinally as an antiseptic.

FUNGI AS FRIEND AND FOE

Over time fungi have developed a bad reputation as being the cause of much death and destruction. One example of a tragedy caused by fungi is the Irish Potato Famine. In the 1840s, a fungal parasite destroyed the potato crops causing 1 million deaths and a mass emigration to North America. Nowadays, fungi are responsible for the failure of 1/8 of the world's crops. In our homes fungi can spoil fruit, bread and other food; destroy clothing and books; cause allergic reactions; or make us or our pets very sick.

So now that we have seen the dark side of this kingdom, let's look at the ways in which fungi are our friends. The most important role fungi play in the environment is that they are the Masters of Recycling. Fungi, along with bacteria and **protozoans** (another kingdom), compost plants after they die and transform them into rich soil. If not for fungi, the Earth would soon be buried in metres of debris and life on the planet would soon disappear.

Another important job fungi have is as **mycorrhizas**. Mycorrhizas literally means "fungal roots". Fungi wrap themselves around the roots of a plant and, like a long drinking straw, suck nutrients from the soil to give to the plant; in exchange, the plant gives the fungi sugar. Up to 95% of land plants rely on mycorrhizas for healthy growth, so it is a very popular arrangement in nature. Scientists are now using mycorrhizas to help with the health of the baby trees planted in reforestation.

NOW ON TO SOMETHING APPETIZING...

If you don't like to eat mushrooms, you might think it wouldn't be a big deal if we lived in a world without fungi. However, as we said earlier, fungi are far more than just the mushrooms on your plate. Fungi also are essential in making breads; certain types of cheese; wine, beer and other alcoholic beverages; soy sauce; and even adding flavour to your favourite soda pop. Mushrooms themselves also contain essential minerals and vitamins. As well, some fungi are also used to make antibiotics such as penicillin that have saved many lives.

We've already talked about how mushrooms are useful as food and medicine but now research is being done using fungi in something called **bioremediation**. What this means is that fungi are being used to absorb and digest dangerous substances like oil, pesticides and industrial waste in places where they threaten the environment. Other research is being done to see how fungi can help control insects that destroy food crops.

Fungi are so much more than just mushrooms. They are a fascinating and charismatic kingdom that is woven into every part of our environment. As humans, we depend on them day in and day out for our very existence. So let's all take a closer look and begin to discover the fungus among us!

How Mouldy is Your Memory?

A

TRUE	OR	FALSE?	
◯		◯	1. Mushrooms are a type of vegetable.
◯		◯	2. The scientific word for the fungal body is "mycelium".
◯		◯	3. Fungi use photosynthesis to make their own food.
◯		◯	4. Some fungi are able to glow-in-the dark.
◯		◯	5. Some fungi trap worms for their food.
◯		◯	6. 5% of plants rely on"fungal roots" to help them grow.
◯		◯	7. Prehistoric humans may have used fungi to help start fires.

B

WHICH OF THESE IS NOT A TYPE OF FUNGUS?

◯ wheat ◯ yeasts ◯ moulds ◯ rusts & smuts

C

HOW MANY SPECIES OF FUNGI ARE THERE IN THE WORLD?

◯ 150 ◯ 1500 ◯ 15 000 ◯ 1 500 000

D

WHICH OF THESE IS NOT FOOD FOR FUNGI?

◯ dead leaves ◯ tin cans ◯ our feet ◯ trees

E

WHICH IS OF THESE IS NOT PART OF A FUNGUS?

◯ mycelium ◯ hyphae ◯ roots ◯ spores

F

WHAT CAN MUSHROOMS LOOK LIKE?

◯ orange peels ◯ ocean coral ◯ a bird's nest ◯ all of these

G

WHAT MAJOR TRAGEDY WAS CAUSED BY A FUNGUS?

◯ sinking Titanic ◯ sinking Atlantis ◯ Irish potato famine ◯ World War II

H

WHAT IS THE MOST IMPORTANT JOB OF THE FUNGI IN THE ENVIRONMENT?

◯ being food ◯ looking pretty ◯ killing crop pests ◯ recycling

I

WHICH OF THESE IS NOT A USE FOR FUNGI?

◯ medicine ◯ cleaning the environment ◯ helping plants grow ◯ mowing the lawn

It's a Fungal Jungle!

Activity 0.2

GRADES
3-6 with a K-2 adaptation

TYPE OF ACTIVITY
Observation puzzle

MATERIALS
- copies of page 14
- pencils
- pencil crayons, crayons or markers

VOCABULARY
algae
citric acid
Dutch elm disease
lichens
mycorrhizal relationship
spores

OBJECTIVE
- To introduce fungi as an intricate part of the living ecosystem and have students begin to see fungi beyond mushrooms

BACKGROUND INFORMATION
Fungi are literally all around us. Everyday we see them, walk by them or on them, eat them, and even breathe them, whether we want to or not. Invited, these fungal friends may accompany us to a family picnic on the menu--sometimes visibly such as on a pizza or as a pâté but sometimes they are more subtle. Some more subtle fungal guises are as a leavening agent in breads; the ripening agent of Brie, Camembert, Roquefort and other blue cheeses; the fermenting agent in alcoholic beverages and soy sauce; and as the precursor to the popular flavouring agent and preservative **citric acid** (commonly found in soft drinks). Both chocolate and coffee involve yeast fermentations during processing. As well, many washing powders contain fungal enzymes.

Fungi may also be seen fruiting as mushrooms near trees with which they have a **mycorrhizal** relationship. They will certainly be busy decaying the dead leaves and grass on the ground. They may also be starting to mould some fruit in the picnic basket. **Spores** will be circulating in the air. Fungi will also likely be found pairing with **algae** as **lichens** on tree bark or rocks. As well, a fungus could be actively attacking an American elm tree as **Dutch elm disease**. This list is by no means complete but it does serve as an introduction to the fungus among us!

TEACHER INSTRUCTIONS
1. Begin by asking students if they have ever invited fungi with them on a picnic (you'll probably get some laughs). Explain that at any given time, there are thousands of fungi all around us.
2. Hand out copies of page 14 to each student and ask them to find as many examples of fungi as they can in the drawing of the picnic.
3. You many encourage them to compare with a neighbour before reviewing the picture as a class and talking about the less obvious fungi that were likely missed.
4. Time permitting, students could also colour their picnic pics.

K-2 ADAPTATION

When working with younger students, you may wish to copy the picture onto a transparency and use an overhead and work through the exercise as a class. You could also hand out individual copies for the students to colour and circle the fungi.

EXTENSION

1. Bring in a stack of supermarket flyers and have students "find the fungi" and cut out items that could contain fungi or fungal products.
2. Have students find the fungi around them in their immediate surroundings, wherever that may be.

IT'S A FUNGAL JUNGLE ANSWER KEY

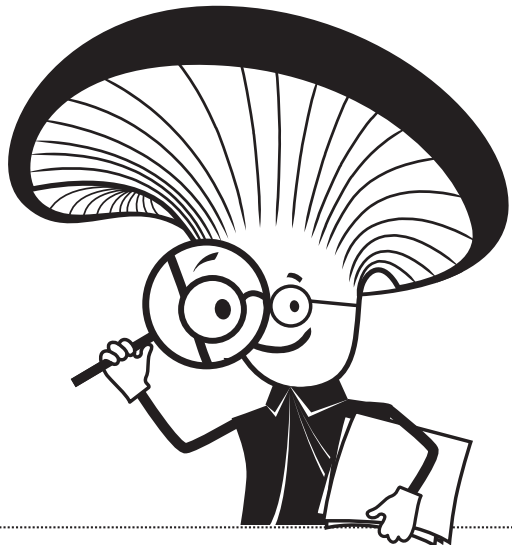
1. lichens (symbiotic relationship fungi and algae)
2. Mushrooms on pizza
3. Dutch elm disease
4. Shaggy mane mushrooms
5. Yeast in bread
6. Citric acid flavouring in cola
7. Mould on apple
8. Ripening agent in cheese
9. Mycelium hidden underground

Other invisible possibilities:

- decay of old leaves and grass;
- mycorrhizas with tree or other plants
- spores floating in air
- clothing dyes
- athlete's foot

Directions

Fungi are all around us! Find and circle as many different examples of fungi you can.



Biology and Classification

Fungi have been erroneously classified as "non-flowering plants" for most of scientific history. However, fungi hold many distinct characteristics that set them aside from the green plants:

- Fungi lack **chlorophyll**, which is an essential component for the process of **photosynthesis**.
- Unlike plants, fungi cannot make their own food and must obtain their nutrition from an exterior source. In essence fungi have their stomachs on the "outside" of their body—**enzymes** ooze out of their body onto their food and then they absorb the simpler compounds—much like a fly.
- Many fungi can live underground or in darkness which is impossible for sunlight-dependent plants.
- Fungi retain a relatively simple and uniform body composed of **hyphae** that give rise to single-celled **spores** whereas plants typically differentiate their form into roots, stems, leaves and flowers, which will produce multi-cellular **seeds**.
- The primary energy storage compound of fungi is **glycogen** (which is also what animals use!) where in plants, it is **starch**.
- The structural component in the cell walls of fungi is heavy duty **chitin**; in plants it's **cellulose**.

CLASSIFICATION

Classification systems are the scientific interpretation of organization in nature. The taxonomic system is hierarchal with *kingdom* as the highest and broadest rank and *species* as the lowest and most specific:

Kingdom The seven* kingdoms are the Animals, Plants, Fungi (**Eumycota**), Protists, Chromists, Eubacteria and Archaebacteria. Some fungus-like organisms including the amorphous slime moulds, water moulds and some parasitic fungi are now classified with the Protists and Chromists.

*It should be noted that the current classification system is always subject to review and revisions. Within any given scientific community, there is always debate in regard to the grouping of organisms; after all, these are clearly defined man-made impositions into a natural world that is constantly evolving completely oblivious to these guidelines and regulations.

Phylum/Division There are currently several phyla of true fungi: the three best known being the Zygomycota which includes the bread moulds and the Ascomycota and the Basidiomycota.

Class The Ascomycota are broken into six classes, many of which are microscopic and the Basidiomycota are broken into three classes (see table below).

Order Classes are divided in orders. All order names end in "-ales".

Family Each order contains one or more families. All family names end in "-aceae".

Genus Each family contains at least one genus and often many genera.

Species Each genus contains species.The scientific name is made up of the genus and species name and is either italicized or underlined.e.g. *Coprinus comatus.*

GROUP	APPROXIMATE NUMBERS	TYPICAL MEMBERS	CHARACTERISTICS
Zygomycota (Yolk "joining" fungi)	~600 species	Black bread moulds, dung fungi, predatory fungi	Branched mycelium produces spores in rounded spore cases
Ascomycota (Sac fungi)	~30 000 species	Yeasts, blue and green moulds, powdery mildew, precursor of Dutch elm disease, cup fungi, morels, truffles	Single cells or mycelium; spores form in asci; "spore shooters"
Basidiomycota (Club fungi)	~25 000 species	Bracket fungi, gilled mushrooms, puffballs, stinkhorns, rusts and smuts	Mycelium produces spores on the outside of club shaped structures called basidia; "spore droppers"

ANATOMY

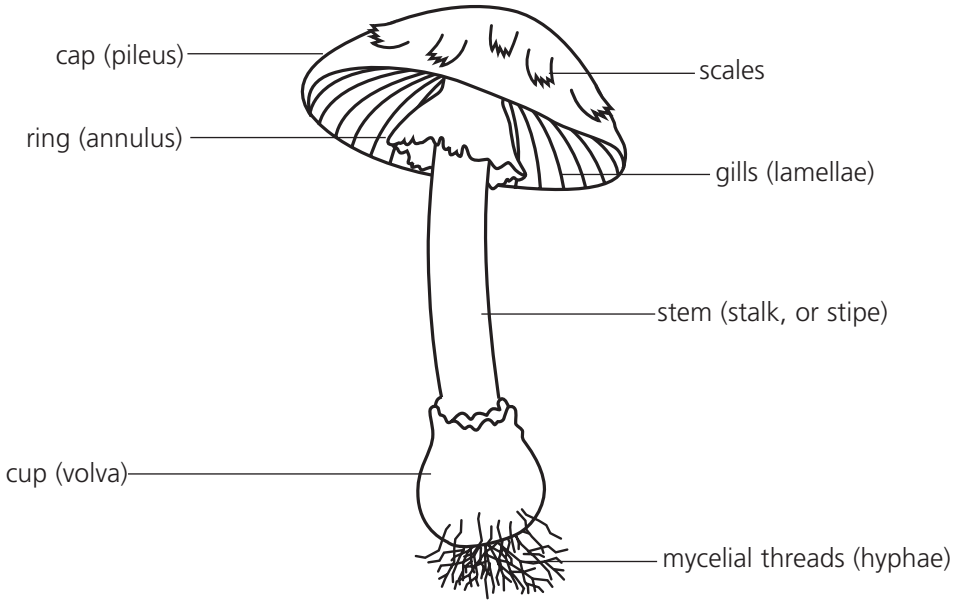


Diagram of a Generic Agaric Mushroom

When we see a mushroom, what we are really seeing is just the **fruiting body** of the much larger fungal body or **mycelium** (mycelia plur.). The mycelium is a network of filamentous, branching threads or **hyphae** (hypha sing.). Some hyphae are so thin that 20 000 of them laid side by side would only be 1 cm wide. The hyphae permeate trees, logs, stumps, or other organic material in search of food. Sometimes hyphae will form **rhizomorphs** which are tough cord-like strands that conduct food and water. The rhizomorphs of the honey mushroom can be more than as 1mm thick. The outer hyphae of the rhizomorphs are thicker with protective walls and the more delicate inner hyphae carry food and water to the fungus as it spreads.

Fruiting bodies (mushrooms) can form where two sexually compatible strains of mycelia meet. The purpose of the fruiting body is to produce and release spores into the environment. **Spore prints**, obtained by placing a mushroom cap on a piece of paper, can be an invaluable tool for identifying mushrooms. A spore print will look much like the spokes of a wheel and can vary in colour just as much as the mushrooms themselves. The typical form of a gilled mushroom is a convex pileus or **cap** which may or may not be covered in **scales**; a straight **stem** (stalk or stipe); lamellae or **gills** (or ridges, tubes or teeth in other fungi) where spores are produced; a skirt-like annulus or **ring** around the stem; and a volva or **cup** at the base of the stem. If the mushroom is dug up with some surrounding soil, some hyphae or mycelial threads should also be visible. Take note that these features are only generalizations—not all features will be present all the time on any given gilled mushroom. In fact, it is their presence or absence that help in mushroom identification.

Flora, Fauna, Fungi or Fiction?

Activity 1.1

GRADES
3-6

TYPE OF ACTIVITY
Origami Quizmaster

MATERIALS
- copies of pages 20-21
- scissors

VOCABULARY
carnivore
cellulose
chitin
herbivore
kingdom
omnivore
spores

OBJECTIVE
- To illustrate the differences between fungi, plants and animals

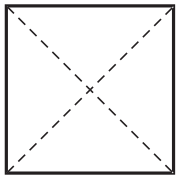
BACKGROUND INFORMATION
Fungi have long been mistaken for plants. It wasn't until fairly recently that they were assigned to their own biological classification or **kingdom**. This activity is meant to draw awareness to some of the unique features of this group of organisms. Please refer to Fungi--The Hidden Kingdom on page 8 for additional background information.

TEACHER INSTRUCTIONS
1. Begin by drawing a simple chart on the board that has the titles Flora, Fauna, Fungi, Fiction and Other. Have the students brainstorm characteristics that match each heading. If anyone lists a characteristic that does not fit in the first three, place it under the "Fiction" or the "Other" heading.
2. Hand out copies of each page to pairs of students. Make sure groups have two different sheets.
3. Construct the Origami Quizmaster. If the class is not already familiar with this technique, refer to page 19.

HOW TO PLAY QUIZMASTER Q&A
Break the group of students into pairs. One person starts with a quizmaster closed on their fingers (Student A) and the other person starts by picking a picture of a fungus from on the outside (Student B). For example, Student B may choose "Morel". Student A opens the "mouth" of the quizmaster and displays a number adjacent to the morel. In this case, the number displayed will be either 1 or 2. If 2 is shown, Student A opens the mouth in one direction and then again in the other direction to equal "2". Student B then picks another number and Student A opens the flap to reveal the question and asks it to Student B. If Student B answers correctly, he/she gets another chance to be asked a question and the above steps are repeated. When Student B answers incorrectly, it is Student A's turn to be asked a question and Student B manoeuvres the other quizmaster. The student who answers all their questions correctly first is the winner.

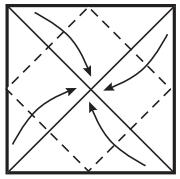
SOURCE
How to make origami diagrams was adapted from those at http://www.yasutomo.com/project/fortuneteller.html

1



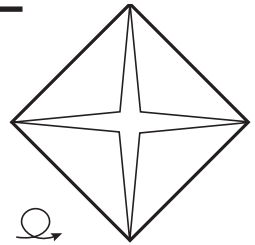
Start with a square piece of paper lying flat on the desk with the PRINT SIDE DOWN. Fold the paper in half diagonally, both ways, corner to corner.

2



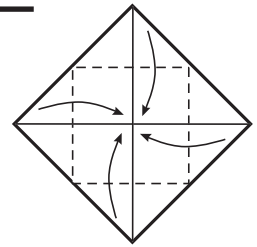
Make sure the paper is still PRINT SIDE DOWN and fold up all corners so that the points meet in the middle.

3



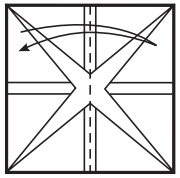
Turn the paper over so that the four flaps are facing down.

4



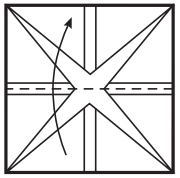
Again, fold all the corners into the centre.

5



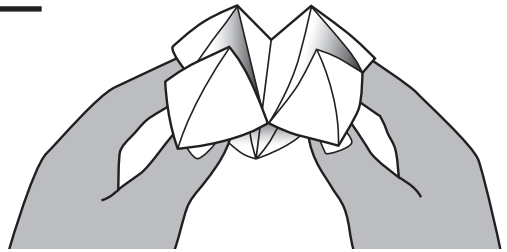
Fold paper in half and unfold.

6



Fold paper in half from top to bottom. Do not unfold.

7



Slide thumbs and forefingers under the squares to move the Quizmaster back and forth.

Bolete
1
I can live off of electricity
fiction
2
My cell walls are made of cellulose
flora
3
Most of my body is found underground
fungi
4
I am mainly green
flora
Bird's Nest Fungi
5
I get nourishment by absorbing my food
fungi
Polypore
6
I can move freely about in my environment
fauna
7
I am the Master Recycler
fungi
8
I reproduce using spores
fungi
Coral Fungi

1
I am the largest organism on earth
fungi
flora
I reproduce using seeds
8
Jelly Fungi
2
I can be a herbivore, carnivore or omnivore
fauna
flora
I can make my own food using energy from the sun
7
3
People used to believe I was created by lightning
fungi
fiction
I have mastered the art of time travel
4
Agaric
5
I make bread light and fluffy
funzi
fungi
My cell walls are made of chitin-- the hardest substance on earth
6
Earth Tongues
Morel

Shaggy Mane: Connect the Dots

Activity 1.2

GRADES
1-3

TYPE OF ACTIVITY
Connect the Dots

MATERIALS
- copies of page 23
- pencils
- pencil crayons. crayons or markers
- mushroom field guides and/or posters

VOCABULARY
habitat
spores

Scientific Classification
Kingdom: Fungi
Division: Basidiomycota
Class: Homobasidiomycetes
Order: Agaricales
Family: Agaricaceae
Genus: Coprinus
Species: *Coprinus comatus,* The Shaggy Mane or Lawyer's Wig.

OBJECTIVE
- To introduce students to a widely distributed and easily recognizable Canadian mushroom

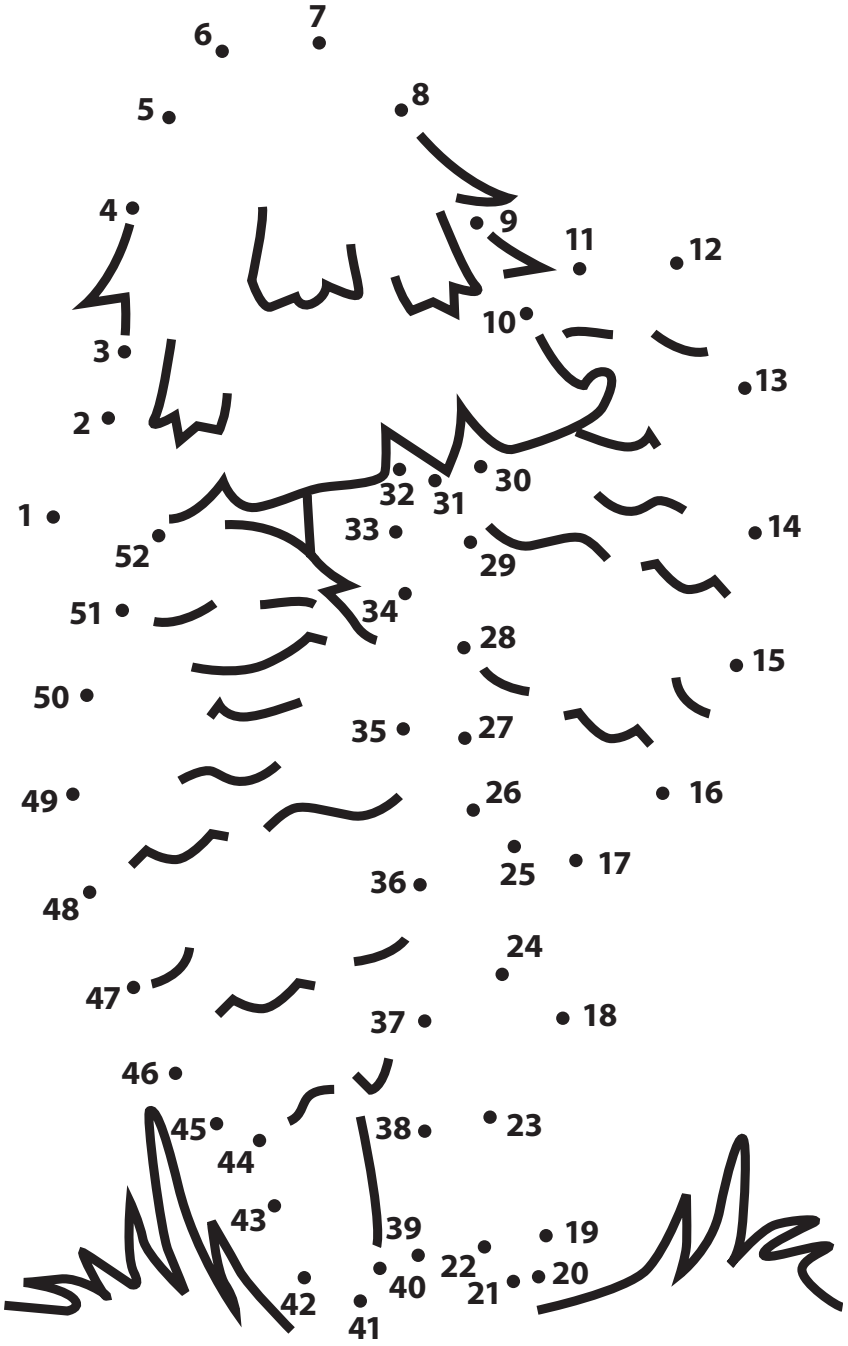
TEACHER INSTRUCTIONS
1.. Make copies of the Connect the Dots worksheet.
2. Hand them out to each student and have them connect the dots.
3. Get them to write the name of the mushroom on the blanks provided. Younger students will need help writing "SHAGGY MANE" in the blanks provided.
4. Ask the students if any of them have ever seen a shaggy mane mushroom. And if so, where was it? Explain that where something grows is called its **habitat**. Shaggy manes are known for their adaptable diets and can be found on roadsides, in meadows and fields and in city lawns from August to September.
5. Why do they think it would be called Shaggy Mane? This mushroom is also sometimes called a Lawyer's Wig. To those who know it well, this mushroom has nicknames: "Shaggie" or "Shag". It is a type of inky cap. Share with them the fact that the mushroom "melts" itself into a black, inky soup to release its **spores**.
6. Help students find pictures of the Shaggy Mane in field guides or on a poster (such as David Arora's EDIBLE FIELD, GARDEN and CULTIVATED MUSHROOMS poster) See Sources and Resources page 91.
7. Although the shaggy mane mushroom is not a colourful mushroom, you could have the students colour the mushroom any way they wish, as mushrooms can be any colour in the rainbow!

TRIVIA
One shaggy mane was so determined to grow that it was reported to have lifted a 5 kg slab of concrete!

Connect the Dots

1.2

Directions ▸ **Connect the dots and colour the picture of this INKY member of the fungal world!**



I am a _ _ _ _ _ _ _ _ _ _

Anatomical Anagrams

Activity 1.3

GRADES
3-6

TYPE OF ACTIVITY
Diagram labeling/ anagram

MATERIALS
- copies of page 25
- pencils

VOCABULARY WORDS
hyphae
mycelium
spores

OBJECTIVE
- To help students become aware of the main anatomical features of mushrooms and moulds

TEACHER INSTRUCTIONS
1. Make copies of the Anatomical Anagrams worksheet.
2. Hand them out to each student and have them unscramble the labels to complete the diagram.
3. Go over the worksheet as a class.
4. Ask students to compare and contrast the mushroom and mould. Notice that the the spores of mushrooms are found in gills. Moulds have spore cases that contain spores. In mould, the mycelium is readily visible but the vegetative (non-reproductive) mycelia of mushrooms is usually hidden in soil or decaying wood.
4. This activity complements Adventures in Yeast and Mould on page 38.

ANSWER KEY (TOP TO BOTTOM)
Mushroom
1. cap
2. ring
3. stem
4. cup
5. scales
6. gills
7. mycelium

Bread Mould
1. spore case
2. spores
3. hypha
4. bread
5. mycelium

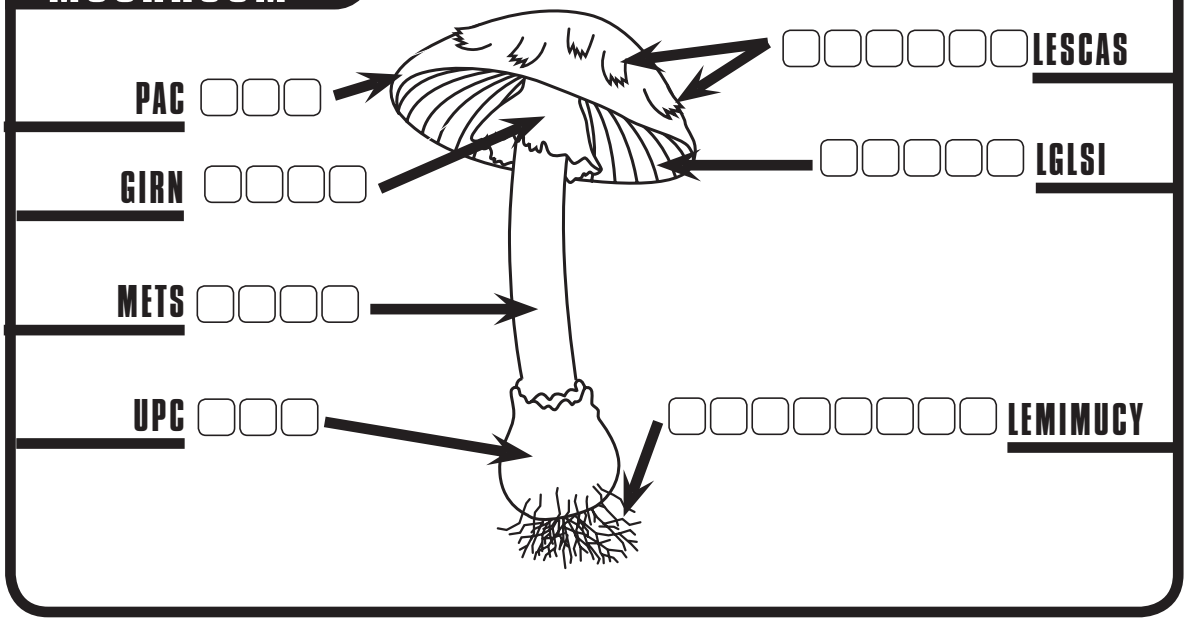
Anatomical Anagrams

1.3

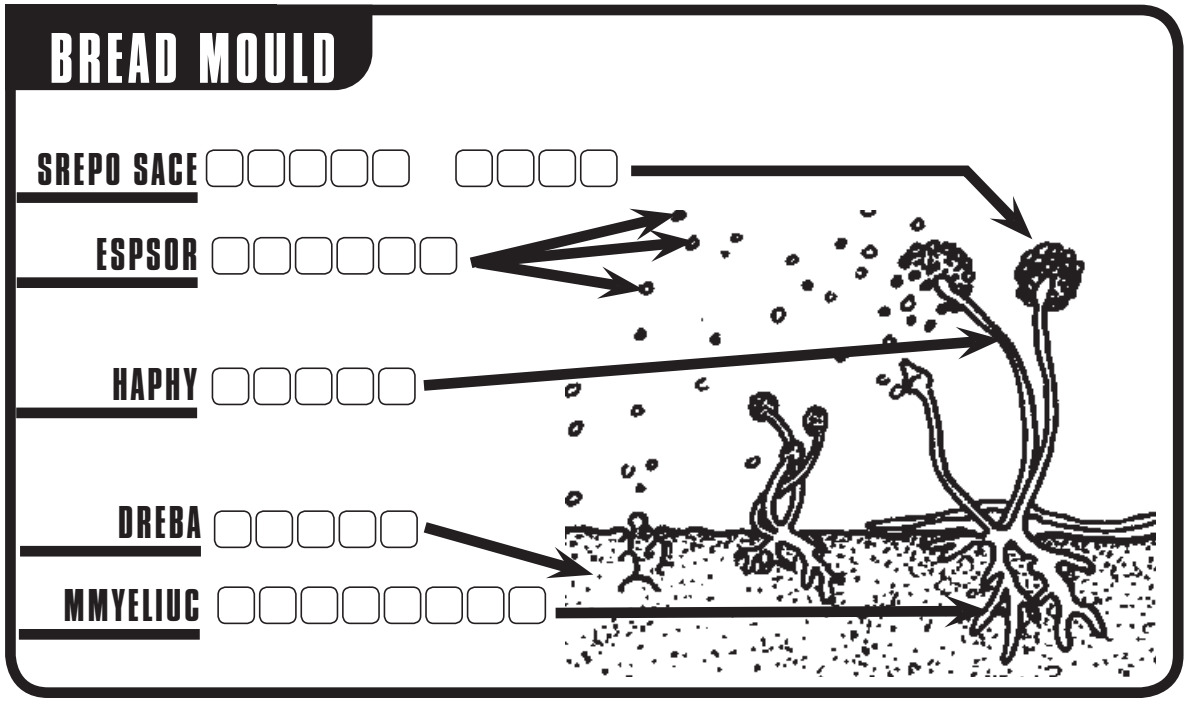
Directions

Unscramble the labels to complete the diagram of the main parts of a typical mushroom and bread mould.

MUSHROOM



BREAD MOULD



Key to the Fungal Treasures

Activity 1.4

GRADES
3-6

TYPE OF ACTIVITY
Identification Puzzle

MATERIALS
- copies of pages 27-29
- scissors
- glue or tape

VOCABULARY
cap
dichotomous key
pores
spines
stem

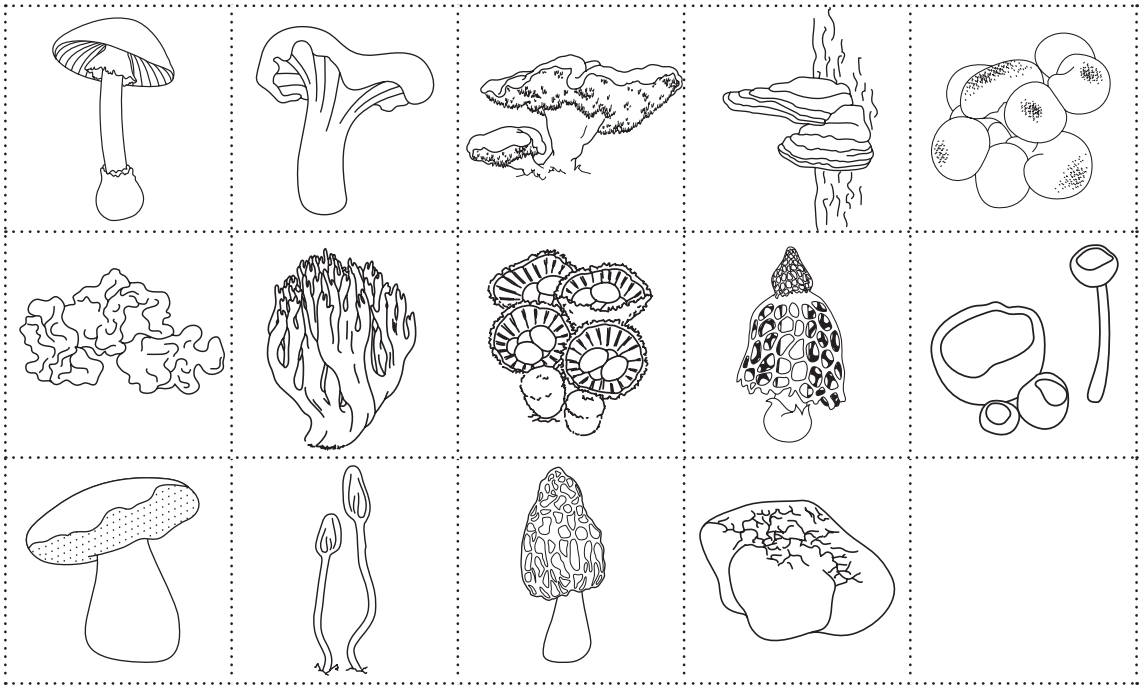
OBJECTIVE
- To familiarize students with the diversity of basic shapes of fungal fruiting bodies using "key-like" deductions.

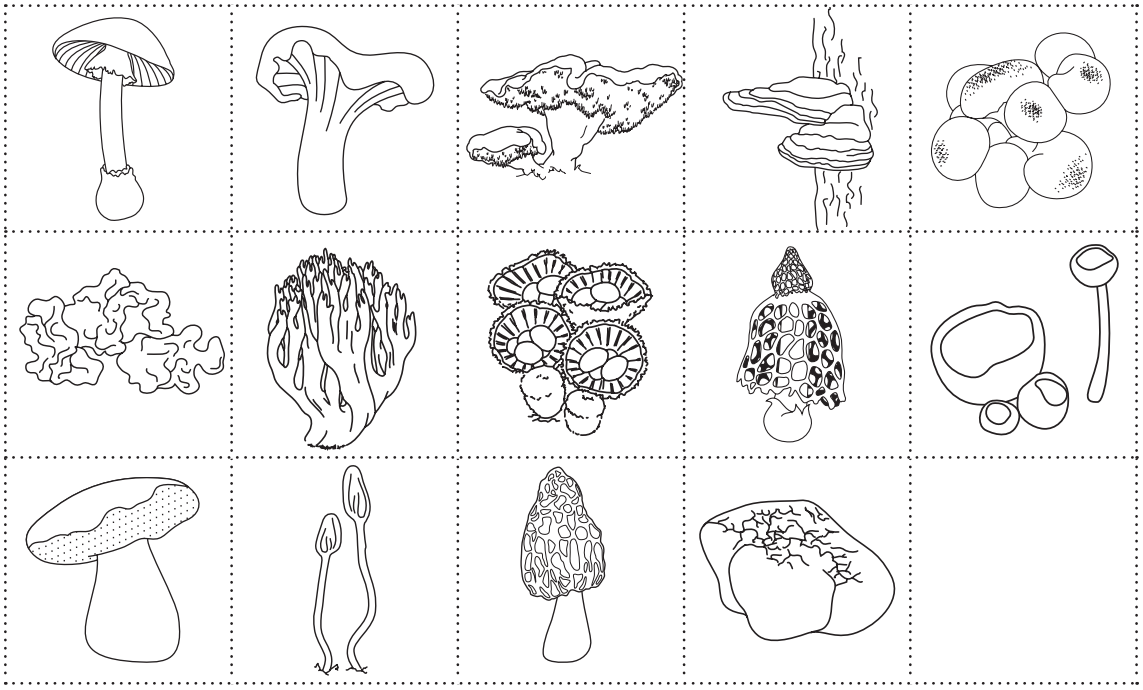
BACKGROUND INFORMATION
Scientists and naturalists use **dichotomous keys** to identify unknown organisms. A dichotomous key is structured on a series of choices between alternative characteristics. Although this activity does not reflect the perfect binary of a true dichotomous key, students are still introduced to the basic principles of keys for identification.

TEACHER INSTRUCTIONS
1. Copy a "Key to the Fungal Treasure" map and a set of mushroom stamps for each student.
2. Tell students they are going to identify 14 mushrooms.
3. Have them cut out the mushroom stamps and, by answering the questions, place them on the map.
4. When they are sure they have them in the right place (or you have checked over their map), have them tape or glue the mushrooms in place.
6. As a class discuss these mushrooms. Are students surprised to see the various shapes? Which of these groups are students already familiar with?

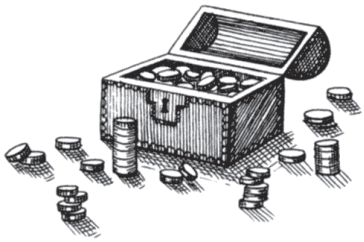
ANSWER KEY

Agaric **1**	Chanterelle **14**	Teeth Fungi **3**	Polypores **7**	Puffballs **8**
Jelly Fungi **6**	Coral Fungi **9**	Bird's Nest Fungi **4**	Basket Stinkhorn **13**	Cup Fungi **5**
Bolete **2**	Earth Tongues **11**	Morel **12**	Truffle **10**	

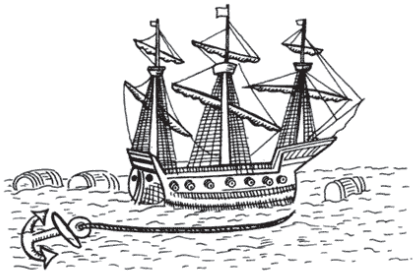




Key To The Fungal Treasure



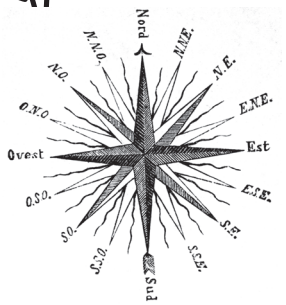
Start here



Bird's Nest Fungi

Does it have lots of jagged spines under the cap?
- Yes → **3** — Tooth fungi
- No → **Does it look spongy underneath the cap?**
  - Yes → **2** — Bolete
  - No → **Does it have gills under the cap?**
    - Yes → **1** — Agaric
    - No → **Does it have a cap and stem?**
      - Yes → **Does it have lots of jagged spines under the cap?**
      - No → **Does it look like a shelf growing on a tree?**
        - Yes → **7** — Polypores
        - No → **Is it cup shaped?**
          - Yes → **Does the cup look like a little nest with eggs"?**
            - Yes → **4** — Bird's Nest Fungi
            - No → **5** — Cup fungi
          - No → **Does it look shapeless, rubbery, and like seaweed?**
            - Yes → **6** — Jelly fungi
            - No → **Does it look like a shelf growing on a tree?**

Oops. You've reached the end of the map. Go back to the start and try again! Good



Truffle

10

Yes

Does it look like a rock or an old potato?

No

Does it look like a matchstick with a flattened head?

Yes

11

Earth tongues

No

Coral fungi

9

Does it look wrinkly or a little bit like a brain?

Yes

12

Morel

Yes

No

Does it look coral from the ocean?

No

Does it look like the mushroom is wearing a lacy skirt?

Yes

13

Basket Stinkhorn

No

No

Does it looks like a clump of little balls?

Is it shaped like a vase with ridges on the underside?

Yes

Yes

Puffballs

8

Chanterelle

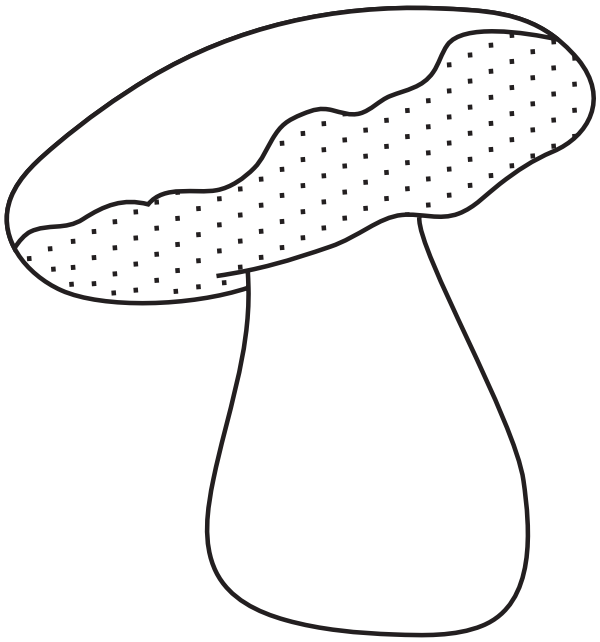
14

Fungal Fun!
jokes, songs and quotes...

What did one mushroom say to the other mushroom?
Your one fungi to be with.

A mushroom went into a bar and saw some algae at a table. He went up to one and said "You're lookin' all gal (*algal*)." She looked him over and said "You look like a fun guy.(*fungi*)"
And they took a liken (*lichen*) to each other.

Why did the mushroom go to the party? Because he was a fun guy. Why did he leave the party? Because there wasn't mushroom!



I'm a fungi
yes I am
you'll find me
in your soda can!

Out in the yard
keepin' clean
I'll be working hard
at recycling.

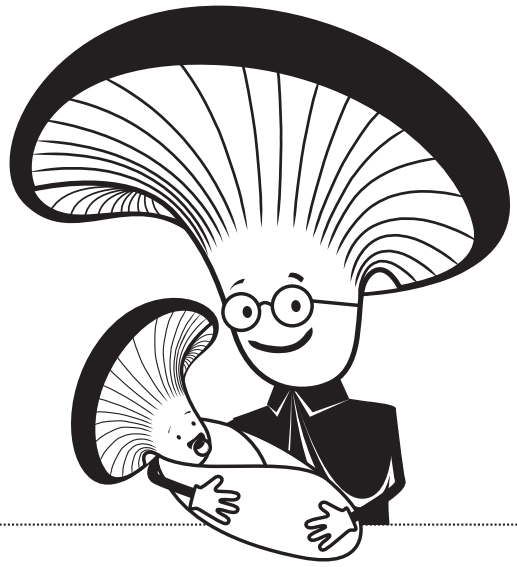
When you are sick
I am here
offering mould
to aid the cure.

If you live to eat
you may find me
hiding under
your pizza cheese.

At recess, some kids were playing baseball when a strange looking fellow walked up to them and asked to join in the game. The kids looked and him and said "no way!" The stranger replied "but why not? I'm a fungi!"

Why did the mushrooms not let the last mushroom on the elevator?
Because he was a basket stinkhorn!

1. All fungi are edible
2. Some fungi are not edible more than once"
--Terry Pratchett



Reproduction and Development

SPORES AND SO MUCH MORE!

At any given time, the air we breathe is filled with the spores of many different types of fungi. They form a large proportion of the "flecks" that are seen when direct sunlight shines into a room. They are also remarkably small; 1800 spores could fit lined up on a piece of thread 1 cm long. Fungi typically release extremely high numbers of spores at a time as most of them will not germinate due to landing on unfavourable habitats, being eaten by invertebrates, or simply crowded out by intense competition. A mid-sized gilled mushroom will release up to 20 billion spores over 4-6 days at a rate of 100 million spores per hour. One specimen of the common bracket fungus (*Ganoderma applanatum*) can produce 350 000 spores per second which means 30 billion spores a day and 4500 billion in one season. Giant puffballs can release a number of spores that number into the trillions. Spores are dispersed via wind, rain, water currents, insects, birds and animals and by people on clothing. Spores contain little or no food so it is essential they land on a viable food source. They can also remain dormant for up to 20 years waiting for an opportune moment to germinate.

WHAT ABOUT LIGHT?

Though fungi do not need light for food production, fruiting bodies generally grow toward a source of light. Light levels can affect the release of spores; some fungi release spores in the absence of light whereas others (such as the spore throwing *Pilobolus*) release during the presence of light.

SEXUAL VS. ASEXUAL REPRODUCTION

Fungi reproduce both sexually and asexually. Sexual reproduction occurs when two compatible mating strains join and recombine their genetic information, whereas asexual reproduction involves only a single parent. There are a variety of ways a fungus could reproduce asexually:

1. There could be a fragmentation of the hyphae in which the pieces go on to grow into their own mycelium.
2. Some fungi, such as yeasts, utilize budding where a small "bud" forms and breaks away from the parent cell.

3. Most commonly, fungi reproduce asexually by forming spores. When conditions are right the spore starts to grow. A hypha grows from the spore, and begins to branch and weave to form the mycelium. If growing conditions continue to be favourable, the mycelium develops fruiting bodies, which produce new spores.

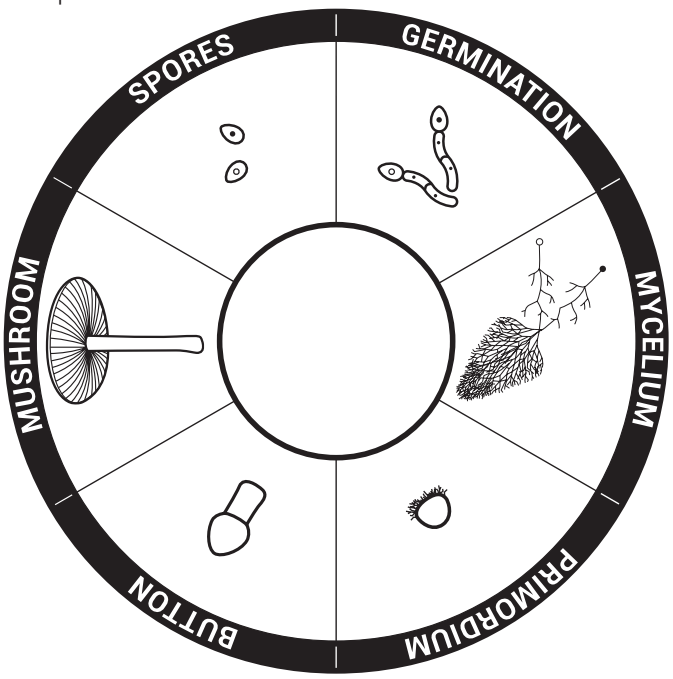
The preferred route for fungi that can reproduce either sexually or asexually is asexual because of its efficiency at producing a massive amount of spores/clones in a short period of time. It appears that sexual reproduction is sometimes undertaken only when conditions become adverse.

SO UH…WHAT GENDER ARE YOU AGAIN?

An interesting point to note about sexually reproducing fungi is that there are often an extremely large number of fungal genders that all look alike; only the fungi themselves are able to tell the difference! This means that almost any two members of the species should be able to undergo sexual reproduction if they meet.

TYPICAL LIFECYCLE OF AGARICS (BASIDIOMYCOTA)

Members of the Phylum Basidiomycota typically reproduce sexually. The basic lifecycle of a basidiomycete—which includes the gilled mushrooms, coral fungi, bracket fungi, puffballs and stinkhorns—follows this pattern:



1. **Spores** are carried away from the fruiting body, and if one lands on an adequate food source, it begins to **germinate** with the formation of a germ tube.
2. The germ tube grows into a hypha which branches into hyphae to form the **mycelium**.
3. If the mycelium encounters another mycelium which is a compatible gender for mating, the strands will join and the fungi will prepare for sexual reproduction. It appears that both moisture and deprivation of food are signals to the fungi to begin the fruiting stage.
4. When the hyphae have absorbed enough food, the mycelium begins to swell at certain points into little bumps called **primordia** (**primordium** sing.).

5. These primordia continue to grow into **buttons** that push upward to the surface.
6. If the conditions remain humid and the button is not subjected to insect attack, a full-sized **mushroom** will develop within a fortnight (two weeks). The mushroom, or fruiting body, is now ready to produce spores that contain a new mix of genetic information that hopefully will be advantageous to the survival of the next generation.

TYPICAL LIFE CYCLE OF BREAD MOULD *RHIZOPUS* (ZYGOMYCOTA)

Black bread mould can either reproduce sexually or asexually. The spores of this fungus are generally quite abundant in living spaces, and this is quite evident when moist bread is left unprotected on a countertop. This is the ideal food source on which the bread mould spore can begin its life cycle.

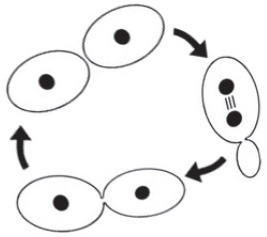
1. Once the spore or spores germinate, their hyphae will penetrate the bread and grow into mycelia.
2. If two compatible mating types meet, they will produce reproductive structures which will unite to form a thick-walled compartment called a **zygosporangium** (zygosporangia plur.).
3. From the zygosporangium, hyphae will grow upward and terminate with a round spore-containing structure called a **sporangium** or **spore case**.
4. When the spores are ripe, the walls of the sporangium split to release the spores.

If the fungus is reproducing asexually (often the preferred method of reproduction), the hyphae themselves will grow erect and form sporangia that contain spores with the same genetic information as the parent mycelium.

TYPICAL LIFE CYCLE OF YEASTS (ASCOMYCOTA)

Like the bread mould, yeasts can potentially reproduce both sexually and asexually. Yeasts are typically categorized by their preferred method of asexual reproduction--which is either by budding or by fission (splitting). Budding occurs when a small bud forms at the poles of the cell on the parent cell and is then released as a clone of its parent. More than one bud can form at any given time so this is a extremely rapid method of reproduction and colonization.

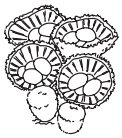
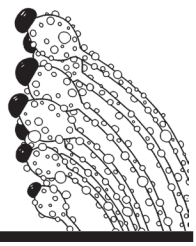
Budding



Yeast can also reproduce sexually, and usually do so under starvation conditions. If they are reproducing sexually, two compatible yeast cells will join to form one cell called an **ascus**. As this cell grows larger, 4-8 spores will form within it. When the spores mature, the cell breaks open and the spores develop into new yeast cells. Alternatively, within the ascus itself, these spores could combine with each other to produce new genetic "offspring" before being released into the environment.

SPORE DISPERSAL

Fungi utilize some incredibly complex methods of getting their spores into the environment. Some of the more interesting methods are explained below:

FUNGI	TECHNIQUE	ILLUSTRATION
Shaggy mane, Inky caps	Most spores are shot away from basidia at the very edge of the gill. The cap then dissolves via autodigestion; enzymes that destroy fungus melting everything, including remaining spores down to the ground.	
Truffles	Truffles produce an odor that attracts mice, squirrels and bears; the spores move undigested through animal's bodies. Truffle hunters in France use dogs and female pigs to sniff out truffles.	
Stinkhorns	Stinkhorns rely on insects; they produce a slimy odorous substance that smells like rotting flesh or excreta. Carrion flies are attracted to the smell and as they walk on the fungus, the spores stick to their feet and are carried off.	
Bird's nest fungi	A drop of water hits an "egg" and it pops out of the nest scattering the spores.	
Puffballs	Some of these fungi have a blowhole, and when it rains, drops fall and hit the sides and cause the spores to jump out. Others are like tumbleweed and blow around spilling their spores as they go.	
Earthstars	The rays of these fungi are closed up and protective when it is sunny. When it rains, the rays open up, and the rain drops splash the spores around.	
Bracket fungi	These fungi reorient if tree falls; in some species, beetles gnaw holes through the fruiting body and the spores fall through the hole into the air.	
Pilobolus	*Pilobolus* is phototropic which means it reacts to light. This fungus grows on horse dung; the clear bulbs at the terminal end explode and shoot spores onto vegetation at speeds up to 50km/hr and as far as 2m! There the spores are eaten by a herbivore whose digestive system dissolves the outer casing, readying it for germination in droppings.	

Wheel of Life

OBJECTIVE
- To familiarize students with the stages of a typical agaric lifecycle.

BACKGROUND INFORMATION
Refer to background information on page 32

TEACHER INSTRUCTIONS
1. Copy the handout Wheel of Life on page 54 for each student.
2. Have the students cut out the six puzzle pieces and arrange them in the order that reflects the agaric lifecycle. When completed correctly, the pieces fit into a circle in order from spores through germination to mycelium to mushroom, and back to spores. See page 37 for solution.
3. You may decide to have students colour the puzzle pieces and glue them onto construction paper.
4. Students may label each stage of the agaric's life cycle. You could call out various characteristics present at a certain stage of the life cycle and have students name the stage it represents or have them tell you the story of the lifecycle as they assemble their puzzle.
5. A great book that shows the mushrooms lifecycle is Barrie Watts' Mushroom 1986. See Sources and Resources page 90.

Activity 2.1

GRADES
K-4

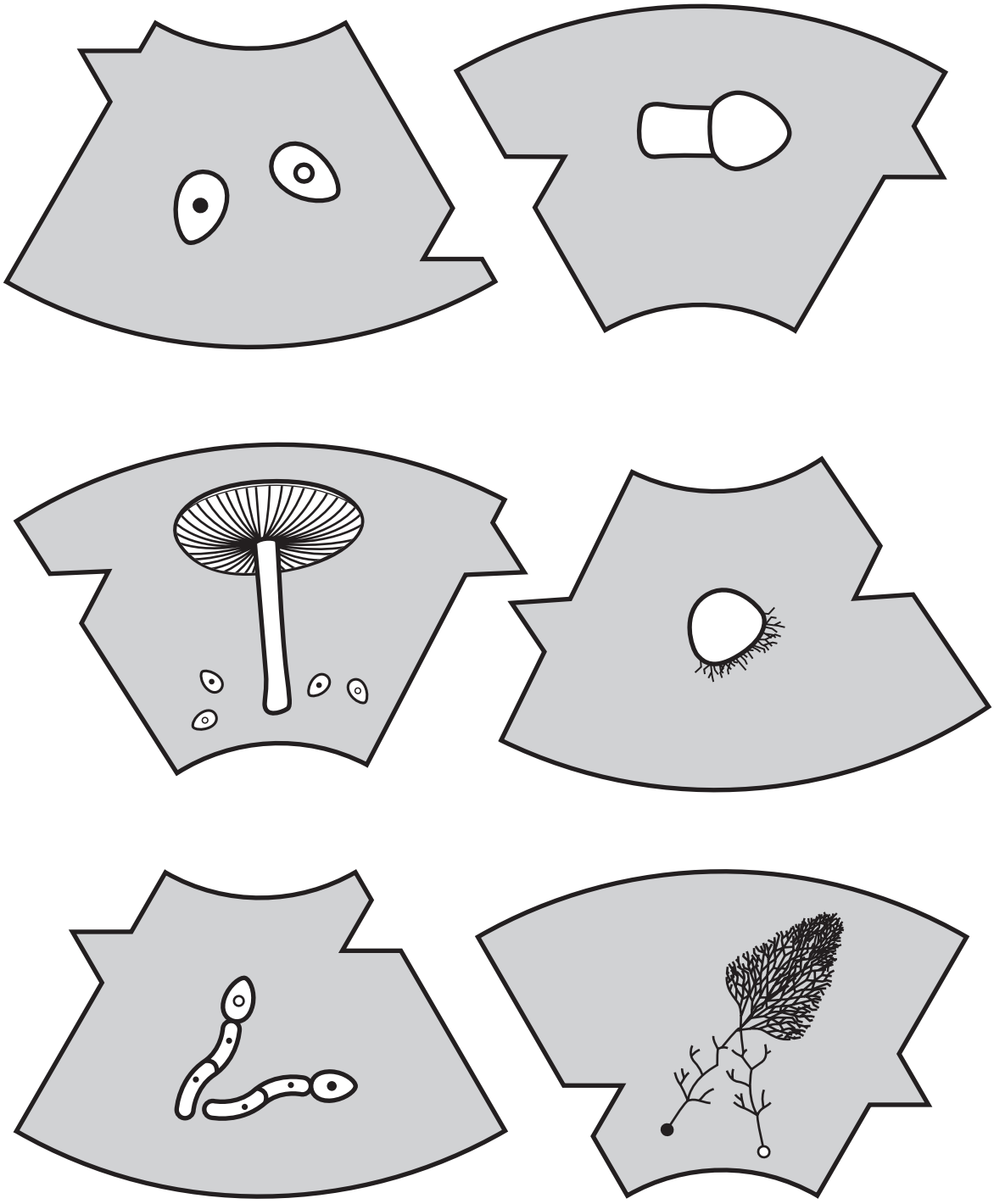
TYPE OF ACTIVITY
Simple Puzzle

MATERIALS
- copies of page 36
- pencil crayons, crayons, or markers
- glue
- scissors
- construction paper (optional)

VOCABULARY
agaric
button
germination
mycelium
mushroom
primordium
spores

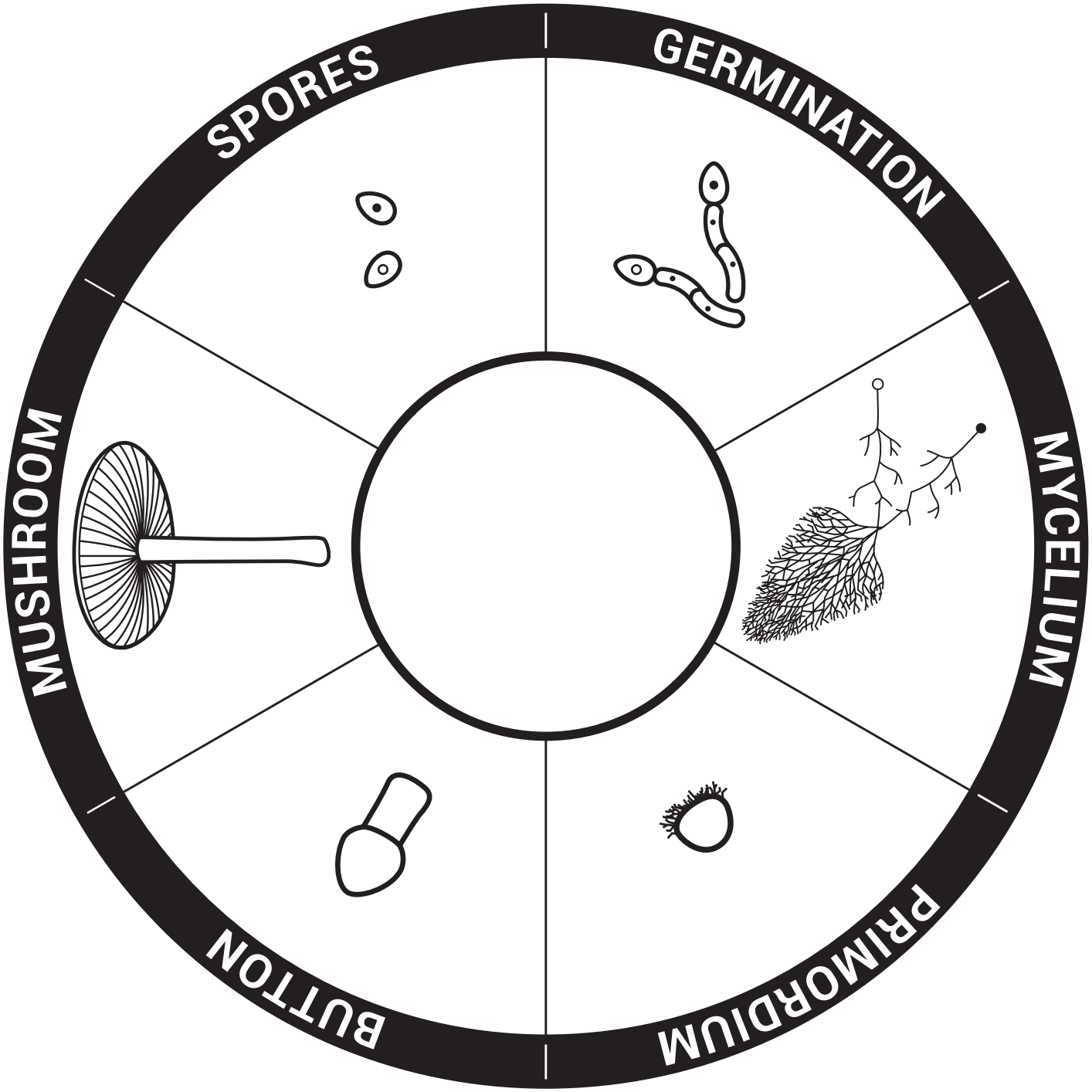
Directions

Cut out the six puzzle pieces and place them in the order that shows a gilled mushroom's lifecycle.



Wheel of Life

2.1



Adventures in Moulds and Yeasts

Activity 2.2

GRADES
2-6; **Worksheet** 4-6

TYPE OF ACTIVITY
Experiments; worksheet

MATERIALS
See text body

VOCABULARY
chitin
fission
spores

WARNING!
Before beginning any of the following experiments, make sure due caution is given to prevent direct exposure to molds:

1. Take care in handling all specimens.
2. Make sure to always view moulds through glass or plastic.
3. Make sure nothing is eaten from the experiment.
4. Make sure hands are washed after handling the materials.
5. If you have any students with severe allergies, they may be advised to leave the class during the experiments.

OBJECTIVE
- To expand student knowledge of fungi beyond mushrooms and illustrate some of the properties of moulds and yeasts

BACKGROUND INFORMATION
Most everyone is familiar with moulds; it is what turns our bread black, makes our oranges mushy, and appears like magic on last week's yogurt. Yeast is also readily recognizable to anyone who has been in the kitchen when bread, donuts, or pizza dough are being made--and surely we all know what mushrooms are! What will come as a surprise to students though is that mushrooms, moulds, and yeasts are all members of the Kingdom Fungi. The characteristics that unite these organisms are: their food must come from an external source (unlike plants which can make their own food); they reproduce using **spores**; and they have cell walls that contain **chitin**.

Although moulds are generally inconspicuous and perceived as a nuisance, they have literally changed history for the better. In 1928 a Scottish scientist named Alexander Fleming made medical history when he discovered that the mould *Penicillium* released a chemical that prevented bacteria from growing near it. From this lemon-loving mould, the antibiotic drug Penicillin was developed. Over the last century Penicillin has saved the lives of millions of people world-wide, as well as protecting crops and farm animals from various infections. That is a lot of heroic work for a little mould!

Yeasts are no slackers either! For being nothing more than a single-celled organism, they have leavened breads and given rise to alcoholic beverages for thousands of years. They have also been celebrated for their nutritional qualities as natural sources of folic acid, niacin, riboflavin, pantothenic acid, and other B vitamins. Yeasts have the capability to go dormant in the absence of food and water, but when moisture, food, heat and oxygen are right, yeasts flourish and will grow rapidly.

In the following activities, students will become more familiar with the lifestyles of these microorganisms.

ACTIVITY 1: MUSHROOMS AND MORE

Materials:

- the best possible variety of mushroom samples. Consider: field mushrooms, shitakes, wood ears, Chinese white fungus (*Tremella*), enoki, oyster mushrooms, chanterelles, morels, blue cheese. Most of these are easily found in supermarkets or Asian markets.
- mouldy bread and/or mouldy citrus in ziploc bags (see Activity 2 for instructions)
- sampling of yeast products. Consider: bread, donuts, root beer, Brewer's yeast, nutritional yeast, Marmite/Vegemite
- an example of a plant. Consider: a head of lettuce, some carrots or beets with their tops
- Anatomical Anagrams worksheet from page 25

TEACHER INSTRUCTIONS

1. Place all the objects on a table. Ask the students to point out the item that does not belong (*the plant*). At first everything might seem edible, but guide students to thinking in terms of the biological kingdoms. Emphasize the mould on the citrus fruit rather than the fruit itself. This is a tricky question!
2. Once the outsider is identified, get the students to group the remaining items into three categories: mushrooms, moulds, and yeasts. Tell them that even though these items look very different, they do in fact have a lot in common; they are all members of the same biological kingdom.
3. Review the characteristics of the Kingdom Fungi. It may help to contrast the plants. These differences are illustrated in the text body of the activity Fungi--The Hidden Kingdom on page 8.
4. Share some information about moulds and yeasts. Remind students that mushrooms are like the fruit of a fungus and are analogous to an apple on an apple tree. It is also interesting to note that from only a small piece of mushroom stem or cap, a whole new organism can grow! This is because a mushroom is just an extension of the fungal body, which usually hides underground.
5. Next, hand out copies of the worksheet, Anatomical Anagrams, and have the students complete the worksheet. Go over the answers as a class.
6. While students are working on their worksheet, draw a simple diagram of yeast budding on the board. Point out the little "bud" and explain why it is called budding. If students get a chance to view active baker's yeast under the microscope at 400X magnification, they will mainly be viewing budding which is the fastest way to reproduce.
7. Have the students copy down the diagram on the back of their Anatomical Anagrams worksheet. Ask them if they have ever watched a person make bread or if they have done it themselves. Touch on the idea of just how fast yeast can reproduce under the right conditions. The faster they bud, the more gas they release, and the faster the bread will rise!

ACTIVITY 2: MOLD GARDEN

Materials:

- bread. Consider a variety: organic whole wheat, "Wonderbread", sourdough, rye, etc.
- variety of foods both organic and containing preservatives. Consider: cheeses, fruits, salad, meats
- items from living origins. Consider: fabric scraps, leather, paper, wood
- items from non-living origins. Consider: plastic utensils, wire, old batteries...
- traditional preservatives: salt, vinegar, sugar
- large jars or transparent plastic containers
- water sprayer
- plastic wrap

TEACHER INSTRUCTIONS

1. Begin with a brief discussion about spores. Explain that mould spores are everywhere and, in fact, most of the flecks we see when sunlight enters the room are actually spores. Remind students that unlike seeds, spores need to land on a suitable food source in order to germinate; seeds carry a "packed lunch" with them but spores do not.
2. Ask students if they have ever seen bread go mouldy. When did this happen? Why do they think it happened?
3. Refer them to the diagram of the mould on their worksheet. Explain that when moist bread is left of a table, it becomes a very inviting meal to spores. Spores will land on the bread and germinate into hyphae and form a mycelium. Then some of the hyphae extend upwards and form spore cases at tips of each upright hyphae. When spores are ripe, walls of spore cases split and the spores are released into the air and the cycle begins again.
4. Tell the students you are going to make a series of mould gardens to discover where moulds will grow-- in other words, their habitat.
5. For each mould garden, students will need to write a hypothesis comparing the likelihood of mould growth. There are so many variants for "themed" gardens. For example, in a "bread garden", students could predict which types of bread would develop mould the fastest. Have students read the labels and look for preservatives that may retard mould growth. There could also be two alternative bread gardens to compare to a control; one in which the bread was misted with vinegar instead of water and another misted with salt water.
6. To prepare the items for gardening, gently mist them with water and leave them exposed for 30 minutes.
7. Place them in the jar or plastic container and cover with plastic wrap; poke a few small holes for air circulation.
8. Put the containers in a warm, dark place and observe after a few days. Have the students record their initial observations. DO NOT open the containers once mould has started to grow.
9. Continue to observe the gardens every few days.
10. Some of the conclusions that students should draw is that mould grows best on moist foods such as soft fruits. Salt and vinegar should inhibit or delay mould growth. Mould also has the potential to grow on things that are made from materials that were once alive. It is highly unlikely mould will form on any plastics in the time frame of the experiment.
11. Discuss with the class things they can do to minimize the chance of mould invading their favourite foods. You can talk about refrigeration and putting lids on things to prevent air circulation. You may also want to talk about the use of salt and vinegar to make pickles as a way of traditionally preserving vegetables and meats/fish and sugar in the preserving of fruit as jam.

EXTENSIONS

1. Place a few dead flies in a jar with some stream water and wait 3 weeks. Students will observe that insects can also be a food source for fungi.
2. Start a compost in an aquarium. Not only will moulds grow, but the whole family of decomposers will come out to play!

ACTIVITY 3: YEASTS GONE WILD!

Part 1 Materials:

- 3 balloons
- 3 empty pop bottles (500mL)
- electrical tape
- funnel

- sugar
- dry baker's yeast (quick rise is good!)
- a warm place, tub with warm water or heating pad
- a thermometer

TEACHER INSTRUCTIONS

1. Remind students briefly about the release of gases during budding. If you capture these gases, you can blow up a balloon BUT you need to give yeast the right conditions in order to do so. (*happy yeast will blow bubbles!*)
2. Mix together 1-1/2 cups warm water, 3 Tbsp sugar and 3 Tbsp dry yeast and using a funnel, pour the mixture into 3 pop bottles.
3. Blow up the balloons a few times to create some "give" in them; then place a balloon over the mouth of the bottles and seal it with electrical tape.
4. Put one bottle in a warm place such as on a heating pad on a low setting or in a warm water bath with the target temperature between 24-30 degrees Celsius.
5. Leave another bottle at room temperature and place the third one in a cool place.
6. Have students make predictions about which yeast will be happiest and which balloon will blow up the fastest.
7. Discuss your observations. What does this say about the conditions yeast needs to multiply? Ask your students if they have ever seen anyone make bread. Where do they put the bread to rise? A warm place or a cool place?

Part 2 Materials:

- variety of natural and artificial sweeteners. Consider: honey, maple syrup, molasses, fruit juice, corn syrup, brown sugar, Splenda, aspartame
- beakers, jars or glasses to correspond to number of sweeteners
- masking tape to label jars
- dry baker's yeast
- a warm place, tub with warm water or heating pad to target 24-30 degrees Celsius
- a thermometer to check ambient temperature
- rulers

TEACHER INSTRUCTIONS

1. Tell students that you will be conducting an experiment to discover yeast's favourite foods. Imagine they are gourmet chefs serving up delicacies to their yeasty patrons. The way they will be able to tell if the yeast is enjoying their meal is by the amount of foam that forms on top of the liquid.
2. Add 1 Tbsp of sweetener and 1 Tbsp of dry yeast to 1/2 cup of warm water. Stir thoroughly. Leave one jar without any sweetener at all.
3. Label the jars.
4. Record the class predictions about what food source the yeast will prefer.
5. After 15 minutes and 30 minutes, measure the amount of foam that has formed.
6. Explain why the yeast did not grow in the jar without sweetener (*no food, no reproduction*). How is this different from plants? (*plants don't need an external food source as they make their own*) Then explain that the yeast did not like the artificial sweeteners because they do not have very much energy in them (which is why people on diets sometimes use them).

Part 3 Materials:
- dry baker's yeast
- a banana

TEACHER INSTRUCTIONS

1. Slice the banana in half lengthwise.
2. Put some dry yeast on one half and nothing on the other.
3. Have the students predict what they think will happen to the banana after a few days.
4. Cover the banana slices.
5. Observe after a few days. The yeast will have gobbled up a lot of the banana as food.
6. Have the students draw the banana slices and compare their prediction to the results.
7. Dispose of the bananas when finished observations. Do not eat!

DISCUSSION

1. Review what yeast need to survive (*food, water, warmth, oxygen*) and compare this to what we need to survive.
2. Given the right conditions, some yeast are able to reproduce at rates that approach exponential growth. See handout "Exponential, My Dear Watson". Instruct students to draw two new yeast cells (for each previous single one) every 30 minutes. It may be helpful to use a stack of pennies (or nickels, or buttons) to help keep track of the yeast replication. For example, start with **one** penny (yeast cell) at 9:00am. One yeast cell buds and becomes two yeast cells so at 9:30am, there are **two** pennies. At 10am, have the students stack a penny onto each of the previous pennies. There should now be a total of **four** cells. Have students count and right down the number of pennies at each time slot before stacking more pennies and moving on. You will need a minimum of 64 pennies per student (or pair of students) to complete the activity.
3. You may want to do the activity together as a demonstration if it seems too complicated for your class. The purpose of the activity is to illustrate the magnitude of yeast reproduction.

Answer key:

9:00 - **1** cell**;** 9:30 - **2** cells; 10:00 - **4** cells; 10:30 - **8** cells; 11:00 - **16** cells; 11:30 - **32** cells; 12:00 - **64** cells

EXTENSIONS

1. As a complement to any of these yeast activities, students could view yeast under the microscope. If you have access to a microscope, set the magnification to 400X. Prepare a wet mount from a solution of yeast in warm water and sugar. Students will be able to observe phenomenal growth right under their eyes! Note that baker's yeast reproduces by budding.
2. Yeasts have a very high nutritional value. Research the role of folic acid, niacin, riboflavin, pantothenic acid, B1, 6, 12 in the body.
3. You could bring in some samples and talk about sourdough bread. Sourdough was the main bread made in Northern California during the California Gold Rush, and it remains a major part of the culture of San Francisco. The bread became so common that sourdough became a general nickname for the gold prospectors. Sourdough "captures" wild yeast and causes the dough to rise.

Exponential, My Dear Watson! 2.2

Directions

Yeast cells are able to reproduce very quickly. Imagine that you had a pet yeast cell and that you fed her a lot of sugar before leaving for school at 9:00am. If she budded a new yeast cell every 30 minutes, and each of her "buds" did the same, how many cells would there be when you arrived home for lunch at noon? (Be prepared to expect a really big party!)

The Fung from the Dung Flipbook

Activity 2.3

GRADES
K-6 (Care partners for K-2)

TYPE OF ACTIVITY
Flipbook

MATERIALS
- letter sized paper (cardstock would be ideal)
- pencil crayons, crayons, or markers
- copies of page 45-46 for each student
- scissors
- heavy duty stapler
- copies of the poem, "Pilobolus, the Fung in the Dung" from Tom Volk's website (see "Extensions")

VOCABULARY
adaptation
coprophilic
spores

Scientific Classification
Kingdom: Fungi
Phylum: Zygomycota
Class: Zygomycetes
Order: Mucorales
Family: Pilobolaceae
Genus: Pilobolus

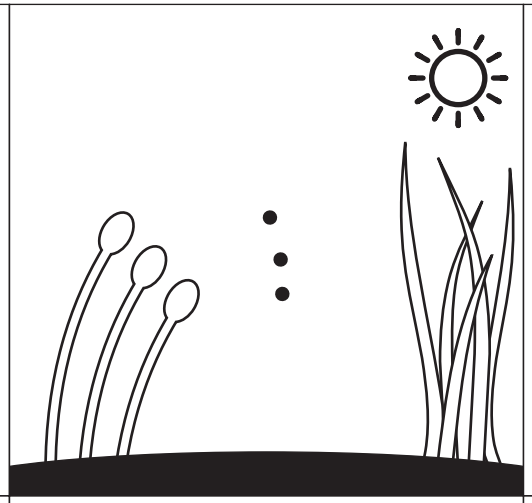
OBJECTIVE
- To illustrate how one fungus disperses its spores

BACKGROUND INFORMATION
Fungi have developed many bizarre and interesting **adaptations** to disperse their spores. The hat thrower fungus, *Pilobolus,* is especially intriguing. This mushroom is **coprophilic** which means it likes to live in dung. *Pilobolus* has evolved a way to shoot its **spores** onto the grass where it is eaten by cattle. Its "shotgun" is a stalk swollen with cell sap, with a black mass of spores on the top. Below, the swollen tip is a light-sensitive area. The light sensing region affects the growth of *Pilobolus* by causing it to orient toward the sun. As the fungus matures, water pressure builds in the stalk until the tip explodes, launching the spores into the daylight at speeds up to 50km/hr and for distances up to 2.5m! Shooting the spores into the daylight gives them a better chance of landing in a sunny place where grass is growing. When the grass is eaten by the cattle, the tough spores pass through their digestive system and begin to grow in a pile of dung where the cycle begins again.

TEACHER INSTRUCTIONS
1. Make copies of pages 45-46 and handout to each student. The flipbook works best if it is photocopied onto thicker paper.
2. Open a discussion with your students about spore dispersal. Remind them that, unlike seeds, spores need to land on a direct food source in order to germinate and grow.
3. Hand out copies of pages 45-46 to each student and have them cut out the squares and stack them in numerical order.
4. Once the squares are assembled, staple the flipbook on the left margin and flip away to see a mini-movie of *Pilobolus* throwing its hat!

EXTENSIONS
1. There is a really cute poem about *Pilobolus* on Tom Volk's website at http://botit.botany.wisc.edu/toms_fungi/mar2006.html Encourage students read the poem after making their flipbooks. Another idea would be to turn the poem into a skit!

10



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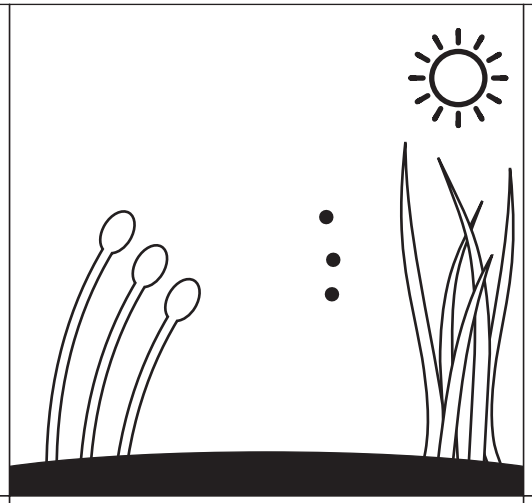

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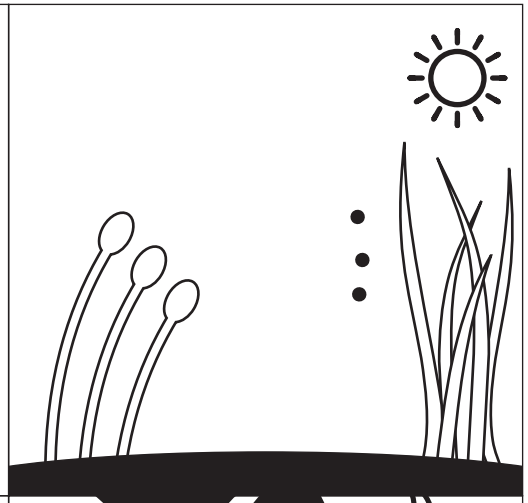

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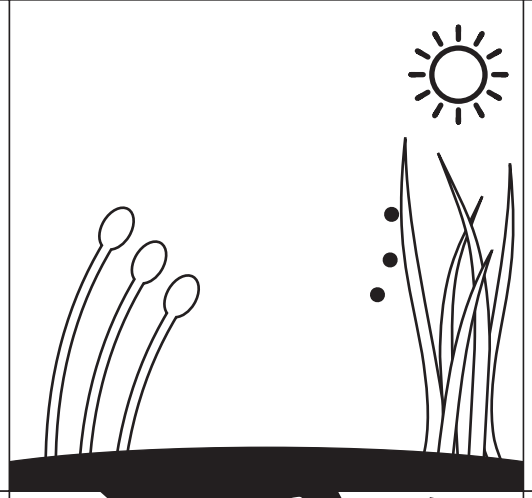

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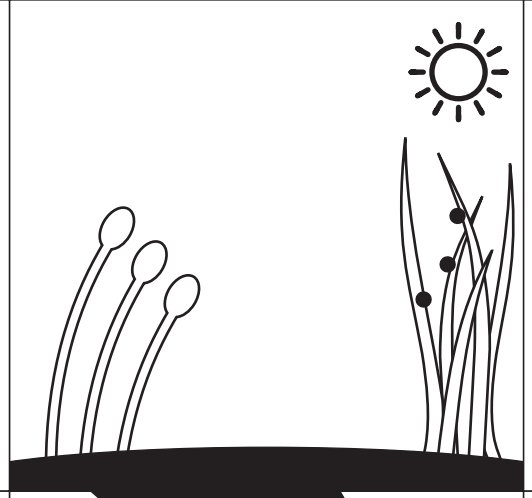

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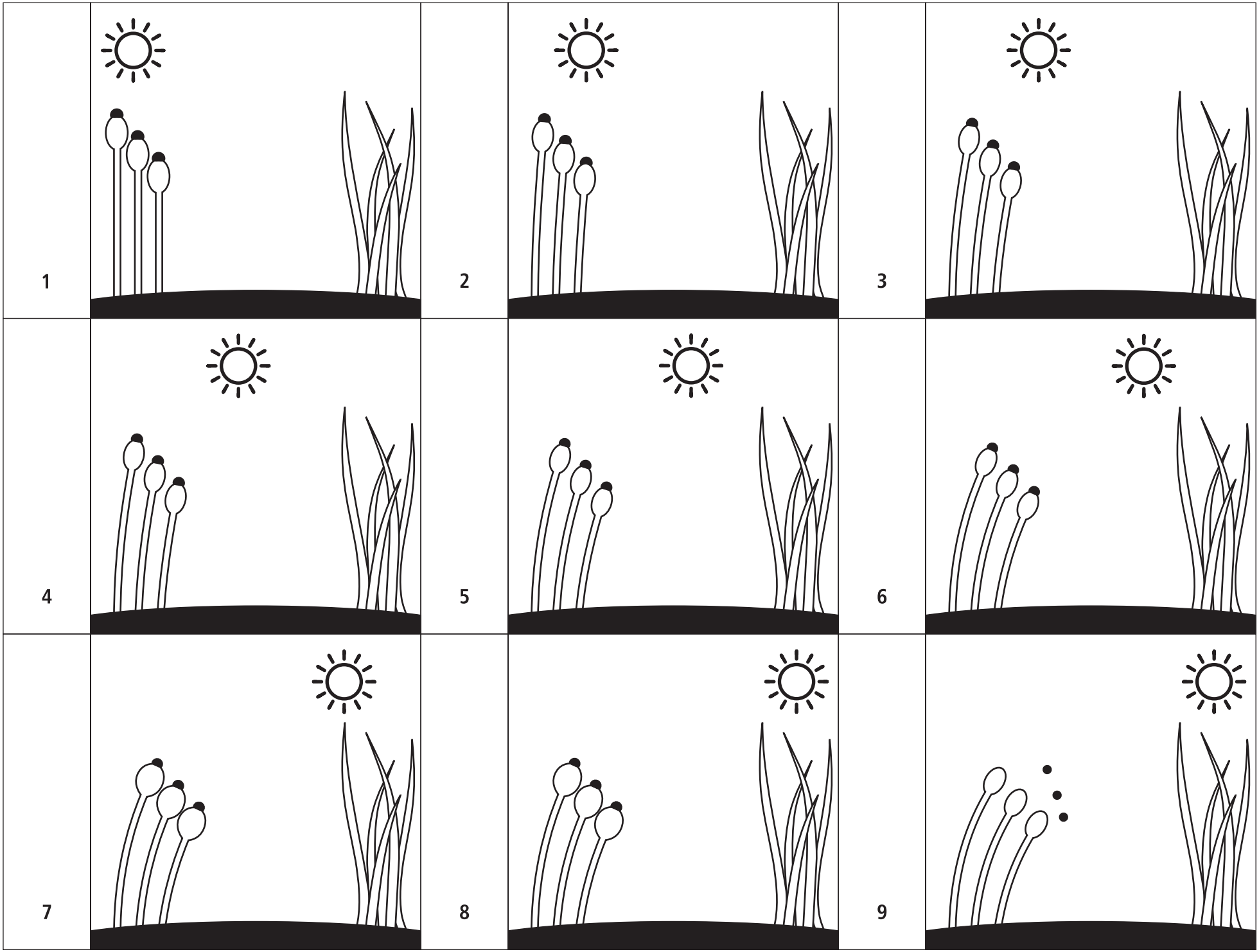
The Fung from the Dung

Starring *Pilobolus*,
the Hat Throwing Fungus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9

Adaptation and Environment

MASTERS OF RECYCLING

Fungi have been in the recycling business for a long, long time—actually as long as plants have been around, which adds up to about 400 million years. Fungi, however, don't do all of the work on their own; they also employ help from **bacteria** and **protozoa** and are collectively referred to as **decomposers**. Realizing that a single broad-leaved tree has approximately 1 million leaves that weigh about 200kg, it can be calculated that in 5 years, 1 tonne of leaves are produced and fall to the ground. This means that 1 billion deciduous trees produce 1 billion tonnes of dead leaves every five years. With these figures in mind, its easy to imagine that without the decay of materials (particularly **cellulose** and lignin), the earth would soon be knee deep in dead material. So besides this obvious reason, why is recycling important?

THE CARBON CYCLE

The answer to this question can be found in what is called the carbon cycle, a process behind which fungi are the driving force. Every molecule of every living tissue contains "trapped" carbon. Plants snare mineral elements from the soil in such a way that they are no longer available to aid the growth of other plants. However, during the recycling process, enzymes ooze from the fungal body and uncouple some of the molecular bonds thereby releasing the carbon (in the form of carbon dioxide) into the atmosphere. Fungi also similarly free nitrates and other simple chemicals. These reduced chemicals end up in the air, water and soil where they become available to green plants and algae that absorb them and process them further. Simplistically speaking, without the decomposers releasing these compounds, the plants would soon run out of carbon dioxide and would soon die, and with their loss, the entire food chain would crumble.

MYCORRHIZAS—A TRULY SYMBIOTIC RELATIONSHIP

Mycorrhizas is a term used to refer to a **symbiotic** relationship that forms between a fungus and the roots of a plant (mycos=fungus rhiza=root). In a mycorrhizal relationship, hyphae cover and penetrate the roots and absorb water and minerals which they pass onto the plant. In this way, they become like far-reaching drinking straws for plants. This increases a plant's ability to withstand drought and

tolerate environmental extremes, which is particularly useful in sandy soils. In addition, the plant receives some protection from soil-borne pathogens including other fungi and **nematodes** (roundworms). In exchange, the fungi receive a sturdy helping of their host's food supply—in some cases up to 25% of the total sugars produced!

More than 90% of all higher plants have mycorrhizal fungi associated with their roots; in lush lowland forests, the soil is so full of mycorrhizal fungi that they connect the trees together, so trees and their seedlings can exchange food and messages. In the tropics, mycorrhizas are absolutely crucial. This is because there is no true topsoil, rather just rotting leaves and fruits. Trees depend on mycorrhizas to get enough water and nutrients from the soil, so that when forests are cleared, there is no plant debris for fungi to feed on and they die under the hot sun. In recent years there has been a developing interest in using mycorrhizal fungi to establish high-yield planted forests, reclaim strip-mined land, and improve growth of important crops.

LICHENS: A PLEASANT MARRIAGE OR A HOSTILE HOSTAGE TAKING?

Lichens have been a source of wonder for most people, even if only for a passing moment. To see this strange organism growing on nothing more than barefaced rock has prompted most of us to wonder: just what IS that bizarre life form?

In short, lichens are a colonial partnership between a fungus and an **alga** in which the fungus, using enzymes to extract nutrients from substrate, provides water and minerals for the alga and in turn receives food from the alga. Worldwide, there are approximately 27 000 species living in places virtually inhospitable to other organisms such as on roof shingles, tree bark, stone walls and on fence posts; they thrive as well in the Arctic; and at absolute zero temperatures in the Sahara desert. They can live as long as 10 years with nothing more than fog moisture as their water source. These fascinating organisms certainly subscribe to the "slow and steady win the race" philosophy: a colony in the arctic grows at a rate of only 5 cm per 1000 years (though the more typical rate of growth is closer to 100-150 cm per 1000 years) and some colonies have been found to be more than 4500 years old!

Lichens grow in three basic forms: as hard flat crusts typically seen on headstones (**crustose**), as tiny flat leaves (**foliose**), or as ground shrubs or "old man's beard" tassels hanging from branches (**fruticose**). They are highly sensitive to changes in the chemistry of air and water and therefore are valuable indicators of atmospheric pollution; they are killed by both acid rain and elevated levels of sulphur dioxide. Lichens are also nutritionally very important, especially to caribou and other native mammals in the arctic; they make up to 95% of the reindeers' total diet.

It has long been thought that lichens were an example of a harmonious symbiotic relationship, much like mycorrhizas--but recent research has given scientists reason to reassess this belief. When grown separately under laboratory conditions, it has been found that algae can live without fungi and actually grow more quickly in their absence. The reverse, however, does not hold true. Fungi are essentially helpless without their algal counterpart. It seems more likely that the fungi are holding the algae hostage in a cell, constructed by their own body, and providing water and minerals like bread and water to prisoners. The clincher comes from an examination of the connective structures between the two organisms—the fungi penetrate the algal body with structures very similar to those formed by pathogenic fungi. Anthropomorphism aside, is this an example of a perfect marriage as it might at first appear or is it something slightly more insidious?

PREDATORY FUNGI

One of the most exciting features of some members of the Kingdom Fungi is the ability to act as predators. There are a number of different predatory fungi that have structures designed with the intention of ensnaring nematodes and other microorganisms. One species of fungi, *Arthrobotrys*, has a particular appetite for threadworms. Threadworms are small **nematodes** that infest plant roots. They can cause illness when ingested by cattle and root-knot disease in crops such as maize, potatoes, tomatoes, carrots and hot peppers. This fungus has rings or loops in their hyphae that are made with a substance the worms find irresistible. The excited worm wriggles into the loop and in 1/10th of a second, the loop blows up like a balloon, snapping the worm shut in its trap. Within 24 hours, the fungus will have digested the worm from the inside out, leaving nothing more than the worm's empty skin as evidence. *Arthobotrys* species may also use sticky knobs or nets to capture their prey. It is interesting to note that these predatory fungi can be fed to cattle and introduced to crops as protection from the nasty nematodes.

A second type of fungus, called the lollipop fungus, prefers to prey on small aquatic animals called rotifers. They have delicious (well so the rotifer thinks) sticky knobs attached to their hyphae that upon contact, glue firmly to their victims mouth. The rotifer may struggle and the knob may break off the hyphae but it is too late--the fungus begins to re-grow from inside its victim, eventually killing it.

The delicious oyster mushroom, *Pleurotus ostreatus*, uses yet another technique. This wood decay fungus produces tiny appendages on its hyphae and these secrete droplets of a potent toxin. This toxin paralyses nematodes in seconds but does not kill them. Specialized hyphae then locate the paralyzed victims, penetrate their skin, and digest the worm. There's nothing like a little protein to spice up a traditional diet of lignin and cellulose!

MARY, MARY QUITE CONTRARY…FUNGAL GARDENERS

Over the years, humans have discovered just how useful fungi can be as fire starters, foods, and medicines. We aren't the only ones that have found fungi to be especially useful. There are actually a number of insects that "garden" fungi.

One such example are the leaf cutter ants that keep fungi in their underground nests and feed leaves to the fungi; the fungi then produce clusters of sweet, round swellings on which the insects and their larvae feast.

Termites are another example of fungal gardeners. The termites eat plant material and grow fungal cultures in their droppings. The fungi eat the droppings and then termites eat the fungi; when a rainstorm is coming, the termites take bits of mycelia outside and spread it on the ground. Days later, mushrooms appear and shed spores and the termites gather some of the fungus and carry it to a new mound.

A final example of an insect that uses fungi to their advantage is the ambrosia beetle. These beetles carry the "ambrosia" fungus into the sapwood of the tree they visit. There they dig out little burrows and grow the fungus on the walls. They will spend most of their lives in the burrows and feeding on the fungus which has absorbed nutrients from the tree. Eventually, the adult females emerge and carry the fungus to a new host tree.

CrissCrossed Fungi

Activity 3.1

GRADES
Puzzle A: 2-4; **Puzzle B:** 5-6

TYPE OF ACTIVITY
Crossword puzzles

MATERIALS
- copies of page 52 or 53, depending on grade level; one per student
- pencils

VOCABULARY
Refer to answer key on page 51

OBJECTIVE
- To introduce new words associated with fungi

BACKGROUND INFORMATION
To learn about fungi, students need to become familiar with the terms used to describe their biology and ecology. These two crosswords will introduce students to some of the terminology associated with fungi along with trivia and factoids.

TEACHER INSTRUCTIONS
1. Copy the crossword puzzle appropriate to the grade level of your class and hand out one to each student.
2. Have the students work through the puzzle on their own or in partners.
3. Go over the solution together and elaborate on the facts presented whenever appropriate.
4. Encourage questions!

YOUNGER STUDENTS
Grade 2 may be capable of doing the first puzzle; you may, however, wish to do it together as a class.

TEACHER'S ANSWER KEY

PUZZLE A (MORE SIMPLE)

Across

1. The top part of the mushroom shaped like an umbrella is called the **cap.**
3. **Fall** is the best time of year to go mushroom hunting.
8. Fungi **recycle** dead leaves, grass, and wood and turn them back into soil.
9. Sometimes fungi will live together with trees and help the tree to get enough **water** and nutrients.
10. The crusty orange stuff you sometimes see on rocks is probably a **lichen.**
11. The "fruit" of a fungus is usually called a **mushroom.**

Down

2. If you squeeze a **puffball**, you will see a "puff" of spores released.
4. Plants reproduce with seeds, but fungi reproduce with **spores.**
5. A **toadstool** is a folk name for a poisonous mushroom.
6. Many tiny threads together form the fungus body called the **mycelium.**
7. When mushrooms grow in a circle, it is called a **fairy** ring.
9. Some **worms** like to eat mushrooms, but some fungi like to eat them!

PUZZLE B (MORE ADVANCED)

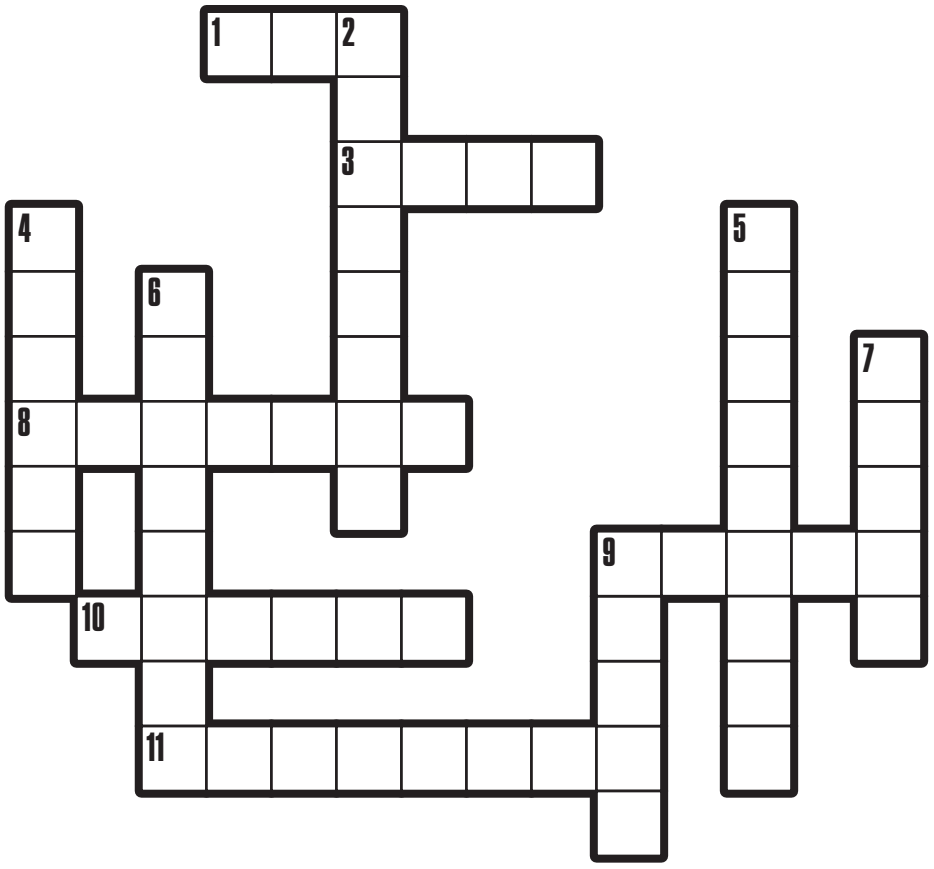
Across

4. When fungi recycle dead plants and animals, they release **carbon** into the atmosphere.
5. **Mycelium** has been called "the Earth's living internet" because it connects many living things to each other.
6. The scientific name for mushrooms that have gills under their cap is **agaric.**
10. The mycelium, or fungal body, is a network of branching threads called **hyphae.**
11. A **spore print**, much like a fingerprint, is a very useful tool in mushroom identification.
12. Fungi that cause diseases are called **parasitic** fungi.
15. **Lichens** are the result of a partnership between fungi and algae.
16. When sunlight enters a room, most of the flecks we see in the air are actually **spores**.
17. Fungi that help plants get nutrients and water from the soil are called **mycorrhizal**.

Down

1. In the food chain, fungi, bacteria, and other small organisms are collectively called the **decomposers.**
2. In France, dogs and female pigs are used to sniff out **truffles,** which are considered a delicacy.
3. **Foray** is the special name for a mushroom hunt.
5. Someone who studies fungi is called a **mycologist.**
7. Some fungi will actually set traps for and eat microscopic **worms** called nematodes.
8. Fungi represent one of the **kingdoms** of biological classification.
9. Baker's **yeast** is a type of fungi that makes bread light and fluffy.
13. Penicillin is the name of an important **antibiotic** drug that comes from fungi and has saved many lives.
14. The cell walls of fungi contain **chitin** which also forms insects' hard shells.

CrissCrossed Fungi A



ANSWERS

CAP
FAIRY
FALL
LICHEN
MUSHROOM
MYCELIUM
PUFFBALL
RECYCLE
SPORES
TOADSTOOL
WATER
WORMS

ACROSS

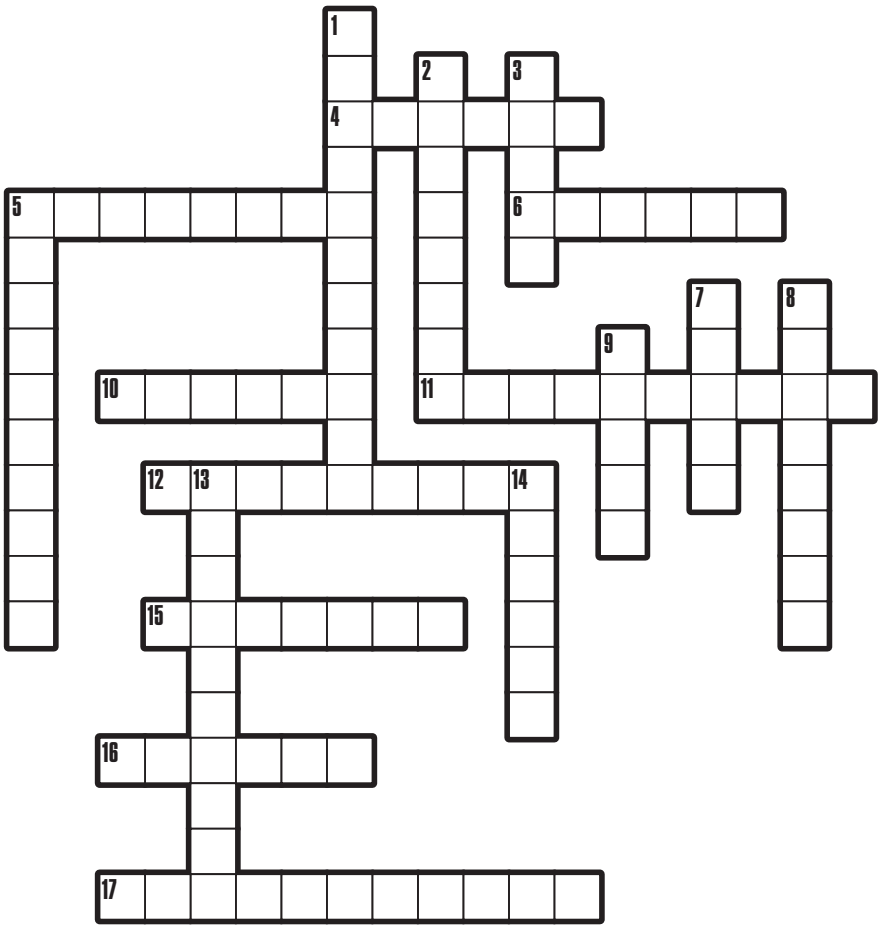
1. The top part of the mushroom shaped like an umbrella is called the _ _ _.
3. _ _ _ _ is the best time of year to go mushroom hunting.
8. Fungi _ _ _ _ _ _ _ dead leaves, grass, and wood and turn them back into soil.
9. Sometimes fungi will live together with trees and help the tree to get enough _ _ _ _ _ and nutrients.
10. The crusty orange stuff you sometimes see on rocks is probably a _ _ _ _ _ _.
11. The "fruit" of a fungus is usually called a _ _ _ _ _ _ _ _.

DOWN

2. If you squeeze a _ _ _ _ _ _ _ _ , you will see a "puff" of spores released.
4. Plants reproduce with seeds, but fungi reproduce with _ _ _ _ _ _.
5. A _ _ _ _ _ _ _ _ _ is a folk name for a poisonous mushroom.
6. Many tiny threads together form the fungus body called the _ _ _ _ _ _ _ _.
7. When mushrooms grow in a circle, it is called a _ _ _ _ _ ring.
9. Some _ _ _ _ _ like to eat mushrooms, but some fungi like to eat them!

CrissCrossed Fungi B

3.1



ANSWERS

AGARIC
ANNULUS
ANTIBIOTIC
BUDDING
CARBON
CHITIN
DECOMPOSERS
FORAY
HYPHAE
KINGDOMS
LICHENS
MYCELIUM
MYCOLOGIST
MYCORRHIZAL
PARASITIC
SPORE PRINT
SPORES
TRUFFLES
WORMS
YEAST

ACROSS

4. When fungi recycle dead plants and animals, they release _ _ _ _ _ _ into the atmosphere.
5. _ _ _ _ _ _ _ _ has been called "the Earth's living internet" because it connects many living things to each other.
6. The scientific name for mushrooms that have gills under their cap is _ _ _ _ _ _.
10. The mycelium, or fungal body, is a network of branching threads called _ _ _ _ _ _
11. A _ _ _ _ _ _ _ _ _ _ _, much like a fingerprint, is a very useful tool in mushroom identification.
12. Fungi that cause diseases are called _ _ _ _ _ _ _ _ _ fungi.
15. _ _ _ _ _ _ _ are the result of a partnership between fungi and algae.
16. When sunlight enters a room, most of the flecks we see in the air are actually _ _ _ _ _ _
17. Fungi that help plants get nutrients and water from the soil are called _ _ _ _ _ _ _ _ _ _ _ _.

DOWN

1. In the food chain, fungi, bacteria and other small organisms are collectively called the _ _ _ _ _ _ _ _ _ _ _ _.
2. In France, dogs and female pigs are used to sniff out _ _ _ _ _ _ _ _, which are considered a delicacy.
3. _ _ _ _ _ is the special name for a mushroom hunt.
5. Someone who studies fungi is called a _ _ _ _ _ _ _ _ _ _ _..
7. Some fungi will actually set traps for and eat microscopic _ _ _ _ _ called nematodes.
8. Fungi represent one of the _ _ _ _ _ _ _ _ of biological classification.
9. Baker's _ _ _ _ _ is a type of fungi that makes bread light and fluffy.
13. Penicillin is the name of an important _ _ _ _ _ _ _ _ _ _ drug that comes from fungi and has saved many lives.
14. The cell walls of fungi contain _ _ _ _ _ _ which also forms insects' the hard shells.

A-Mazing Mycorrhizas

Activity 3.2

GRADES
1-6

TYPE OF ACTIVITY
Maze

MATERIALS
- copies of page 55
- pencils
- pencil crayons, crayons, or markers
- a mushroom field bookmarked to a picture of a bolete mushroom

VOCABULARY
bolete
hypha
lichen
mycelium
mycorrhizas
symbiosis

Scientific Classification
Kingdom: Fungi
Phylum: Basidiomycota
Class: Agaricomycetes
Order: Boletales
Family: Boletaceae
Genus: Boletus

OBJECTIVE
- To visually introduce students to the symbiotic phenomenon of mycorrhizas

BACKGROUND INFORMATION
Mycologist Paul Stamets has called mycelium the 'Earth's living internet' because it "connects the ancient intelligence in the mushroom to all life on earth." When fungal mycelia enter into a symbiotic relationship with the roots of plants, they are called **mycorrhizas** which literally means "fungus roots". The mycelia cover and penetrate the roots of the plant and provide it with water and minerals in exchange for sugar (food). Approximately 90% of land plants are in a mycorrhizal partnership.

TEACHER INSTRUCTIONS
1. Make copies of the A-mazing Mycorrhizas worksheet.
3. Hand them out to each student and, depending on the age of your students, discuss "symbiosis" and "mycorrhizas".
4. Show your students some pictures of bolete mushrooms. Explain to them that **bolete** mushrooms are mostly mycorrhizal. Point out that boletes are defined by the presence of pores, rather than gills, underneath the cap. Boletes are some of the more popular edible species around the world.
5. Instruct your students to follow a **hypha** of the mycorrhizal mycelium (from the arrow) to the bolete (the second mushroom from the right). Students may wish to colour their mazes after completion.
6. Ask if any of the students have ever found a bolete mushroom. Did they notice if any trees were growing nearby? If so, there is a good possibility they were the mushrooms' mycorrhizal partner.

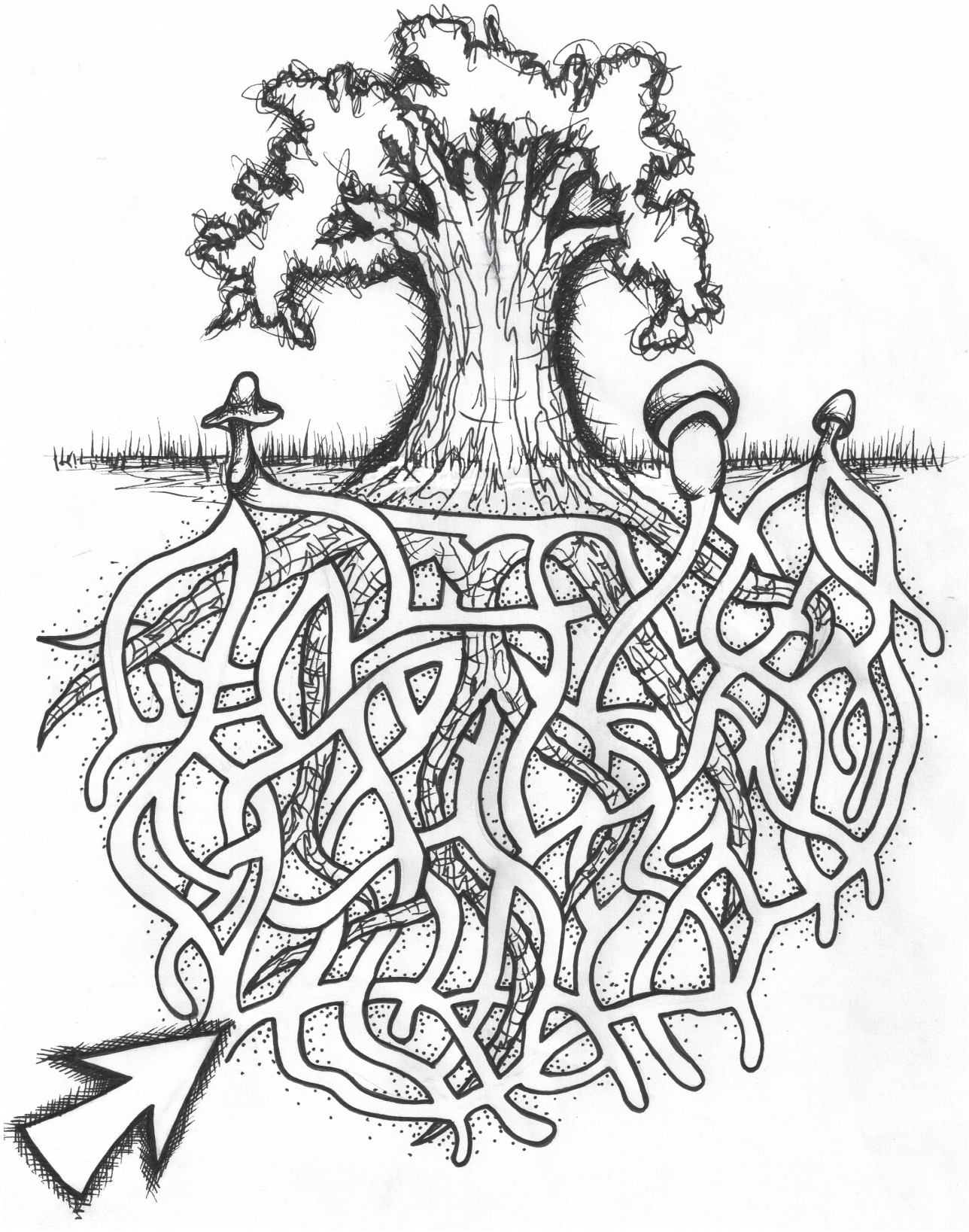
EXTENSIONS
1. Recently it has become obvious that sensitive fungal populations are being affected by high levels of pollution, which is causing a domino effect in the environment: There are fewer edible mushrooms available for human and animal consumption; microhabitats for insects and rodents are vanishing; decomposition/nutrient cycling rates are being affected; and ultimately, entire forests are becoming endangered. (See Fungi and Pollution on page 59 for more information). You could have your students draw up warning posters illustrating the ecological consequences of pollution on fungi.

A-Mazing Mycorrhizas

3.2

Directions

Many mushrooms wrap their mycelium around tree roots and help the tree get water and nutrients while getting food from the tree in return. This is called a mycorrhizal relationship. Find your way through the mycelium up to the mycorrhizal Bolete.



The Mushroom as Muse

The Mushroom is the Elf of Plants
by Emily DIckinson

The Mushroom is the Elf of Plants --
At Evening, it is not --
At Morning, in a Truffled Hut
It stop upon a Spot

As if it tarried always
And yet its whole Career
Is shorter than a Snake's Delay
And fleeter than a Tare --

'Tis Vegetation's Juggler --
The Germ of Alibi --
Doth like a Bubble antedate
And like a Bubble, hie --

I feel as if the Grass was pleased
To have it intermit --
This surreptitious scion
Of Summer's circumspect.

Had Nature any supple Face
Or could she one contemn --
Had Nature an Apostate --
That Mushroom -- it is Him!

.....

When the moon is at the full
Mushrooms you may freely pull.
But when the moon is on the wane
Wait ere you think to pluck again.

(an old rhyme from the county of
Essex in England)

.....

Mushroom hunting;
Tall People
Are no good at it.
--Yayu

Mushrooms
by Sylvia Plath

Overnight, very
Whitely, discreetly,
Very quietly

Our toes, our noses
Take hold on the loam,
Acquire the air.

Nobody sees us,
Stops us, betrays us;
The small grains make room.

Soft fists insist on
Heaving the needles,
The leafy bedding,

Even the paving.
Our hammers, our rams,
Earless and eyeless,

Perfectly voiceless,
Widen the crannies,
Shoulder through holes. We

Diet on water,
On crumbs of shadow,
Bland-mannered, asking

Little or nothing.
So many of us!
So many of us!

We are shelves, we are
Tables, we are meek,
We are edible,

Nudgers and shovers
In spite of ourselves.
Our kind multiplies:

We shall by morning
Inherit the earth.
Our foot's in the door.

The Fungus Among Us

FUNGAL FOLKLORE

Mushrooms have been the source of a great deal of superstition, myth, and folklore throughout most of recorded human history, and with good reason. The Kingdom Fungi is host to many strange, biological phenomena such as colour changes of the flesh, poisonous and hallucinogenic qualities, offensive odours, rapid growth, and bioluminescence. The uncanny, rapid, and often overnight emergence of these enigmatic life forms lay behind a long-standing, cross-cultural belief that mushrooms were spawned by the interaction of thunder and lightning. In the Middle Ages, the rapid growth of mushrooms contributed to their being relegated to the realm of the occult. They were seen as the craftsmanship of evil spirits, witches, or the devil, and numerous folktales animated the occurrence of human diseases brought on by eating or touching them. On a more positive note, nearly all European countries attribute magical and spiritual power to mushrooms, and many ancient societies used mushrooms for shamanistic and divination rites.

The suspicious habit of some mushrooms to grow in circles, or "fairy rings", led people to believe these were dangerous places where elves danced, toads met, deer rutted, or the devil set his churn at night. Superstition likely had a hand in naming many mushroom species including Witch's Butter, Witch's Hat, Elfin Saddles, Elfin Cups, Fairy Hair, Fairy Stools, Destroying Angel, Satan's Bolete, and Devil's Urn. Like fairy rings, glow-in-the-dark mushrooms and mycelia (the non-reproductive feeding portion of a fungus) have also been the subject of ancient myth and old wives' tales and often considered to be a potent source of magic.

Nowadays, fungi are deeply connected to fairy folklore as well as modern children's literature and films. Just crack open any book of fairy tales and more likely than not, you will find an illustration of the classic Fly Agaric, *Amanita muscaria*, with its shiny blood-red cap dappled with white spots. Mushrooms also play a significant role in Lewis Carroll's Alice in Wonderland, on top of one of which sits the hookah-smoking caterpillar. The caterpillar advises Alice to eat from one side of the mushroom to grow larger and eat from the other side to become smaller; this is reminiscent of the hallucinogenic effects of *A. muscaria* which can cause a distortion of size perception. As well, bioluminescent mushrooms are featured in Pixar's animated movie A Bug's Life.

FUNGI IN FOOD AND MEDICINE

Shikate, portobello, crimini, oysters, morels, boletes, truffles…these are the names of some fungal friends you might recognize from a recipe, the grocery store, or a fancy high-end gourmet restaurant. Avid mycophagists, or people that eat fungi, will be ready instantaneously to discuss and debate the subtle attributes of the meaty bolete or earthy shiitake. Too often myco-cynics have declared that mushrooms have "no nutritional value" but this is entirely untrue; though they are low in calories, they are a great source of essential vitamins and minerals as well as some protein. The popular oyster mushroom, for example, contains the amino acids lysine and tryptophan (which are absent in grains) as well as nicotinic acid, riboflavin, pantothenic acid and vitamins B, C and K. With the increasing popularity of vegetarianism, the food industry is looking to mushrooms to make "meatless" vegetarian products using mycoproteins.

Aside from seeing a mushroom on your plate, there are many more subtle ways the Kingdom Fungi finds its way into our stomachs. The use of yeasts was first documented in 6000 BC with their primary uses being the formation of alcoholic beverages and the leavening of breads. The mold *Aspergillus niger* is used to produce citric acid by fermenting sugar. Citric acid is an extremely popular food additive and preservative and is commonly found in soft drinks. Though made famous by its antibacterial properties, *Penicillium* species also contribute to food production; *P. camemberti* is used in making Brie and Camembert cheeses (the mycelium is still strongly evident as the rind of these cheeses!), and *P. roqueforti* colours and flavours Roquefort and Danish blue cheese.

Before the discovery of penicillin in 1928 by Scottish scientist Alexander Fleming, an infection from a scratch might lead to amputation of a limb of even death. Besides the well known penicillin, a whole host of antibiotics are of fungal origin. Other fungal compounds such as Cyclosporine function as immunosuppressants for organ transplants; regulators of immune system activity; and cholesterol lowering agents.

Though there is a growing trend towards a more widespread use of mushrooms in the western nutraceutical industry, fungi have been central in Chinese pharmacopeia for centuries. The Shiitake mushroom contains lentinan which is an antiviral and antitumour agent; the reishi mushroom boosts immune system, slows tumour growth, improves circulation and heart function, and aids digestion. Many North American species such as the honey mushroom, maitake, and Tuckahoe have been shown to have an effect on cancers and hepatitis. Traditionally, the dried powder of old puffballs has been used as an astringent by First Nations people.

FUNGI AS PESTS

Sadly, fungi are more known throughout history for their bad deeds than for their good. In addition to being responsible for famine and emigration as in the Irish potato blight, fungi have also led to the hanging of innocent people during the Salem witch trials. Ergotism is a term used to describe poisoning caused by the *Claviceps purpurea* fungus which typically grows on rye grain. There are two types of ergotism: the first results in gangrene and loss of limbs and the second causes convulsions and hallucinations. During the Salem witch trials of 1692, two girls fell ill and began to accuse the townsfolk of bewitching them. As a result, 250 innocent people were arrested and 19 hanged. The most likely explanation of their "bewitching", however, was ergotism caused by eating bad bread. Ergotism made many earlier appearances in history during the Middle Ages as St. Anthony's Fire. Victims would claim that their limbs were "burning" which was due to ergot's vasoconstrictive properties and inadequate blood flow. Nowadays, what was once foe, has become friend; ergotamine

is now marketed under names of Cafergot, Ergate, Migril to treat migraines and has also been used to lessen chance of hemorrhage after childbirth.

Each year rusts and smuts are responsible for approximately 13% loss of crops, specifically wheat, oats, corn, rye, beets, pears, peas and cherries as well as damage to hemlocks, pines, coffee trees and fig trees. These fungi damage the leaves of their hosts, causing the plant to lose water and decreasing their food generating potential. Powdery mildew can also be found as parasites on leaves of flowering plants such as apple trees, pumpkins and rose and lilac bushes.

Another fungus is currently receiving a lot of bad press, that is the species responsible for Dutch elm disease which is a insect transmitted disease that is leaving once tree-canopied city streets as barren as the arctic. How does this happen? Well, beetles carrying sticky spores of the fungus *Ophiostoma* bore into the wood of an American elm tree. The tree reacts to the presence of the fungus by plugging its own water transportation system, which leads to wilting and finally the death of the whole tree. In the process, the fungus breaks down the wood thereby making it more nutritious for the beetles and grubs that also feed on the fungus. Measures can be taken to stop Dutch elm disease. The transportation of infected firewood is a likely way for the disease to spread, so making sure elm firewood is not transported or stored is a good start. Once a tree has contracted the disease, treatment methods can be very expensive and usually only have temporary results. Alberta hosts a group called STOPDED (the Society to Prevent Dutch Elm Disease) that promotes awareness of Dutch elm disease.

Unfortunately, the wrath of fungi does not end here. Fungi cause more than a hundred diseases or mycoses in humans. These range from the generally innocuous athlete's foot, to candidiasis (yeast infections and thrush), to respiratory diseases and systemic infections. The mould *Aspergillus* produces aflatoxins which contaminate food, cause liver damage and are the most potent carcinogens known. As well, both home owners and ship owners will readily shake their fists at the dry rot fungi that bring great destruction to wood structures.

FUNGI AND POLLUTION

In recent years, there has been a noticeable decrease in the number of both edible and poisonous mushrooms growing in European forests as well as a drop in the size of the mushrooms that are growing. Of the fungi listed on the Red data lists of threatened and endangered species, 1/3 are mycorrhizal. The reason behind this is not yet concrete, but the number one suspect is air pollution from factories, farms, and automobiles; there is a correlation between increased levels of sulphur oxides, nitrogen oxides and other air pollutants and a decrease in mushroom populations (both number of fruiting bodies and diversity of species). It is unknown whether or not this phenomenon is also occurring in North America as records haven't been kept here for as long as in Europe. This decline may actually be harming forests as trees may lose their mycorrhizal partners and, as a result, age and die more quickly. An additional factor to consider in forest health is that larger fungi can accumulate heavy metals in their mycelia, thereby concentrating toxic material in upper soil layers where it may damage trees and other plants, and of course, any animals along the food chain that ingest the fruiting bodies.

LICHENS AND RADIATION

Lichens are sponges of radioactive materials that come to them from the atmosphere, and cause effects all through the food chain. In 1965 a study was launched to examine the effects of radioactive fallout from nuclear bomb tests. The scientists were expecting to use the Sami people as a control group due to their isolated location, but the results showed that the Sami people's tissues had 55X more radioactivity than the Finns living further south and up to 1/3 of the maximum permissible radioactivity according to the standards of the time. It was found that radioactive cesium and strontium were concentrated by lichens then eaten by reindeer which were then eaten by people. Similarly, after the Chernobyl disaster in 1986, meat from reindeer in Norway and Sweden had 10X the legal limit of measurable radiation and in some areas it exceeded the limit by 20X. The rate of lichen growth is also highly dependent on the condition of the air; where the air is polluted, they will grow very slowly, if at all.

Although valuable indicators of ecological health, lichens are also of economic importance to humans. Half of all lichen species tested show some antibiotic activity and some other lichen extracts have been shown to reduce tumours in mice. The lichen *Usnea*, recognizable as Old-man's Beard and commonly found hanging from tree branches, has been used medicinally for at least 1000 years. The active compound in this lichen is usnic acid, a potent antiobiotic and antifungal agent that is now marketed under the name Usno. Extracts of *Usnea* are also widely used in the perfume and fragrance industry. Lichens have also been used through the centuries as a dyeing agent.

CONSERVATION

The world is losing its biological richness. As a result of human activities, species of living organisms are being driven irretrievably into extinction every day. Changes in land management worldwide are cited as the biggest factor in the decrease of diversity of fungi. Many fungi are host specific and localized, therefore loss of a host is paramount. Clearly there are challenges to fungal conservation—specifically the fact that they are generally hidden underground and therefore we are dependent on the presence or absence of fruiting bodies for population assessments. In conservation efforts, we must take into account relationships between flora, fauna, and fungi with the understanding that everything in the natural world is inextricably connected. It is vital to maintain the integrity of all members of the ecosystem to sustain the health of the forest and ultimately, the Earth.

Fungal Folklore and Beyond

Activity 4.1

OBJECTIVE
- To stimulate interest in fungi through student-specific exploratory activities

BACKGROUND INFO
There isn't a fairytale-loving child who is not familiar with the bright red cap and dappled scales of the classic *Amanita muscaria*, the fly agaric mushroom. Anyone ever so fortunate as to meet this most spectacular mushroom in its natural habitat will immediately understand why so much folklore surrounds the Fungi--this mushroom is simply too beautiful and too mysterious to be of this earth--and this is just the beginning! Some fungi, like the Jack o' Lantern and the mycelia of the honey mushroom, glow in the dark! Coral mushrooms look like they were taken directly from the ocean and dropped in the forest. The basket stinkhorn is decorated in a gown of the finest lace and an Octopus Stinkhorn could easily be mistaken for a large, neon spider!

Folkore and mythology are typically traditional stories and legends that are transmitted orally from generation to generation. Such stories are often born from attempts to explain natural phenomena like the northern lights, unusual physical characteristics of animals (like a beaver's flat tail), and of course, mushrooms.

In this activity, students will be introduced to some of the mythology surrounding mushrooms throughout the ages. Using these tales as a springboard, students explore the world of mushrooms through whatever creative medium they find appealing--be it poetry, drama/skits, or art.

TEACHER INSTRUCTIONS
1. Explain to your students that fungi have long been thought to be mysterious and magical. It wasn't until very recently that people understood what mushrooms are and where they come from. Ask your students if they are aware of any folklore/myths about mushrooms (like the origin of fairy rings) and then share some fungal folkore from the next page with your students.
2. Refer to the activity suggestions on page 63 to help guide students through their own explorations into fungi and folklore.
3. You may wish to set aside an area of the classroom to display all of your students' wonderfully mushroomy creations.

GRADES
3-6

TYPE OF ACTIVITY
Teacher read and student-led activities

MATERIALS
- assortment of fairytale books containing mushrooms (esp Brian Froud books) or access to a library with a supply of fairy tale books
- mushroom picture books or field guides with good plates (eg.Arora's Mushrooms Demystified),
- art supplies for painting and drawing
- clay/playdoh
- props for skits
- copies of "What's in a Name" chart on page 63 for each student or an overhead of the chart

SOURCE
Text adapted from FAIRY RINGS AND FUNGAL SUPERSTITIONS http://www.virtualmuseum.ca/~mushroom/English/Folklore/fairy.html#

ON ORIGINS

- The sudden and rapid eruption of mushrooms from the soil led people to believe that dark or terrible forces were at work. Lightning strikes, meteorites, shooting stars, earthly vapours, and witches have all been proposed as agents of their origin.
- In parts of Africa, mushrooms were sometimes regarded as souls of the dead or as symbols of the human soul.
- In Silesia, morel mushrooms were once believed to be the work of the Devil.
- In parts of Central America, a children's tale relates that mushrooms are little umbrellas carried by woodland spirits to shelter them from the rain; the spirits leave the mushrooms behind at dawn when it is time to return to their underground world.

ON FANTASTICAL FAIRY RINGS

- In France, fairy rings were called sorcerers' rings and in Austria, witches' rings.
- A Tyrolean legend claims that the rings were burned into the ground by the fiery tail of a dragon.
- In Holland, they were said to mark where the Devil rested his milk churn.
- In England, they were considered places where fairies came to dance. The mushrooms around the perimeter of the ring were seats where the sprites could rest after their exertions. People in rural England claimed to have seen fairies dancing at fairy rings as recently as a hundred years ago.
- One common theme in all these traditions is the belief that dire consequences await anyone foolhardy enough to enter a fairy ring. Trespassers would be struck blind or lame, or even disappear to become slaves in the fairies' underground realm.
- Occasionally fairy rings were said to bring good luck to houses built in fields where they occur.
- In Wales, it was also widely believed that if animals grazed within a fairy ring, their milk would putrefy.
- In another tradition, the rings were sites of buried treasure, but there was a catch—the treasure could only be retrieved with the help of fairies or witches.
- If a maiden washed her face with dew of the grass from inside a ring, the fairies would spoil her complexion.

ON THE NOTORIOUS *AMANITA MUSCARIA*: THE FLY AGARIC

- Even Santa Claus has been linked to fungi. One anthropologist has suggested that his red and white outfit symbolizes Fly Agaric. Siberian shamans were known to consume this mushroom, and Santa's use of the chimney is similar to a shaman custom of leaving a dwelling through its smoke hole during a festival.
- According to the Norse, Odin and his attendants were riding across the sky on their horses when suddenly they began to be pursued by demons. In order to escape these demons, they had to ride their horses very hard. As a result, the horses began to foam at the mouth and bleed. The blood and foam mixed and wherever it struck the ground, a red fly-agaric with white spots sprang up.
- Koryak Siberians have a story about the fly agaric which enabled Big Raven to carry a whale to its home. In the story, the deity Vahiyinin ("Existence") spat onto earth, and his spittle became the wapaq, and his saliva becomes the warts. After experiencing the power of the wapaq, Raven was so exhilarated that he told it to grow forever on earth so his children, the people, can learn from it.
- Some pop culture uses of the mushroom are in the video game series Super Mario Bros. and the dancing mushroom sequence in the 1940 Disney film *Fantasia*.

WHAT'S IN A NAME?

Of all the living things that have been identified, classified, and named, fungi have received the bear's share of odd ones. Listed below are some of the common names given to mushrooms. These names alone are rich sources of inspiration for young artists exploring "all things mushroomy".

Yuck on a Stick	**Witches' Butter**	**Dryad's Saddle**	**Fuzzy Foot**	**Dead Man's Fingers**
Bleeding Mycena	**Train Wrecker**	**Destroying Angel**	**Fried Chicken**	**Angel's wings**
Tree Ears	**Parrot Mushroom**	**Laughing Mushroom**	**Old Man of the Woods**	**The Blusher**
Pinwheel	**Slippery Jack**	**Horse Mushroom**	**Liberty Cap**	**Cannon Ball**
Inky Cap	**Sweating Mushroom**	**Apricot Jelly**	**Hen of the Woods**	**Poison Pie**
The Gypsy	**The Prince**	**Turkey Tail**	**Orange Peel**	**Jack-O-Lantern**

ACTIVITY SUGGESTIONS

For the writers...

Pass out copies of the "What's in a Name" table and have students write their own mythologies about one of these oddly named fungi.

For the pen and brush artists...

Encourage students who like to draw or paint to create an illustration of one of the mushrooms listed above.

For the hands on artists...

Students who like to make things with their hands could invent their own mushroom and mold it out of clay or playdoh. After seeing the colour plates in a book like Mushrooms Demystified, they will know that the sky is the limit! Have them name their mushroom and share it with the class.

For the actors...

Students interested in acting could perform a 5-minute skit demonstrating one of the mythologies you shared with the class, or they may act out their own mythology.

For the researchers...

Send book-loving students to the library and have them hunt down pictures of mushrooms in fairy tale books. Have older students document where they found the mushrooms (both in context and bibliographical).

Guess the Guest of Honour

Activity 4.2

GRADES
3-6

TYPE OF ACTIVITY
Word search

MATERIALS
- copies of page 65
- pencils

VOCABULARY
antibiotics
bioremediation
Dutch elm disease
potato blight
lichen
mildew
mould
mycorrhizas

OBJECTIVE
- To increase awareness in students of the prevalence of fungi and fungal products in all areas of our lives

BACKGROUND INFORMATION
Fungi have been called the "hidden kingdom" because most of their body is hidden underground. However, fungi are also "hidden" in many everyday products from soy sauce to soda pop. Each of the words hidden in the word search is an example of some of the fungus among us.

TEACHER INSTRUCTIONS
1. Hand out copies of page 65.
2. Review the instructions with the students. They are to circle each LETTER of the words they find in the word search. For example,

   (S) (P) (O) (R) (E)

3. Starting in the top left hand corner, write the remaining letters in the square boxes provided below to reveal a secret message.
4. Good luck to everyone!

GUESS THE GUEST OF HONOUR ANSWER KEY

Secret message:
SOME ARE SMALL,
SOME HUMONGOUS!
LET'S DISCOVER THE
FUNGUS AMONG US!

Guess the Guest of Honour

4.2

Directions

Circle each individual letter of the words in the word search. Then, starting in the top left hand corner, enter the unused letters into the blanks below to reveal the secret message. Good luck!

Allergies
Antibiotics
Athlete's foot
Bioremediation
Cheese
Dyes
Compost
Dutch elm disease
Fairy tales
Potato blight
Lichens
Mildew
Mould
Mycorrhizas
Perfumes
Pizza
Puffball
Ringworm
Soda pop
Soy sauce

E	A	S	E	M	U	F	R	E	P	S	L	A	S	O
C	S	N	M	E	A	Z	Z	I	P	O	I	T	A	S
R	O	A	T	P	E	S	M	A	L	Y	C	H	L	E
S	O	M	E	I	O	M	E	H	U	S	H	L	M	I
O	N	G	P	S	B	P	O	U	S	A	E	E	L	G
D	Y	E	S	O	I	I	A	E	T	U	N	T	S	R
D	I	S	C	O	S	D	O	D	V	C	S	E	E	E
E	S	E	E	H	C	T	M	T	O	E	R	S	T	L
P	U	F	F	B	A	L	L	L	I	S	H	F	E	L
M	R	O	W	G	N	I	R	F	E	C	U	O	N	A
W	E	D	L	I	M	G	U	S	A	H	S	O	M	M
S	A	Z	I	H	R	R	O	C	Y	M	C	T	O	O
T	H	G	I	L	B	O	T	A	T	O	P	T	N	U
F	A	I	R	Y	T	A	L	E	S	G	U	S	U	L
N	O	I	T	A	I	D	E	M	E	R	O	I	B	D

Secret Message:

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_ _ _ _ _ _   _ _ _ _ _ _   _ _!

Hurray for Foray

Activity 4.3

GRADES
K-6

TYPE OF ACTIVITY
mushroom hunt

MATERIALS
See text body

VOCABULARY
foray
mycorrhizas
symbiosis
decomposition
nutrient cycling

OBJECTIVE
- To introduce students to mushroom hunting

BACKGROUND INFORMATION
In many countries around the world, mushroom hunting is considered a national pastime. Some people hunt mushrooms for their edibility, others for their medicinal properties, and some for pure entertainment! A mushroom hunt, or **foray**, is a fantastic way to help kids connect with the natural world around them. The great thing about fungi is that they are literally everywhere! You don't need to arrange a complicated field trip to a forest to find mushrooms. There is a very good chance you can find them in your schoolyard or on your front lawn! A guided foray is a sure way to illustrate the ecological concepts already touched on in this guide: find a mushroom growing near a tree, and talk about **mycorrhizas**; discover some lichen on a rock and explain **symbiosis**; unearth some rotting leaves and converse about **decomposition** and **nutrient cycling**. There is a fantastical fungal world just waiting to be found!

PART 1: PREP DAY

MATERIALS
- an assortment of mushroom field guides and/or posters
- copies of pages 74 to 82 for each student
- a few types of mushrooms from the grocery store i.e., field mushrooms, shiitakes, wood ears, Chinese white fungus (Tremella), enoki, oyster mushrooms, chanterelles, morels
- rulers
- "Fungus Fred goes Foraying" by Maggie Hadley (optional).--see Suggested Resources and Sources page 91

TEACHER INSTRUCTIONS
1. Collect an assortment of mushroom field guides from a local library. If you can find posters of mushrooms (like the ones for sale at www.fungiperfecti.com), this would be very helpful too. It would be beneficial at this time to have students assemble their Field of Fungi mini field guide from page 73.
2. In preparation for the foray, bring some domestic mushrooms to look at together as a class. Use these specimens to point out physical characteristics that will be useful in identifying wild specimens.

3. Review the basic parts of the mushroom: cap, gills/spines/pores, scales, stem, ring, cup and mycelium. Depending on the mushrooms you were able to acquire, discuss the presence or absence of these features. Please note that it is extremely unlikely you will find domestic mushrooms with mycelia intact. Note however that the *entire* mushroom is made up of tightly packed hyphae.
4. Encourage students to take a closer look at the mushrooms. Use the following questions to guide your investigations:

CAP
- What colour is it?
- Is it smooth, sticky or scaly?
- What is underneath the cap: gills? pores? spines? or none of the above?

STEM:
- How long is it?
- How wide?
- Is it smooth or rough?
- What colour is it?
- Is it hollow inside?
- Does the mushroom have a cup on the bottom?

IDENTIFICATION
- What group is it from? You may wish to use the Key to The Fungal Treasure on page 26 to help answer this question.
- What colour is the spore print?
- Can you find a picture of it in a field guide?
- What is it called?
- Where was it growing (if a wild specimen)? In a woodland? grassland? near or under a plant? on wood? in soil? on manure?

5. Try to get a spore print from a fresh mushroom (see part 3 of this activity) to give students a chance to familiarize themselves with the technique.
6. Take the time to discuss edibility of mushrooms. Let students know that even though the mushrooms they have examined today were edible, they must never ever eat any wild mushroom that has not been identified by an expert as being safe. Although only a few mushrooms are deadly, many will cause hallucinations, nausea, vomiting and diarrhea, and liver or kidney failure. It is never worth the risk of getting sick!
7. Ask students if they know what old wives' tales are. Do they know any? Review some of the common tales about mushrooms and explain that they are false. Some examples are: deadly ones will darken silver; if it peels it is good to eat; if animals eat them, so can humans. There is NO SIMPLE TEST to assess the edibility of a mushroom.
8. You could share (and explain!) a little riddle/joke from Terry Prachett with your students about poisonous mushrooms:
    1. All fungi are edible
    2.Some fungi are not edible more than once"
9. As a class, you may with to read the story book Fungus Fred goes Foraying by Maggie Hadley.

PART 2: THE HUNT

MATERIALS

- wax paper or bags for collected mushrooms (never use plastic bags as they accelerate decomposition of the specimens)
- trowel or knife to dig mushrooms from the ground
- permanent markers
- plastic cups
- sandwich bags (for lichen collection)
- digital camera
- magnifying glass or hand lens for each group
- notepad
- pencils
- rulers
- copies of data cards from the field guide page 82

TEACHER INSTRUCTIONS

1. Assemble a foray kit ahead of time so you will be prepared when the weather is suitable (ideally that means a warm day just after a rain).
2. Ask your students where they think a good place to look for mushrooms will be. All answers will be right as mushrooms can grow virtually anywhere--including under concrete. Some good places to begin the hunt are in shady spots, wooded areas, decaying leaves, damp rotting wood, or dead trees. However, you can also find them on lawns and flower beds, sidewalks, parking strips, manure and sawdust piles, stumps, trees, shrubs; pasture, barnyard for meadow mushrooms and dung loving species; forest or woodlot areas...virtually anywhere!
3. Remind students never to put their hands in their mouth after handling wild mushrooms.
4. There is a good chance you will encounter puffballs, shaggy mane mushrooms (which have very varied diets), and little brown mushrooms.
5. You may have students hunt in pairs or small groups, or you may prefer to stay together as a class; do what works for your group to maximize the "hands-on" component.
6. When students spot a mushroom, have them sketch the basic structure on one of the "data sheets" from their field guide. Also have them measure the mushroom and take note of its habitat before collecting it. Was it from a grassy area? Were there trees nearby? Was it growing in woodchips? Explain that the habitat is like the mushroom's home address and this will help with identification later on.
7. When collecting mushrooms, dig up some of the surrounding soil rather than just breaking the stem, and collect only big, distinctive, colourful types. Digging up soil will help keep identifying features intact. Talk again about the difference between plants and fungi; picking a mushroom is like picking a fruit but pulling a plant or flower up by the roots will kill the whole plant. Use a shallow basket to collect, and wrap in waxed paper to separate and protect it or put the mushroom into a plastic cup. Take a few a mushrooms back to the classroom for spore printing, closer examination and identification.
8. While collecting mushrooms, have students note the habitat they are collecting from and label the specimen accordingly. It would be beneficial to photograph the mushrooms in their natural habitat as well. It can be tricky to remember habitat once back in the classroom.

9. You might look for **lichens** on boulders, grave stones, or on tree bark. Remind the students that lichens are easily harmed by pollution, so they may not be found in areas with high pollution. To collect a lichen, break off a SMALL piece of bark, and put it in a sandwich bag and label. You can view it under a hand lens.
10. Point out the ecology of the mushrooms you find. Are there mushrooms near decaying leaves? These mushrooms are **decomposing**! Are there mushrooms growing close to a tree? These could very likely be **mycorrhizal** mushrooms. Talk about mycorrhizas. Guide the students into explaining the relationship. Review the term **mycelium**; if you're observing a mushroom, this is just the tip of the mycelial iceberg! This is why fungi are called the "hidden kingdom".
11. Highlight some fungal trivia throughout the foray. For example:
    - puffball spores were used by First Nations people to stop bleeding
    - the Iceman Otze was found with bracket fungus on him
    - bracket fungi can be used to start fires or as an artist's canvas
    - fairy rings are a source of a great amount of folklore
    - shaggy mane mushrooms disperse their spores by "melting"
    - stinkhorns 'use' flies to distribute their spores
    - the mycelium of a honey mushroom is thought to be the largest organism on earth and it glows in the dark!
12. Remember, though these instructions may seem complicated, this foray is meant simply as an introduction to mushroom hunting and should remain fun at all times! Do not get caught up in details. Flow with the rhythm of the class and explore with the intention of fostering an interest in ecology and the natural world.

PART 3: THE DEMYSTIFYING

MATERIALS

Identification

- assortment of field guides specific to the local area. A superb example of a field guide with lots of colour plates and a fun attitude is David Arora's All That the Rain Promises and More.
- mini field guide from page 73
- a dissecting microscope (optional)
- pencil crayons

Spore Printing

- knife
- a black and a white piece of paper
- a glass
- pencils
- fixative spray

TEACHER INSTRUCTIONS

1. With a little luck you will return from your foray with a plethora of fungal friends! Now you and your students can begin solving the mystery of who's who.

2. Refer students to their data cards and their specimens. Have the students "fill in any blanks" they did not fill in before. Now that you are back in the classroom, encourage them to colour their sketches to match the mushrooms.
3. To begin, have the students decide which group their mushrooms belong to. Guide them through the identifying features such as the reproductive structures under the cap (gills, pores or spines?).
4. Set a few mushrooms aside to be spore printed. Choose a few mature, undamaged, even-shaped caps with gills.
5. Get to know your mushrooms! Smell them, touch them, and talk about them. How are they similar or different to the store-bought varieties? What would be a good name for them if you were going to name them yourself and why?
6. Direct your students to the field guides. Once they have decided on the group they think the mushroom(s) belong to, have them try to find it in a field guide. Draw attention to the presence of both Latin and English names for each mushroom. Inform them that the Latin name is a universal code that is understood all around the world. This way mushroom hunters from Japan to Russia to Canada can all speak the same language when referring to a mushroom they've found. The Latin name is backwards from their own name in that their 'family's name' is written first (*Genus*) and their individual name second (*species*).
7. Do not get stuck on the details of accurate identification. This is an exercise in familiarization with field guides, and and not intended to be a class in taxonomy. Unless some very obvious species are found (like puffballs and shaggy manes), it is likely you will have a basket full of little brown mushrooms. Tell students that identifying these mushrooms can be tricky even for mushroom experts!
8. Explain that there is one technique that can be helpful in identifying plain looking mushrooms--spore printing; like a fingerprint, a spore print can reveal the secret of a mushroom's identity. Remind students that spores are similar to seeds with one major difference. What is it? Spores are a single cell and don't 'pack a lunch'; they need to land on a direct food source to germinate.
9. Lead the class through spore printing:

Spore Printing

1. Cut the stem very close to the cap.
2. Place the cap gill-side down on a piece of paper that is black on one half and white on the other.
3. Now place a bowl or glass jar over the cap to protect it from disturbance.
4. Leave the cap for 2 hours or more.
5. Carefully remove the bowl and cap and take a look at the print left behind.
6. Spray with clear fixative to preserve the print.
7. What colour is the print? Did spores show up on the dark side or the light side or both?

DISCUSSION

1. Try and get some feedback about the foray. Did students enjoy the mushroom hunt? What did they learn about where mushrooms like to grow?
2. What else would they like to learn about mushrooms? As a class you could compile a list of questions and direct them to a local mycological club. The contact information for organizations affliliated with NAMA are listed on the following page.

Canadian Mycological Societies Contact List

Keep in mind that the co-coordinators for these programs are volunteering their own time. Please, give them time to respond to your inquiries.

BRITISH COLUMBIA

Vancouver Mycological Society
#101-1001 W Broadway Box 181
Vancouver, BC V6H 4E4

www.vanmyco.com

The Vancouver Mycological Society is an amateur organization devoted to the study of mushrooms. Meetings are held on the first Tuesday of each month (except - December, January, July and August). Meetings are at the Van Dusen Botanical Gardens - Classroom, Oak and 37th Avenue, 7:30 p.m.. Call their mushroom hotline (604) 878-9978 for more information on VMS forays, field trips, meeting programs and events.

South Vancouver Island Mycological Society
2552 Beaufort Rd.
Sidney, BC, Canada V9L 2J9

www.svims.ca

SVIMS is a small society interested in all aspects of mycology and mushroom appreciation. Its members include professional mycologists, mushroom growers, mushroom pickers, cooks, photographers, and other enthusiasts. Meetings are held at 7:00 p.m. on the 1st Thursday of Feb.-June and Sept.-Nov., at the Pacific Forestry Centre, 506 Burnside Road West, Victoria, B.C.

SVIMS members produce a great newsletter which is available for viewing at their website.

Fraser Valley Mushroom Club
c/o Othmar Kagi
32522 Best Avenue
Mission, British Columbia, V2V 2S6

www.fvmushroomclub.ca

EMail: info [at] fvmushroomclub.ca
Contact: Othmar Kagi

Sunshine Coast Shroom
5027 Bear Bay Road
Garden Bay, British Columbia V0N 1S1

www.scshroom.org
EMail: info [at] scshroom.org
Contact: Ann Harmer,
Shroomworks [at] bluffhollow.ca

ALBERTA

Alberta Mycological Society
#1921-10405 Jasper Avenue
Edmonton, AB T5J 3S2

www.wildmushrooms.ws

The AMS meets on the the 4th Wednesday of the month at 7:00 pm at the Riverbend Library located at the strip mall at Rabbit Hill Road and Terwillegar Drive. Members will receive 4 newsletters during the year with interesting articles, foray information and maps. There is also the opportunity to exchange yarns and ideas with other members with similar interests.

ONTARIO

Mycological Society of Toronto
2106-812 Birnhamthorpe Rd.
Toronto, ON M9C 4W1

www.myctor.org
Contact: Michael Warnock

This is mostly a group of amateurs supported by a number of active or retired professional mycologists eager to collect, study and identify fungi, particularly the larger mushrooms. The Society encourages activities that explore the ecological role of fungi, and support the conservation of wild mushrooms. They organize five informative meetings a year for their members. These are held at the Civic Garden Centre in Toronto. Guest speakers are invited to give presentations on various topics associated with the field of mycology. The annual Cain Foray usually takes place on the third weekend of September in the Haliburton area. After the fungi are gathered and identified, they are displayed at the "Fungi Fair" held at the Civic Garden Centre (Lawrence and Leslie) on the Monday following that weekend.

QUEBEC

Cercle des Mycologues de Montréal
4101 Rue Sherbrooke Est
Montréal, QC H1X 2B2
www.mycomontreal.qc.ca

The CMM is based in Montréal, QC. The members are French-speaking, or bilingual, French-English. All the literature is in French.

NORTH AMERICA

North American Mycological Association
Rebecca Rader, Executive Secretary
PO Box 64
Christiansburg, VA 24068-0064

www.namyco.org
Contact: Sandy Sheine, Education Committee
EMail:rebeccahrader@hotmail.com

NAMA, the North American Mycological Association, is a non-profit organization of amateur and professional mycologists with more than 60 affiliated local mycological clubs throughout North America. NAMA's mission is "to promote, pursue, and advance the science of mycology."

Fields of Fungi Mini Field Guide

OBJECTIVE
- To familiarize students with the major groups of fungi

BACKGROUND INFORMATION
Field guides are essential tools to any naturalist interested in identifying local species. They generally provide information about the distribution, **habitat**, distinguishing features, common and scientific names, and size of species. Exposing students to field guides will show them the diversity of fungi and the colour plates may spark an interest to "get to know" some of their local fungal friends.

TEACHER INSTRUCTIONS
1. Make single-sided copies of pages 74-82 for each student.
2. Talk to your students about the value of field guides to the scientist and naturalist.
3. Tell them they are going to make their own field guides then hand out the pages and have the students cut them out. Fold the page in half so that the mushroom is on one side and the text is on the other. Stack the pages according to page number.
4. Using a heavy duty stapler, staple the guide together with 2 staples on the top seam.
5. The distinguishing features of many of the fungi in this mini guide have been highlighted. Using a combination of posters, an assortment of field guides and the text provided next to the drawings, have the students colour in the drawings of the fungi. Remind them that there can be a great deal of variation in colour from mushroom to mushroom, even withing the same species, so there is no right or wrong way to colour.
6. Ask them which fungi they are already familiar with and where they may have seen these mushrooms. Remind them that the place where mushrooms grow is called their **habitat**.
7. Take notice that some of the information provided in the field guide would be useful to help answer questions raised through activities in the educator's guide, and you may wish to encourage your students to use their field guides for this purpose.
8. Recommend your students take the field guides with them if they go on a foray.

EXTENSIONS
1. Have students choose a group and then research some of the species in the group and then present some interesting facts to the class.

Activity 4.4

GRADES
3-6

TYPE OF ACTIVITY
Colouring and Assembly of a Mini Field Guide

MATERIALS
- copies of pages 74-82
- scissors
- pencil crayons, crayons or markers
- assortment of field guides for mushrooms of North America (see sources)
- heavy duty stapler
- mushroom posters (optional)

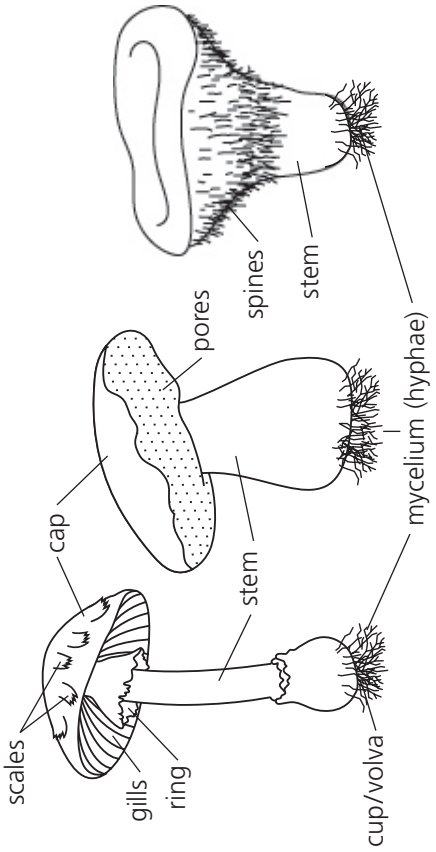
VOCABULARY
habitat

Fields of Fungi

MINI FIELD GUIDE

GILLS, PORES, OR TEETH?

A review of shroomy terminology



The Golden Rules of Mushroom Hunting

1. **NEVER** eat a fungus unless you are absolutely sure that it is safe. Get help from an expert and...

   IF IN DOUBT, DON'T EAT IT!

   There's no quick and easy test to show if a mushroom is poisonous.

2. **ALWAYS** wash your hands after touching fungi.
3. **NEVER** go onto someone's property without getting permission first.
4. Watch out for **POISON IVY.** Remember, leaves be three, let it be - or it could ruin your day.

Agarics "The Gilled"

WHAT DO THEY LOOK LIKE?

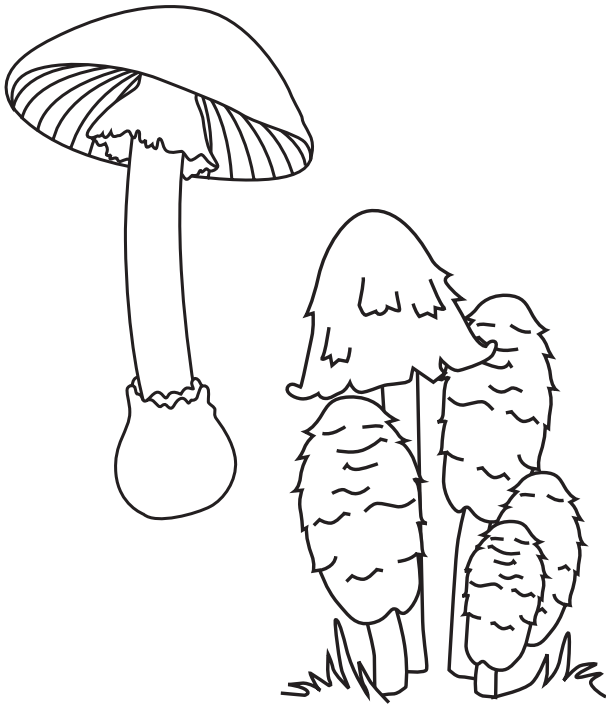
They have a **cap** and **stem** with **gills** underneath the cap.

WHERE ARE THEY FOUND?

Anywhere and everywhere!

FUN FACTS

- Most commonly thought of as "mushrooms"
- 4000 species
- Found on all continents except Antarctica
- The deadly Destroying Angel mushroom is from this group as is the glow-in-the-dark Jack o' Lantern mushroom!
- A single mushroom may produce as many as 10,000 million spores!



Shaggy Mane

Boletes "The Pored"

WHAT DO THEY LOOK LIKE?

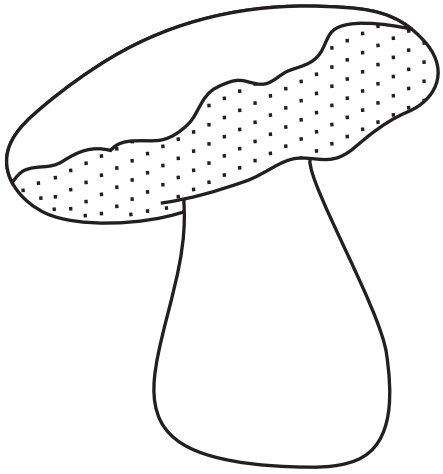
They have a **cap** and **stem** with **pores** underneath the cap; these mushrooms look "spongy".

WHERE ARE THEY FOUND?

These mushrooms are usually found growing on the ground but sometimes grow on wood. They are also **mycorrhizal;** see if you can find the tree they are partners with.

FUN FACTS

- One bolete called the Devil's Bolete, turns from a creamy colour to bright sky-blue if you cut its flesh. The man who discovered this mushroom said that after he had smelled it, he was sick for days, so he thought it must have been created by the devil.



Chanterelles

WHAT DO THEY LOOK LIKE?

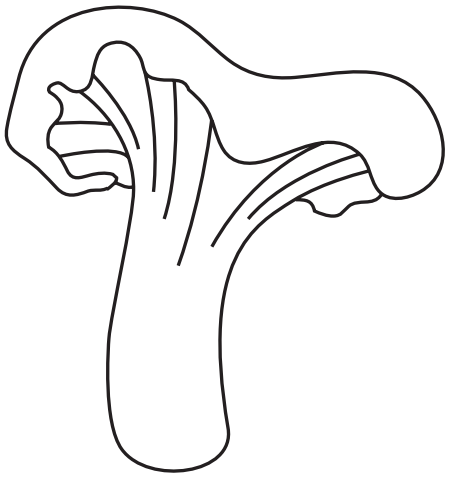
These mushrooms are vase or trumpet-shaped with **ridges** that start under the **cap** and go down the **stem.**

WHERE ARE THEY FOUND?

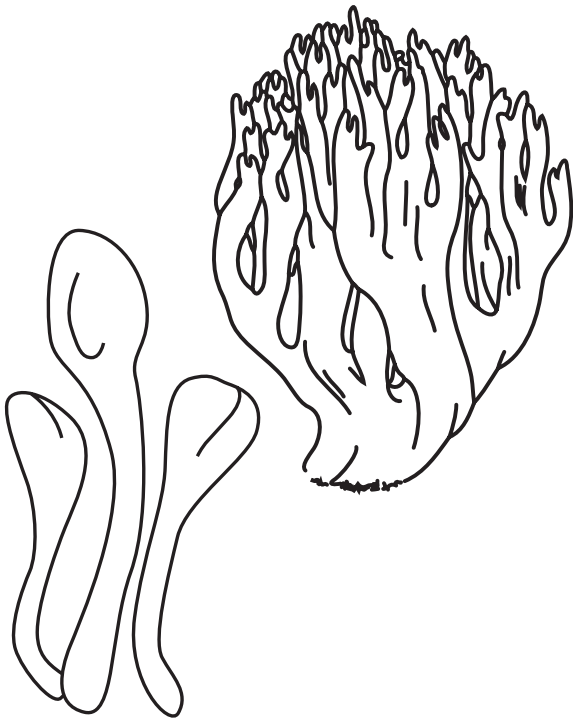
These mushrooms are also **mycorrhizal;** see if you can find the tree they are partners with.

FUN FACTS

- The chanterelle is prized for its wonderful smell, which most people describe as "fruity and like apricots."
- Some people even make a chanterelle sorbet as a dessert!



Coral fungi



Club fungi

Club & Coral Fungi

WHAT DO THEY LOOK LIKE?

Coral fungi are usually branched and really do look like marine coral! They can be white, yellow, orange, red, purple, or tan.
Club fungi are finger-like or club-shaped and can be almost any colour as well.

WHERE ARE THEY FOUND?

They are found on the forest floor, on twigs, or on well decayed logs.

FUN FACTS

- Some coral fungi can be up to 20kg in weight.

Teeth Fungi

WHAT DO THEY LOOK LIKE?

These fungi have a **cap** and **stem** with "teeth" or **spines** that hang like icicles.

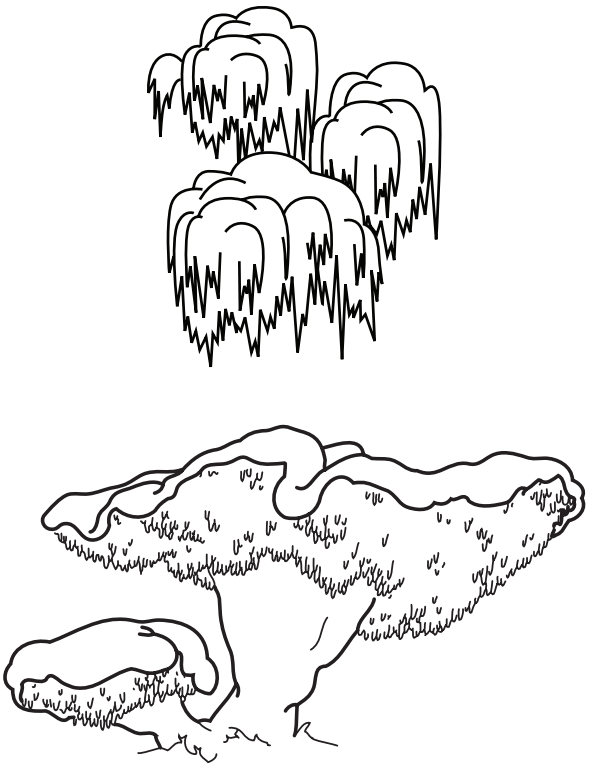
WHERE ARE THEY FOUND?

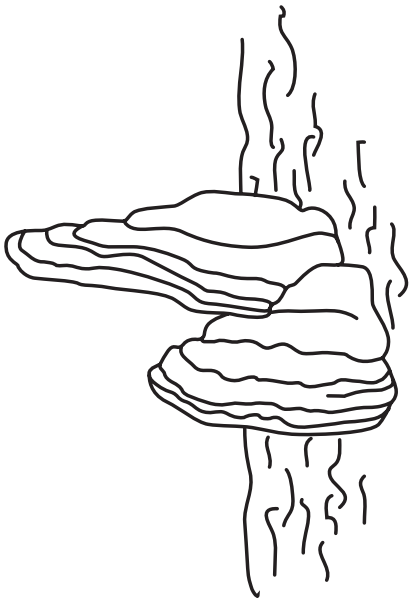
Teeth fungi can grow either on wood or on the ground.

FUN FACTS

- Some teeth fungi are edible and can be found for sale in Chinese markets.
- Some of these mushrooms are used for natural dyes.
- The branching teeth fungi can look like coral fungi but they hang down (like stalactites) whereas the coral fungi grow up (like stalagmites).

Hanging tooth fungi





Polypores

WHAT DO THEY LOOK LIKE?

Also called **bracket fungi,** they have **pores** on their underside but no cap or stem like the boletes and are tough (like leather or wood).

WHERE ARE THEY FOUND?

These mushrooms grow on trees and are heavy-duty wood recyclers!

FUN FACTS

- Shelf fungi are used as herbal medicines and were found in a bag on the body of the 5,300 year-old Ice Man mummy (Otze).
- Artists sometimes use these fungi as a canvas.
- If the tree where the mushroom is growing falls over, the mushroom will regrow so its pores always face downward.

Jelly Fungi

WHAT DO THEY LOOK LIKE?

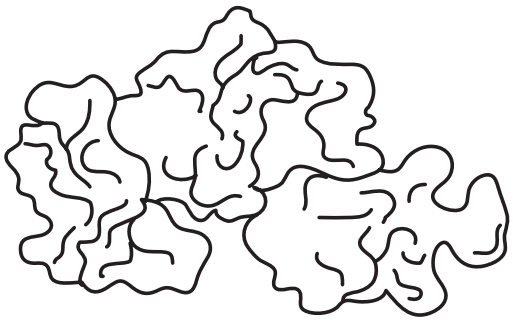
Jelly fungi are rubbery, seaweed-like mushrooms. They can be white, orange, pink, rose, brown or black. They could be shapeless, shaped like cups, railroad spikes or branched like coral.

WHERE ARE THEY FOUND?

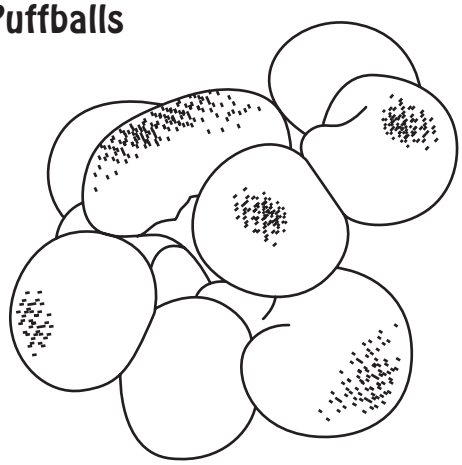
Jelly fungi often grow on logs, stumps and twigs. Some species are **parasitic** on other fungi, mosses, ferns or plants.

FUN FACTS

- They shrink when the air is dry and then swell up again when it rains.
- The common name of yellow to orange species is witches' butter.



Puffballs



Earthstar

Puffballs & Earthstars

WHAT DO THEY LOOK LIKE?

Puffballs are round or pear-shaped.
Earthstars are also round or pear-shaped when young, but they open into a star shape with a thin-skinned spore sac in the centre.

WHERE ARE THEY FOUND?

Puffballs are found directly on the ground or on rotten wood. They can be found in meadows, under small stands of trees, around forest openings, and even in your playground! Look for them in late summer and fall.

FUN FACTS

- Some puffballs can be as large as a watermelon.
- They have been called wolf farts or fairy farts.

Bird's Nest Fungi

WHAT DO THEY LOOK LIKE?

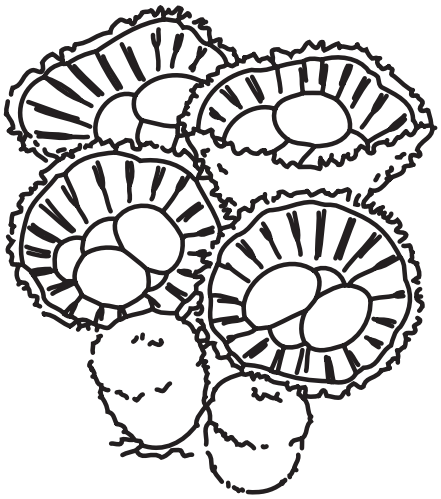
Bird's Nest fungi really do look like a miniature bird's nest. They are very, very small--usually no more than 1cm in diameter.

WHERE ARE THEY FOUND?

The best place to look for these mushrooms is on wood or twigs.

FUN FACTS

- When raindrops fall into the cup, the eggs (that hold the spores) are splashed out some distance away from the nest.



Basket stinkhorn

Stinkhorns

WHAT DO THEY LOOK LIKE?

You may actually smell this mushroom before you see it! They have a **stem** and a **cap-like**, smelly, slimy top with a **cup** or **volva** at its bottom. The beautiful **basket stinkhorn** lives in the tropics and actually has a lacy skirt When these mushrooms are small, they look like perfect hardboiled eggs.

WHERE ARE THEY FOUND?

These mushrooms are found on the ground, on rotten wood, on lawns, or in gardens or mulch.

FUN FACTS

- Some stinkhorns can reach a length of 20 cm in only 2-3 hours!
- Their bad smell is meant to attract flies to distribute their spores.

Cup Fungi

WHAT DO THEY LOOK LIKE?

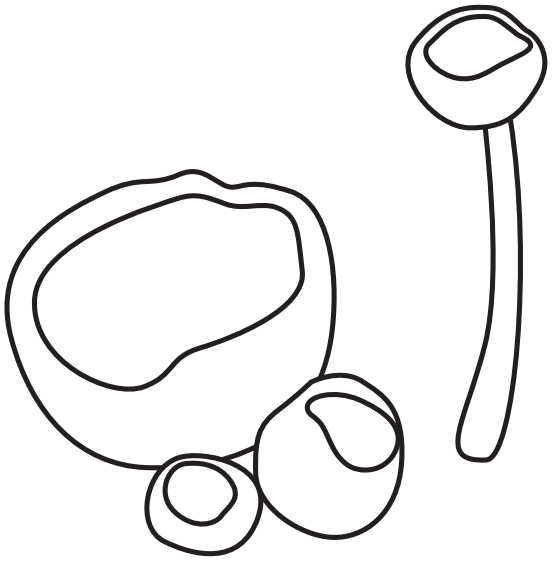
These mushrooms can look like little cups, ears, flasks, goblets, saucers, or orange peels.

WHERE ARE THEY FOUND?

They are found in a wide variety of habitats including in damp basements! Look for them during cool, early spring weather, and again in the fall.

FUN FACTS

- The cup or saucer shape is to expose a large area of hymenium, not to catch raindrops. If you breathe on a ripe cup fungus, you may see it puff.



Earth Tongues

WHAT DO THEY LOOK LIKE?

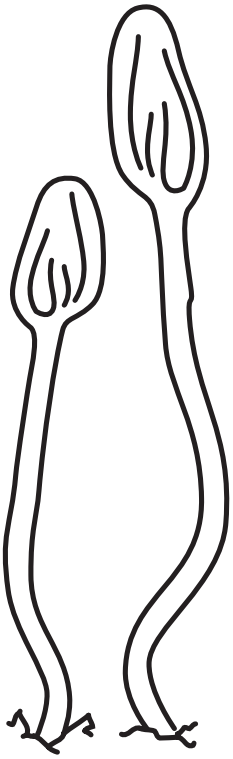
These mushrooms look like mini fire pokers or lollipops. They can also look like matchsticks with flattened "heads"or tongues.

WHERE ARE THEY FOUND?

The larger earth tongues live on soil, humus or wood while most of the smaller ones are parasitic on plant stems, leaves and other tissues.

FUN FACTS

- One type of earth tongue named *Neolecta* has been called a "fungal dinosaur".



Morels & Elfin Saddles

WHAT DO THEY LOOK LIKE?

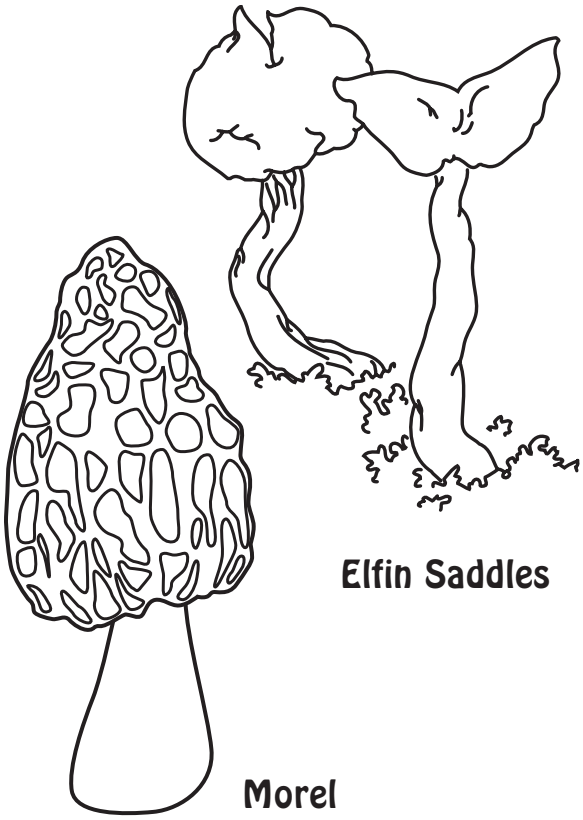
Morels have a **stem** and honeycomb-like **cap.**
False morels have a wrinkled **cap** and look like little, brown brains.
Elfin Saddles have a **cap** that is wrinkled and saddle-like or cup-shaped as well as they have a **stem.**

WHERE ARE THEY FOUND?

Morels and elfin saddles grow in many different habitats. Look for these "early birds" in the spring!

FUN FACTS

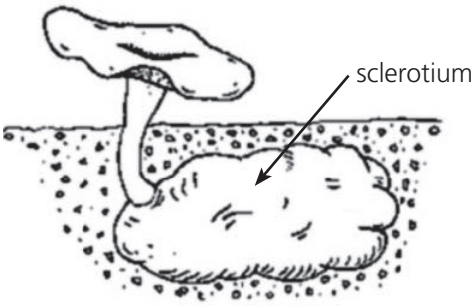
- Morels are considered such a delicacy that they sell for $50-60 per kilogram.
- False morels are very poisonous when eaten raw because they contain gyromitrin which is an ingredient in rocket fuel.



Elfin Saddles

Morel

Truffle



Canadian Tuckahoe

Truffles

WHAT DO THEY LOOK LIKE?

Both truffles and the Canadian tuckahoe look like old potatoes.

WHERE ARE THEY FOUND?

Both of these fungi live underground so they are hard to find! They are also **mycorrhizal;** see if you can find the tree they are partnered with.

FUN FACTS

- Truffles have been called "gold in the soil" and have been considered magical.
- Collected by people for at least 3600 years
- An amount the size of a candy bar would cost $800.
- The truffles' spores are spread by chipmunks that find the truffle from their delicious smell.

Checklist of Fungi I Have Found

- ❑ Agarics
- ❑ Boletes
- ❑ Chanterelles
- ❑ Club Fungi
- ❑ Coral Fungi
- ❑ Teeth Fungi
- ❑ Polypores
- ❑ Jelly Fungi
- ❑ Puffballs
- ❑ Earthstars
- ❑ Bird's Nest Fungi
- ❑ Stinkhorns
- ❑ Cup Fungi
- ❑ Earth Tongues
- ❑ Morels
- ❑ Elfin Saddles
- ❑ Truffles

Draw the fungi you find here:

How many centimetres tall is it?

Is it growing on a tree or on the ground?

Does it have gills, pores or spines under the cap?

Which group does it belong to?

Draw the fungi you find here:

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Which group does it belong to?

Glossary

Adaptation a physical or behavioural feature of an organism that helps it to survive in its habitat

Agaric [**ag**-uh-rik or uh-**gar**-ik] a mushroom with gills

Alga (pl. **algae**) [al-**ga**; **al**-jee] a simple, flowerless green plant usually living in water

Annulus (see **ring**)

Antibiotic a drug that interferes with the growth of bacteria. Penicillin, made by mould, was the first antibiotic. Antibiotics are widely used in the prevention and treatment of infectious diseases.

Ascomycete [as-kuh-**mahy**-seet] a fungus that reproduces by making spores inside a sac-like structure called an **ascus**

Autodigestion self-digestion

Bacteria any of a large group of one-celled organisms that lack a cell nucleus; reproduce by fission or by forming spores; and in some cases cause disease

Basidiomycete [buh-sid-ee-oh-**mahy**-seet] a fungus that reproduces by producing spores on the outside of a club-shaped cell called a **basidium**.

Bioremediation the use of biological agents, such as bacteria, fungi, or green plants, to remove or neutralize contaminants, as in polluted soil or water. Bacteria and fungi generally work by breaking down contaminants such as petroleum into less harmful substances.

Bolete [**boal**-eat] a fleshy mushroom with a spongy layer of tubes underneath its cap

Button a young mushroom before it opens up

Cap the cap-like part of the fruiting body which supports the spore-bearing surface, also called the pileus

Carnivore a living thing that eats meat. Carnivores are primarily mammals, such as tigers and dogs but can also be plants, such as the Venus flytrap.

Cell wall the protective, rigid, outer layer of the cells of plants, fungi, and bacteria

Cellulose a compound composed of glucose units; it's a major constituent of wood and of plants' cell walls

Chitin [**kahy**-tin] a chemical found in the cell walls of fungi, as well as in the shells of lobsters and insects

Chlorophyll the green pigment found in plants that permits them to make their own food through photosynthesis

Citric acid a colourless translucent crystalline acid; derived by fermentation of sugar and used mainly in the flavouring of beverages, confections, and pharmaceuticals

Coprophilous [kuh-**prof**-uh-luh s] living or growing on dung, as certain fungi

Cup (also known as the **volva**) the sac-like cup or tissue surrounding the base of the stem after the veil has broken

Cup fungi ascomycetous fungi that expose their hymenium in a wide concave fruitification; most common in the spring

Decomposers organisms that are responsible for breaking down organic matter into a simpler form and recycling nutrients into the soil

Dichotomous key [di-**kot**-uh-muhs] a key for the identification of organisms based on a series of choices between alternative characteristics

Dutch elm disease a disease of elm trees caused by the fungus *Ceratocystis ulmi*; it is spread by the European elm bark beetle and by the contact of the roots of healthy elms with those of infected trees. It produces brown streaks in the wood and results in the eventual death of the tree. No cure has been discovered, but prevention methods include the injection of insecticide into healthy trees and the destruction of all elms in infected areas.

Ecosystem all the living and non-living things in a certain area including air, soil, water, animals, and humans

Enzyme [**en**-zahym] any of various proteins originating from living cells and capable of producing certain chemical changes in organic substances by catalytic action, as in digestion

Eukaryotic single-celled or multicellular organisms whose cells contain a distinct membrane-bound nucleus.

Fairy ring an arc or circle of mushrooms

Fruiting body the part of the fungus where the spores are produced; typically called the mushroom

Fungophile someone who loves fungi

Fungophobe someone who fears fungi

Fungus (pl. **fungi**) [**fuhng**-guhs; **fuhn**-jahy, **fuhng-**gahy] one of the kingdoms of living things. They lack chlorophyll, have no true roots or stems, do not produce their own food and reproduce from spores

Germination the process whereby seeds or spores sprout and begin to grow

Gills plate-like structures on the under-surface of the cap of most mushrooms.

Glycogen [**glahy**-kuh-jen] a polysaccharide, molecularly similar to starch, constituting the principal carbohydrate storage material in animals and occurring chiefly in the liver, in muscle, and in fungi and yeasts

Habitat a place with a particular kind of environment suitable for the growth of an organism

Herbivore an animal that feeds chiefly on plants

Hypha (pl. **hyphae**) [**hahy**-fuh or **hahy**-fee] individual thread-like filament that forms the mycelium and fruit body. Hyphae secrete enzymes that digest food so that it can be absorbed by the fungus.

Kingdom the highest rank of the classification into which living organisms are grouped in Linnaean taxonomy, ranking above a phylum. There is debate as to whether there are 5, 6, or 7 kingdoms.

Lichen [**lahy**-kuh n] the symbiotic association of a fungus with an alga. The fungal component of a lichen absorbs water and nutrients from the surroundings and provides a suitable environment for the alga. The algae live protected among the dense fungal hyphae and produce carbohydrates for the fungus by photosynthesis.

Crustose crust-like lichens that may be buried in tree bark, or even between the crystals of rocks
Foliose flat leaf-like lichens
Fruticose miniature shrub-like lichens--one lichen of this type is the famous "reindeer moss" of Lapland
Squamulose scaly lichens made of numerous small rounded lobes, intermediate between foliose and crustose lichens.

Life cycle the complete life history of an organism from one stage (e.g.; the spore) to the recurrence of that stage. The life cycle of an agaric is: spore-->germination (hyphae)-->mycelium-->primordium -->button-->mushroom-->spore.

Mildew [**mil**-doo] any of various obligately parasitic fungi that form a superficial, usually whitish growth on living plants

Mould [mohld] a growth of minute fungi forming on vegetable or animal matter, commonly as a downy or furry coating, and associated with decay or dampness. Some moulds are added to food intentionally.

Mushroom the fruiting body of a fungus, typically containing a cap with spore producing gills resting on top of a stalk. The purpose of the mushroom is to manufacture and release spores.

Mycelium (pl. **mycelia**): [mahy-**see**-lee-uh m] a mass of hyphae (usually underground) that makes up the main body of the fungus

Mycologist a scientist who studies fungi

Mycology [mahy-**kol**-uh-jee] the scientific study of fungi

Mycorrhiza (pl. **mycorrhizas**): [mahy-kuh-**rahy**-zuh / -zee] "fungus root"; the formation of a symbiotic relationship with plant roots. The fungus obtains sugars from the plant, whilst the plant gains increased supplies of nutrients extracted from the soil by the fungus.

Nematode [**nem**-uh-tohd] unsegmented worms with an elongated rounded body which is pointed at both ends; mostly free-living but some are parasitic

Nutrient cycling all the processes by which nutrients are continuously transferred from one organism to another in an ecosystem. For instance, the **carbon cycle** includes uptake of carbon dioxide by plants, ingestion by animals, and respiration and decay of the animal by decomposers.

Omnivore an animal that feeds on both animal and vegetable substances

Organic matter anything that is or was once alive

Parasite an organism living in or on another living organism (host) from which it extracts nutrients

Parasitic mushroom/fungi a mushroom that lives on or feeds off a living animal or plant or another fungus

Penicillin (see **antibiotic**)

Photosynthesis the process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using light as an energy source

Pores (also called **tubes**) hollow cylinders containing spores and forming the spongy underside of bolete and polypore caps

Potato blight any of various highly destructive fungus diseases of the potato

Protozoa [proh-tuh-**zoh**-uh] any of a large kingdom of single-celled, usually microscopic, eukaryotic organisms, such as amoebas, ciliates, flagellates, and sporozoans

Primordium an aggregation of cells indicating the first trace of an organ or structure

Ring (also called an **annulus**) a circular skirt on a mushroom stalk formed by a broken veil

Rhizomorph [**rahy**-zuh-mawrf] a dense mass of hyphae forming a root-like structure characteristic of many fungi

Sac fungi (also called **Ascomycetes**) fungi that make their spores in sacs. This group of fungi includes single-celled bread yeast and multi-celled truffles. Other types of sac fungi can harm plants and animals.

Saprobic mushroom a mushroom that feeds off dead trees, dung, leaves, litter, or other organic matter

Scales raised pieces of broken skin on a cap or stalk surface

Sclerotium (pl.**sclerotia**) [skli-**roh**-shee-uh m; -shee-uh] a dense mass of branched hyphae, as in certain fungi, that contain stored food and are capable of remaining dormant for long periods (e.g., Canadian Tuckahoe)

Seed a mature fertilized plant ovule consisting of an embryo and its food source and having a protective coat; common to plants

Species the major subdivision of a genus, regarded as the basic category of biological classification, composed of related individuals that resemble one another, and are able to breed among themselves

Spore the reproductive unit of fungi, similar to the seed in plants. It differs from a plant seed in that it does not have its own food reserves.

Spore case (also called **sporangium**) the part of mold that produces spores

Spore print the picture formed on paper by mushroom spores; the print's colour and pattern help in identification

Stalk (also called the **stem** or **stipe**) the part of the mushroom that holds up the cap; similar to the stem of a plant

Starch a carbohydrate, occurring in the form of minute granules in the seeds, tubers, and other parts of plants, and forming an important constituent of rice, corn, wheat, beans, potatoes, and many other vegetable foods

Symbiosis a relationship between two different organisms that is beneficial to both. (e.g. mycorrhizal fungi and plants; a fungus and an alga in a lichen).

Taxonomy the science of classification; the arrangement of organisms into groups based on their natural features

Toadstool a popular name for a poisonous mushroom

Toxin a poisonous substance

Tubes (see **pores**)

Universal veil the tissue that covers and protects a developing mushroom and that breaks as the mushroom grows

Volva [vol-vuh] (see **cup**)

Yeast a single-celled fungus such as Brewers' Yeast (*Saccharomyces cerevisiae*) used in brewing and baking.

Suggested Resources and Sources

TEACHING AIDS

How the Mushroom Got its Spots: An Explainers Guide to Fungi by Sue Assinder. British Mycological Society (BMS) and the Biotechnology and Biological Sciences Research Council (BBSRC).
ISBN 0708406459

This guide is aimed at non-experts who want to tell children more about the fascinating world of mushrooms, toadstools, moulds and other fungi, and is useful for teachers, leaders of wildlife groups and science clubs. "How the mushroom got its spots" is available free from the British Mycological Society at www.britmycolsoc.org.uk Additional BSM teaching materials can be found at www.fungi4schools.org

DSM II Fungi—Small Wonders (Grades 5-6). by N.H. Hudson Delta Science Module (DSM) series. Delta Education, 1994.
ISBN 0875041094

Students compare various fungi with plants by extracting pigments to test for chlorophyll. They discover that fungi—with no seeds, roots, stems, leaves, or flowers—are in a class (actually, a kingdom) by themselves. They dissect mushrooms to investigate spore reproduction. Students also grow mold gardens in different cultures to test fungicides. Many activities focus on the one-celled fungi--yeast. Students observe yeast growth, budding, and fermentation (and yeast at work in pretzel dough) while controlling food and temperature variables. Based on activities and research, students debate the benefits and hazards of fungi. (12 Activities)

The Good, the Bad and the Fungi: Introducing Fungi to Children by Liz Holden. Field Mycology Volume 4(1), January 2003 pp 19-27
http://www.britmycolsoc.org.uk

If you are faced with a group of thirty 10 year olds and the task of trying to enthuse them about mycology, you might need some help. You can get it here!

GENERAL REFERENCE BOOKS

Magical Mushrooms, Mischievous Molds by George W. Hudler
Princeton, N.J. : Princeton University Press, c1998.
ISBN 0691028737

Hudler's light-hearted approach to the subject of the impact of fungi on the human history is refreshing and will attract students and lay people who have some interest in this area. In this lively book, George Hudler leads us on a tour of an often-overlooked group of organisms, which differ radically from both animals and plants. Along the way the author stops to ponder the marvels of nature and the impact of mere microbes on the evolution of civilization. Magical Mushrooms, Mischievous Molds is full of information that will satisfy history buffs, science enthusiasts, and anyone interested in nature's miracles.

Slayers, Saviors, Servants, and Sex : an Expose of Kingdom Fungi by David Moore.
New York : Springer, c2001.
ISBN 0387951016 (alk. paper)
ISBN 0387950982 (softcover : alk. paper)

In this highly entertaining book, mycologist Moore presents a fascinating and lively guide to the fungal kingdom. He explores their role in food and agriculture and their dual role as infectious agents and providers of the most potent antibiotics.

Fungi: Delight of Curiosity by Harold J. Brodie. Toronto ; Buffalo : University of Toronto Press, c1978.
ISBN 0802022898
ISBN 0802067662 (pbk.)

Introductory Mycology by Constantine J. Alexopoulos. John Wiley & Sons, 1996
ISBN: 0471522295

This is a comprehensive mycology textbook that discusses the numerous activities of fungi that directly or indirectly impact other living things, including humans, in the context of their close relatives. It contains scores of illustrations, life cycle drawings, tables and new photographs.

Fungi: Folklore, Fiction and Fact by WPK Findlay. Richmond Publishing Company. London, 1982

Provides a historical background for those interested in mushrooms.

Mushrooms : a Separate Kingdom by Loni Parker. Birmingham : Oxmoor House, 1979.
ISBN 0848705017

Fungi by Roy Watling. Washington, D.C. : Smithsonian Books, 2003.
ISBN 1588340821

Richly illustrated with high quality colour photographs, this text for general readers describes a wide variety of fungi. Coverage includes such topics as the importance of fungi to the larger ecosystem, the collection and preservation of specimens, and the scourge of "dry rot" in houses.

The Fifth Kingdom by Bryce Kendrick. Focus Publishing. R. Pullins Company; 3rd edition, 2001
ISBN 1585100226

This 3rd edition is a compact but comprehensive encyclopedia of all things mycological. It explores every aspect of the fungi, from aflatoxin to zoospores, with an accessible blend of verve and wit. The 24 chapters are filled with up-to-date information of classification, yeast, lichens, spore dispersal, allergies, ecology, genetics, plant pathology, predatory fungi, biological control, mutualistic symbioses with animals and plants, fungi as food, food spoilage and mycotoxins. (amazon.com)

I**n the Company of Mushrooms : A Biologist's Tale** by Elio Schaechter. Harvard University Press; Reprint edition (October 30, 1998)
ISBN: 0674445554

Call them the foot soldiers of the forest floor. Unassuming and prolific, mushrooms clear a path for new life by expertly and efficiently recycling accumulated dead matter, from the tiniest leaf to the tallest tree. It may sound like a dirty, thankless job, but as microbiologist and author Elio Schaechter enthusiastically notes, we should be singing praises to the fungi of the Earth; without them, all but the tallest of creatures would be buried under a global blanket of decomposing matter. Schaechter is obviously fascinated by his subject, and his spirit is contagious, making In the Company of Mushrooms as entertaining as it is informative. Though the book serves as a guide to hunting, identifying, and classifying mushrooms--its primary aim is to convey the wonders of the fungi world and its essential function in nature. Along the way Schaechter discusses the history of the mushroom and its role in the diets and healing practices of both ancient and modern cultures. He also offers such delectable tidbits as the fact that fungi are more closely related to humans than plants on the evolutionary scale. Mycology has never been so engaging. (amazon.com)

FIELD GUIDES

Mushrooms of North America by Roger Phillips
Boston : Little, Brown, c1991.
ISBN 0316706124
ISBN 0316706132 (pbk.)

Mushrooms of the Boreal Forest by Eugene F. Bossenmaier. Saskatoon : University Extension Press, University of Saskatchewan, c1997.
ISBN 0888803559 (pbk.)

More than 200 species from Alaska to Minnesota, with full-colour photos and descriptions, are arranged by major groups to simplify identification. Sections on biology and ecology of wild mushrooms help readers learn which mushrooms are edible and which are poisonous.

Mushrooms Demystified : a Comprehensive Guide to the Fleshy Fungi by David Arora.
Berkeley : Ten Speed Press, c1986.
ISBN 0898150108

Simply the best and most complete mushroom field guide and reference book, with over 950 photographs.The text is extremely extensive and inclusive. Many of the photos are in black and white.

All That the Rain Promises, and More ... : A Hip Pocket Guide to Western Mushrooms by David Arora.Ten Speed Press (April 1991)
ISBN: 0898153883

A concentrated form of Mushrooms Demystified. Great colour plates and fun myco-tidbits. A fantastic guide for kids to explore.

Mushrooms of Western Canada by Helene M. E. Schalkwijk-Barendsen. Later copies printed in 1994 have title: **Mushrooms of Northwest North America.** Edmonton, Alta. : Lone Pine Publishing, c1991.
ISBN 0919433472 (pbk.)
ISBN 1551050463 (pbk.)

CHILDREN'S BOOKS

Fungi by Jenny Tesar ; with illustrations by Wendy Smith-Griswold. Woodbridge, Conn. : Blackbirch Press, c1994.
ISBN 1567110444

This award-winning series emphasizes the fascinating patterns in the natural world, enabling readers to discover their own place in the network of life.

Slime, molds, and fungi by Elaine Pascoe ; photographs by Dwight Kuhn. Woodbridge, Conn. : Blackbirch Press, 1999.
ISBN 1567111823

Using hands-on natural science projects, explores and explains different types and characteristics of fungi.

Fungi by Charles Murray Rotter.
Mankato, Minn. : Creative Education, c1994.
ISBN 0886825938

Introduces the fungi kingdom, discussing the varieties, physical structure, and reproduction, and well as the fungi's role in the ecosystem, and human uses of fungi.

What is a fungus? by D.M. Souza
New York : Franklin Watts, c2002.
ISBN 0531119793 (lib. bdg.)
ISBN 0531162230 (pbk.)

The plant and fungus kingdoms are richly diverse and filled with fascinating organisms. This series covers both basic and little-known facts about plant and fungus biology, including reproduction, structure, and species variation. Readers learn about unusual species and their habitats, as well as threats to their existence. Also covered are the ways in which plants and fungi are important in human life--as medicines, sources of food and clothing, and items of unsurpassed beauty.
*This is a quality book and highly recommended.

Discovering Fungi by Jennifer Coldrey.
New York : Bookwright Press, 1988.
ISBN 0531181707

Introduces, in brief text and illustrations, the characteristics of fungi, where they may be found, the many varieties that exist, and their relationship to animals and human beings.

Fungi by Alvin, Virginia, and Robert Silverstein.
New York : Twenty-First Century Books, 1996.
ISBN 0805035206

Introduces fungi, discussing their varieties, physical structure, reproduction, role in the ecosystem, and uses.
*This book is also highly recommended!

Molds and Fungi by Buffy Silverman.
San Diego : Kidhaven Press, c2005.
ISBN 0737720751

Molds and other fungi live all over the world. Despite the amazing variety of fungi, all are alike in important ways. This book describes the characteristics of the Fungi kingdom and portrays the life cycles of unusual and important fungi. The role of fungi in the food chain is explored, as is the impact of fungi on people. (amazon.com)
*This book has really nice photos and simple text. Its a very good introduction to the fungi.

Mushroom by Barrie Watts.
Morristown, N.J. : Silver Burdett Co., 1986.
ISBN 0382092872 (lib. bdg.)
ISBN 0382093011

Discusses the parts of mushrooms and how these fungi grow.
* This book has simple illustrations and good photos.

Carnivorous Mushrooms : Lassoing Their Prey? by Victor Gentle. Milwaukee : Gareth Stevens Pub., 1996.
ISBN 0836816560

Introduces some varieties of fungi that eat eel worms, describing the damage these tiny worms cause to both plants and animals and the different ways that the fungi trap their prey.
* This is a very cool book with great scanning electron micrographs (SEMs)!

Mushrooms of the World With Pictures to Color by Jeannette Bowers, David Arora. Dover Publications (July 1, 1984)
ISBN: 0486246434

92 fascinating mushroom species are revealed. Detailed captions accompany the ready-to-colour illustrations. Scientific and common names, countries of origin, and growing conditions are also included. List of Synonyms. Index. 39 black-and-white illustrations. (amazon.com)

A Young Persons Guide to the Fungi by Bryce Kendrick. Mycologue Pubns (June 1, 1986)
ISBN: 0969223714

"This delightful book combines humor and mycological expertise in a presentation that should capture the imagination. It will especially appeal to pre-teens, but will educate older children and adults as well. This is perhaps the best book available to junior mycologists in North America." (North American Mycological Association Bulletin)

"This is a remarkably simple, entertaining and informative book on fungi. Twenty-six pages of beautiful, full-page, black-and-white line drawings show all different kinds of fungi at their best. Each illustration is paired with a few paragraphs describing the fungus; enter the `Tree-Eaters' and the `Vegetable Caterpillar' to delight the curious mind. A wonderful natural science resource." (New York State 4-H Newsletter)

Magic School Bus Meets the Rot Squad: A Book about Decomposition Based on the TV Show. Scholastic Us (October 1995)
ISBN-10: 0590400231

The students in Ms. Frizzle's class embark on another journey when the Magic School Bus tours a decomposing log that introduces the latter end of the life cycle and teaches readers that there's more to rot than meets the nose.

Fungus Fred goes Foraying by Maggie Hadley. British Mycological Society, 2002. www.fungi4schools.org/KS2-3_resources.htm

This book tells an engaging story about how Fungus Fred investigates the different types of fungi in nature. The book is full of fungi facts and encourages children to do what Fred has done and have fun learning. Suitable for children in the age range 7-11 years. You can read the book online or you can also order a printed copy by mail from the website.

FICTION BOOKS

The Fungus That Ate My School by Arthur Dorros ; illustrated by David Catrow. New York : Scholastic Press, 2000.
ISBN 0590477048

While the students are home for spring vacation, the fungus they are growing in their classroom grows and grows and takes over the entire school.

Mushroom in the Rain by Mirra Ginsburg. Aladdin; Reissue edition (April 1, 1997)
ISBN: 0689714416

Caught out in the rain, an ant takes shelter under a very tiny mushroom. Soon, a wet butterfly, then a drenched mouse, a dripping sparrow, and even a rain-soaked rabbit each beg to join him under his miniature umbrella. How can the ant let the others in when there is barely room enough for one? But as the rain comes down and down, they all somehow manage to squeeze together and share the tiny shelter. And when the sun finally comes out, the ant discovers a magical secret of just what happens to mushrooms in the rain! (amazon.com)

FUN SITES FOR KIDS

The Fungus Among Us

http://www.virtualmuseum.ca/~mushroom/English/index2.html

Fun Facts About Fungi

www.herb.lsa.umich.edu/kidpage/factindx.htm

This page at the University of Michigan introduces students to the kingdom of fungi through games, puzzles and experiments.

RESEARCH

Tom Volk's Fungi

http://www.tomvolkfungi.net/

Canada's Species: Fungi

http://canadianbiodiversity.mcgill.ca/english/species/fungi/index.htm

WHERE TO FIND POSTERS

EDIBLE YARD, FIELD and Cultivated MUSHROOMS by David Arora
depicts numerous edible mushrooms which are cultivated, found on stumps, in open spaces or in back yards and gardens.

EDIBLE FOREST FLOOR MUSHROOMS by David Arora
illustrates numerous edible mushrooms which can be found in the forest floor.

http://www.gourmetposter.com/Mushroom.htm
http://www.gmushrooms.com/BOOKS.HTM
http://www.fungi.com/gifts/index.html
http://www.art.com/asp/display-asp/_/id--9338/Mushroom.htm
http://www.edugraphics.net/gf-food/gf280.htm