

Detecting Mold in School Buildings:

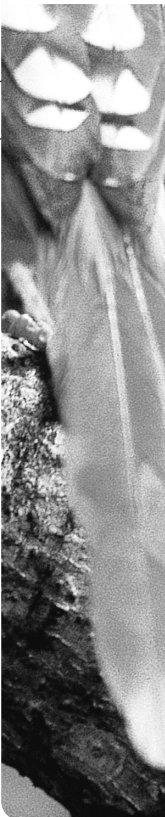
An Exercise in Biodiversity

Fungal spores are an invisible part of our environment. However, given the right growth conditions, the spores can grow into an amazing variety of shapes and colors. Other than eating the occasional mushroom pizza or discarding moldy cheese, many students are unaware of the diversity of these often unseen organisms. In the project described here, students surveyed their school building for different types of mold. The idea for this project began with a group of middle school students concerned

ANTHONY L. FARONE MARY B. FARONE

about their health and the health of their teachers in a school with potential sick building syndrome (Scheel et al., 2001). It was developed into a science laboratory project for a different school without sick building problems, yet it provided the seventh-grade students with an excellent inquiry-based learning experience. The students assisted in designing the investigation, made predictions based on their design, and collected and analyzed the data. Growing and identifying the molds provided opportunities for several life science studies because the students were able to observe simple, yet diverse, multicellular organisms. They were able to make connections between structure and function of the fungal components and learn how these different components enhance survival in the environment. They also learned about organisms with both asexual and sexual forms of reproduction.

ANTHONY L. FARONE, Ph.D., is an Associate Professor in the Biology Department of Middle Tennessee State University, Murfreesboro, TN 37132; e-mail: afarone@mtsu.edu. MARY B. FARONE, Ph.D., is Assistant Professor in the Biology Department of Middle Tennessee State University, Murfreesboro, TN 37132; e-mail: mfarone@mtsu.edu.



The Common Mold

Fungi are comprised of unicellular (yeasts) and multicellular (molds and mushrooms) organisms. The multicellular molds are made up of filaments of cells called hyphae (singular: hypha). These filaments intertwine and grow into a tangled, visible mass called a mycelium. This visible mycelium is what we call a mold. The hyphae can also be classified according to their function. The vegetative hyphae, which comprise most of the visible mass, digest and absorb nutrients. Aerial or reproductive hyphae will grow vertically from the mycelium. These hyphae produce the reproductive structures called spores. The fungi are classified by the structures of their reproductive hyphae and spores. Fungi can produce both asexual and sexual spores.

Asexual spores are the products of mitosis of a single parent cell. There are two basic types of asexual spores: sporangiospores and conidia. Sporangiospores are formed within a saclike structure called a sporangium, which is attached to a stalk-like hypha. The spherical sporangiospores are released when the sporangium ruptures. Conidia (or conidiospores) are free spores not enclosed by a saclike structure. They develop at the tips of reproductive hyphae (conidiophores).

They have a wider variety of sizes and shapes ranging from cubical to spherical to vase-shaped.

The sexual spores form from the fusion of two parental nuclei followed by meiosis. There are three types of sexual spores: zygospores, ascospores, and basidiospores. The sexual spores are produced less frequently than the predominant asexual spores, however, they are important in providing genetic diversity for the fungi and ensuring their adaptation and survival. Although all fungi can propagate themselves with asexual spores, not all fungi reproduce using sexual spores. Fungi without a known sexual stage are often referred to as the imperfect fungi. (For more information and images of fungal structures, refer to Box 1).

The spores of fungi are spread by air, water, and insects, but may also enter the indoor environment through windows, ventilation systems, or on animals and people. The presence of mold spores does not necessarily indicate that a mold is growing. When mold spores land on nutrient-rich areas of excessive moisture or humidity, they can grow into a visible mold. Indoors, molds are most often found in basements, bathrooms, and kitchens. They grow on foods, carpets, shower tiles and grout, wood, wallboard, ceiling tiles, paper products, textiles, and in refrigerators, humidifiers and heating, ventilation and air conditioning (HVAC) units. Table 1 lists and describes the mold types encountered most frequently indoors, although any mold can be brought indoors with any plant or soil.

Box 1.

Helpful readings and Web sites for information and images of fungi

Readings

Clay, K. 2004 Golden moldies. *Natural History*, 113,40-42.

Kendrick, B. (2000). *The Fifth Kingdom, 3rd Edition*. Newbury, MA: Focus Publishing.

Larone, D.H. (2002). *Medically Important Fungi: A Guide to Identification, 4th Edition*. Washington, DC: ASM Press.

Web Sites

Centers for Disease Control and Prevention

<http://www.cdc.gov>

Doctor Fungus

<http://www.doctorfungus.com>

Gordon Mycology Laboratory

<http://www.gordonmycologylab.com>

Mycologue Publications

<http://www.mycolog.com>

Myko Web

<http://www.mykoweb.com>

The WWW Virtual Library: Mycology

<http://biodiversity.uno.edu/~fungi/>

Student Planning

After an introduction to the fungi, the students began their experimental design to study the mold types that might be present in the school building. Floor plans were photocopied from the school emergency evacuation plan. The school building that served as the focus of this study was completed in three phases: Phase I was 50 years old, Phase II was 12 years old, and Phase III was 2 years old. The students' objective was to compare the mold types and their abundance between the three phases of the school construction. Their hypothesis was that the older phases of the building would have progressively more mold spores than the newer phase. Based upon their knowledge of how mold spores enter indoor environments, the students predicted the most likely sites for mold spores. They chose to sample areas around the HVAC vents, windowsills, and the floor. Based on the number of students in this study (15), groups of two to three students were formed (six groups). Two rooms from each building phase were sampled (HVAC vent, windowsill, and floor) for a total of 18 samples. These numbers can easily be adjusted for the number of students and rooms or sites chosen for sampling.

Table 1. Molds commonly found indoors^a

GENUS OF MOLD	APPEARANCE ON SDA			Sexual Spore ^b	Other Characteristics
	Surface Color	Texture	Reverse		
<i>Alternaria</i>	grayish-white; can become greenish-black or brown	woolly	black	N	widespread indoors
<i>Aspergillus</i>	white; becomes yellow, green, brown or black	velvety	white, gold, or brown	N	widespread indoors; allergenic
<i>Auerobasidium</i>	white; can become black	leathery	black	N	found in continually moist areas
<i>Chaetomium</i>	white; becomes gray to olive	cottony	tan to red, or brown	A	allergenic
<i>Chrysosporium</i>	white, yellow, tan, pink, or orange	cottony or granular	white or brown	N	most often associated with soil and animals
<i>Cladosporium</i>	greenish-brown or black	velvety with folds	black	N	widespread indoors
<i>Epicoccum</i>	yellow, orange, or pink; becomes green-brown to black	cottony or velvety	same as surface	N	most often associated with soil and plants
<i>Monilia</i>	white; becomes salmon-colored	powdery to fluffy	white to buff	N	“red bread mold”
<i>Mucor</i>	white; can become gray	cottony	white	Z	most often associated with soil; allergenic
<i>Paecilomyces</i>	white; becomes yellow, yellow-green, olive-brown, or pink	powdery or velvety	white, buff, or brown	A	allergenic
<i>Penicillium</i>	white; becomes bluish-green with white border	powdery	white, red, or brown	A	widespread indoors; allergenic
<i>Rhizopus</i>	white; can become gray	cottony	white	Z	rapidly growing; “bread mold”
<i>Stachybotrys</i>	white; becomes black	cottony	white; becomes black	N	found in continually moist areas; allergenic
<i>Ulocladium</i>	olive-brown to black	cottony	olive-brown to black	N	most often associated with soil

^a Table information derived from Kuhn & Ghannoum (2003), Larone (2003), and www.gordonmycologylab.com.

^b Type of sexual spore produced, A = ascospore, Z = zygospore, N = no sexual spore identified

The Experiment

Laboratory Skills

Although this experiment was designed primarily to teach the students about fungal structure and diversity, the students also gained experience in experimental design, sterile technique, microbiological media inoculation, fungal culture, light microscopy, observation of macro- and microscopic appearance, data analy-

sis, and maintaining a laboratory notebook. These activities also provided opportunities for improvement in time management and teamwork skills.

Materials

This experiment was performed with a group of 15 seventh-grade students. The students were divided into six groups of two to three students each. Each group was assigned a room to sample, and three sites were

sampled in each room (for a total of 18 samples), giving each student the opportunity to sample and inoculate a plate of growth medium. The materials list reflects the numbers of students and sites sampled for this study.

Students

- Floor plan of the building
- Permanent markers (1/group)
- Cotton swabs (preferably sterile; 18 or 1/sample site; \$11.00/100 sterile swabs*)
- Sterile, capped test tubes (18 or 1/sample site; \$23.00/100 tubes)
- Test tube racks
- Petri dishes of Sabouraud's Dextrose Agar (SDA; 18 or 1/sample site; \$15.60/pack of 10 pre-poured plates; alternatives are Melt n' Pour set of 40/\$32.00 or Yeast and Mold Count Petrifilm \$60.00/pack of 50)
- Rulers
- Masking tape or parafilm
- Light microscope (preferably with oil immersion lens)
- Mold identification key (6 or 1/group)
- Student notebook (1/student)

Teacher or Other Professional

- Microscope slides (1/mold type; approximately 20; \$8.10/box of 72)
- Coverslips (\$3.10/pack of 100)
- Lactophenol cotton blue stain (\$60.00/50 staining kits)
- Microbiological inoculating needles or dissecting needles (\$5.00/2 needles)
- Clear fingernail polish
- Scanner or digital camera

* Prices for all supplies are from Carolina Biological Supply Company, Burlington, NC (www.carolina.com) or Fisher Scientific, Pittsburgh, PA (www.fishersci.com). Estimated consumable cost per student is \$4.25.

Methods

Teacher Preparation

Sabouraud's Dextrose Agar Plates

For determining the number of plates for the class, instructors should consider ordering or preparing

extra plates as some plates may be incorrectly inoculated. For this study, SDA plates were purchased from Carolina Biological Supply Company. Alternatively, SDA plates can be prepared from dehydrated media, and following autoclaving, poured into 100 x 15 mm sterile Petri dishes. The recipe for the Emmons Modification of SDA is as follows:

- 20 g dextrose, \$3.60/100g
- 10 g peptone, \$4.15/25g
- 15 g agar, \$33/250g
- 1000 ml distilled water
- final pH 6.9

Mold Microscope Slides

In order to identify the molds that grow on the culture medium, microscopic slides must be prepared. Unless the instructor has experience with mold culture, these procedures should be performed by microbiologists from universities or hospitals, who can also assist with the identification of the molds. To prepare slides, one slide and coverslip will be needed for each mold colony. Place a drop of the lactophenol cotton blue stain (available from Fisher Scientific) in the center of a slide. Use a sterilized inoculating needle or dissecting needle to carefully remove some of the mold colony. Place the specimen in the stain and use a second needle to gently tease it apart. Place a coverslip over the specimen and seal around the edges with clear nail polish to preserve the slide. Microscopic examination of the slides and the macroscopic appearance of the mold colony types can be used to identify the molds. Alternatively, a piece of clear adhesive tape can be gently touched to the mold colony and then touched to the drop of stain on the slide and mounted as above.

Mold Identification

The molds will need to be identified by microscopic and macroscopic morphology. Unless the instructor has experience with fungi, microbiologists from regional universities or hospitals should be contacted. These individuals are usually very willing to help and involve students at all levels.

Mold Identification Key

A mold identification key can be prepared by the instructor from images of the actual molds. Students will need images of both the surface and reverse of each colony type. For our study, student plates with different colony types were scanned using a Samsung videopresenter SVP-6000 over-

head projector/scanner system that captured the images, however a digital camera would work just as well. Color images of the surface and reverse sides of the different mold types were compiled onto a single page in Microsoft Word and labeled with the genus of the mold. Color laser printouts of the keys were given to each group of students. Alternatively, once the mold colonies have been identified, color images could be scanned from books or downloaded from the internet (see Box 1 for resources).

Step 1. Sample Collection (45-60 minutes)

Test tubes were pre-labeled with the date, room location, and sample site. It is particularly important to label the tubes clearly to ensure a correlation between site and the number of molds. A sterile swab was used to swab the designated collection site and the swab was immediately placed into the test tube (the end of the swab can be cut off if it is too long for the tube). Clean cotton swabs could also be used as long as an unused swab was assayed for growth as a control. Swabs were stored in the capped test tubes at room temperature until inoculation onto growth medium.

Step 2. Inoculation of Growth Media (45-60 minutes)

Students labeled the bottom of SDA plates (warmed to room temperature) with the date and sample location and source. Students were shown how to inoculate the surface of the growth media by swabbing in an X pattern for each sample (Figure 1). The swab was returned in its sterile tube for re-inoculation of a new plate if a

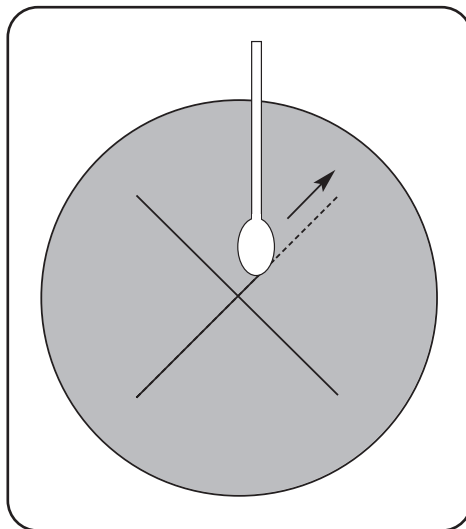


Figure 1. Swabbing the surface of a SDA plate

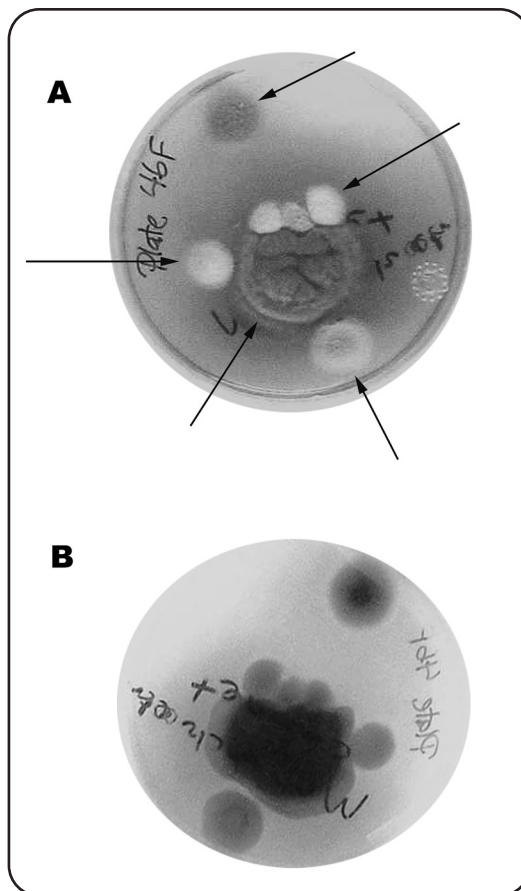


Figure 2. An example of mold colonies on a SDA plate

View A shows the surface of a plate. The arrows are pointing to individual colonies. View B shows the reverse side of the plate. Note the darker appearance of the colonies.

mistake was made. The plate was sealed with parafilm or masking tape, and inoculated plates were incubated upside down (lid down so no moisture accumulates on the surface of the plate) at room temperature in the classroom under normal lighting conditions.

The sample collection and inoculations can be performed in the same or separate laboratory periods.

Step 3. Incubation & Observation of Plates (10-15 minutes/day; 1 week)

Each group was responsible for checking its plates daily for growth. Students maintained laboratory notebooks with daily records of the mold colony numbers and their growth characteristics. Growth characteristics are dependent upon the type of fungus present and can appear as soon as 48 hours or as long as a few weeks. Figure 2 shows a plate with several different mold colonies. A reasonable time of incubation would be one week. After one week, or earlier depending upon the amount of growth present, all plates should be refrigerated to prevent one type of fungus from overgrowing, thereby preventing the clear identification of the other organisms on the plate. Once growth occurs, students or teachers should not open the plates. Each plate contains billions of spores and their release could cause an allergic reaction in individuals sensitive to mold.

Step 4. Collection of Data (1-3 hours)

After one week of incubation, microscopic slides should be prepared for each colony type on the plates (see "Teacher Preparation"). Once we had identified the colony types based on their macroscopic

(colony) and microscopic morphologies, a mold identification key (see Teacher Preparation) was prepared so students could identify the mold colonies by matching their colony types to those on the mold identification key. This involved comparison of both the surface and reverse colony morphologies to those on the key. Students made additional observations on the sizes of the colonies, variety of colors, and textures present. Students not only counted and identified the molds on their own plates, but all the groups observed the other groups' plates to gain experience in observation and generate discussion and a consensus on the number and types of molds on each plate. Students recorded all results in laboratory notebooks and a class table was generated for the plates.

Once students identified the molds macroscopically, they observed the microscope slides for each mold type. These microscope slides were prepared during the identification of the molds but prepared slides are also available for purchase (Carolina Biological Supply Company). Microscopic examination allowed the students to see the hyphae and spore structures and make

comparisons such as darkly-pigmented colony types having pigmented hyphae versus lighter-colored mold colonies having clear hyphae.

The collection of data and observations of the microscope slides can be made in several laboratory sessions. The fungal plates should be refrigerated between sessions to prevent excess growth of the molds.

Step 5. Analysis of Data (2-4 hours)

After compiling the class results for numbers of molds per plate, the students' assignment for the following week was to prepare a results table using an appropriate software program (our students used Microsoft Word), that would be included in a formal laboratory report. Table 2 represents the table generated as part of this exercise. As part of a class discussion on how to present their data, the students chose to analyze both the total number of mold colonies generated per building phase as well as the number of different types per building phase. Using the data in the table, students calculated standard deviations of the mean.

Table 2. Sample data table of molds in the three building phases of the school

Building Phase ^b	Number of Mold Colonies Isolated ^a																	
	I						II						III					
	1			2			3			4			5			6		
Room No.	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Alternaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Aureobasidium	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysosporium	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cladosporium	4	7	5	5	3	0	6	0	1	7	0	1	1	0	0	8	1	1
Monilia	0	1	0	0	0	0	10	3	0	4	0	1	0	4	0	5	0	0
Mucor	1	0	0	1	1	1	0	3	0	1	0	0	0	0	0	0	0	0
Penicillium	5	7	6	2	2	1	2	0	0	0	0	0	2	1	0	0	0	0
Other ^d	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0
Different colony types per room	5			7			5			3			4			3		
Total colony number per phase	47						40						25					

^a The number of mold colonies represents the number of individual colonies counted per plate.

^b Building phases indicate the three different construction phases of the school building. Building phase I was 50 years old; building phase II was 12 years old; and building phase III was 3 years old.

^c Samples for three plates were collected from each room. Plate A represents the sample taken from the HVAC vent. Plate B contains the sample from the floor and on plate C is the sample from a windowsill.

^d Other colony types refer to bacterial or yeast colonies which may also be present but in general are smaller, more uniform, and often have a smooth shiny texture.

This was their first introduction to statistical analysis.

The students did find a statistically greater number of total mold colonies in the oldest phase compared to the newest but did not find a statistically greater number of mold types. The data in the table were also used to make comparisons between the prevalence of particular molds and whether more molds could be isolated from windowsills, vents, or the floor, although our class did not perform statistical analyses on these comparisons. However, additional tables were prepared by some students to better illustrate these differences. Because the students were not familiar with the mold *Cladosporium*, the most prevalent mold type isolated in our study, it prompted much interest and research.

Safety Issues

As previously noted, once the growth medium has been inoculated, plates should be sealed and remain unopened. It is also important to remind students that the presence of mold spores does not necessarily indicate that the mold is actively growing in the environment. Spores will grow only if growth conditions are appropriate. This will avoid alarm when students see the growth occurring on the plates. It also stimulates discussion as to what conditions must exist for growth to occur, for example, on the windowsill.

Students should be reminded to wash their hands thoroughly with disinfectant soap after handling the sealed plates and the work area should also be cleaned with disinfectant.

For the teacher preparation of microscope slides, only instructors familiar with the handling of fungi should prepare the slides for fungal identification. Instructors who prepare their own slides should wear protective gloves and masks and note that the lactophenol cotton blue stain contains phenol, a caustic agent. For additional help with identifying the fungi, the microbiology faculty at universities are usually willing volunteers, as we were, for this type of project. Other professionals who may be willing to assist with this are medical laboratory personnel at regional hospitals.

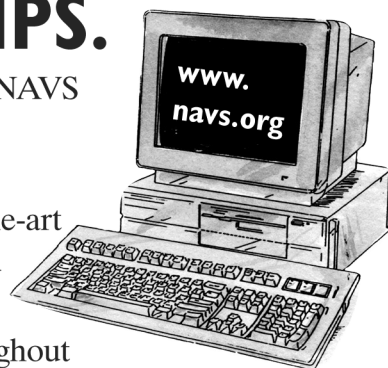
Possible Modifications

Our laboratory project was designed for a seventh-grade class becoming familiar with cell structure and function as well as the diversity of organisms in the environment. Because many of the students had been at the school during the most recent building addition and were aware of the different ages of the school, they chose to study differences between the building phases. These studies could be adapted to other school environments as well. For instance, students could compare

THE LARGEST SELECTION OF DISSECTION ALTERNATIVES IS AT YOUR FINGERTIPS.



- ✓ Consider the cost savings of using the free NAVS Dissection Alternatives Loan Program when planning your life-science curriculum.
- ✓ Choose from the most extensive state-of-the-art collection of CD-ROMs, models, software and videos—featuring more than 18 species.
- ✓ Join the growing number of teachers throughout the U.S. and Canada who have discovered the educational advantages of using alternatives to dissection.
- ✓ Find out how easy it is to borrow these exciting “hands-on” alternatives for your classroom.



FREE LOAN PROGRAM. CALL 1-800-888-NAVS

The National Anti-Vivisection Society, 53 W. Jackson Blvd., Suite 1552, Chicago, IL 60604 Visit our Web Site: <http://www.navs.org> © 2001, NAVS

Box 2. Suggested Practical Exam Questions

Station 1. Describe the macroscopic characteristics of Mold A.

(Students observe a plate with Mold A on it.)

Station 2. Describe the microscopic characteristics of Mold A.

(Students observe a microscope slide of Mold A.)

Station 3. Based on the colony color of the mold on the plate, what predictions would you make about the microscopic appearance of the hyphae?

(Students observe a plate with either a darkly-pigmented mold or a white mold.)

Station 4. Draw the structure of the mold spores you observe on this microscope slide.

(Students observe a microscope slide of a mold with well-defined spores.)

Station 5. How many different mold types do you see on this plate?

(Students observe a plate with a variety of mold colony types.)

mold types between cafeterias, classrooms, restrooms, libraries, and gymnasiums. Comparisons could also be made between smaller- and larger-sized rooms, or between different grade-level classrooms. Different options could be presented to students who could then discuss and design the experiment.

For the daily observations of the molds, the students may wish to use rulers to measure changes in the diameter of the mold colonies as an indication of growth. Comparisons can then be made between the different types of molds and their growth rates.

These studies could also be performed without the microscopic identification of the mold types. The students could count and tabulate the numbers and visually determine different types of molds they see for each plate without knowing the identity. This could be performed with or without the preparation of a mold identification key. If the teacher chooses to prepare a key, images of the different mold types could still be compiled and identified as mold colony type 1, mold colony type 2, etc. Prepared microscope slides of fungi could be purchased to demonstrate various mold microscopic morphologies. However, in our experience, the students are very inquisitive about what they were actually able to culture from their school!

Student Assessment

For our experiment, students maintained laboratory notebooks with Title, Purpose, Procedures, Results, and Conclusions sections. In the Results section, they included their daily observations of mold colony growth as

well as tables of their group and class data. The students were also required to prepare a formal laboratory report with computer-generated tables, statistical analysis, and a discussion of their results. The formal report and results table were prepared during their computer lab time. Students were required to include at least five references from the library or the Internet using an appropriate format for the citations. The students also prepared a poster for presentation to the entire faculty and principal. The poster was also presented in the science lab during the school Open House.

Students were evaluated on the experiment as part of a laboratory practical exam. They were asked questions based on the microscope slides or mold colonies on the plates. Students were given approximately two minutes at each station and wrote their responses to questions on a prepared answer sheet. Sample practical questions are shown in Box 2.

Ecological, Personal, Social & Historical Perspectives

This laboratory exercise was designed to both introduce and excite students about fungi. The students were amazed at the range of colors and textures of the molds and that microscopically they were composed of specialized structures. Yet some were shocked that these odd-looking forms could potentially grow in their own environment. Their discovery of molds evolved into many opportunities for us to incorporate middle-school science standards, particularly the students' own inquiry-based design of the experiment, studying structure and function, reproduction, and diversity of the fungi, as well as the personal, social, and historical impacts of the fungi (Table 3).

Before this exercise, many students may be unaware of fungal diversity, yet there are an estimated 1.5 million fungal species. (Raven et al., 2005). As students observe the rapid mold growth on their plates, they can be introduced to the phenomenon of fungi such as *Armillaria ostoyae* having the capacity to grow into a mycelial mass covering up to 2,200 acres (Ferguson et al., 2003). Fungi are being used as biocontrol agents for insect pests and plants (Becker, 1998). Plants can also benefit from endophytic fungi that can produce toxins thereby preventing predation by grazing animals (Ball, 1993; Clay & Holah, 1999; Mileus, 2003). Fungi themselves can be predators as well, using their hyphae as a snare to trap nematodes (Gray, 1985). These are just some of the many examples of adaptations of fungi and their ecological significance to which students can be introduced.

The fungi also exemplify important personal and social perspectives. Fungi are important to the students' personal health. They are an increasing cause of

Table 3. Importance of Fungi

POSITIVE IMPACTS

NEGATIVE IMPACTS

ECOLOGICAL AND ENVIRONMENTAL

Decomposition of rock and organic matter in soil and water—recycles CO₂ and minerals.

Mycorrhizae—fungi attached to plant roots—plant feeds the fungus through photosynthesis and the fungus anchors plant in soil and improves uptake of minerals such as phosphorus from soil.

The seedlings of orchids (the largest plant family) are parasitic on fungi.

Lichens—symbiotic associations of fungi and cyanobacteria or green algae—serve as food for animals.

Molds such as *Metarhizium* and *Hirsutella* are used for the biocontrol of insect pests.

Endophytic fungi—fungi living within plants—produce toxins preventing predation by animals.

Some leaf-cutter ants grow edible fungi on pieces of leaves in their underground nests.

White rot fungi are used in the bioremediation of organic chlorine compounds.

Fungal diseases of plants—including Dutch elm disease—caused by *Ophiostoma ulmi*—since 1930 have killed over half of the elm trees in the northern United States.

Fungi connect myco-heterophytes—plants that lack chlorophyll and are parasitic on trees—to their tree host.

FOOD AND AGRICULTURE

Edible mushrooms—including morels, shiitake, truffles, portobello

Foods containing edible yeast and other fungi such as Vegemite, Quorn myco-protein^a, and protein animal feed

Yeast or mold fermentation of grains, fruits, vegetables, and milk for products such as breads, beer, root beer, cider, vinegar, wine, sake, and soy sauce

Yeasts and molds provide flavor and color for some cheeses such as Camembert, Limburger, Roquefort, and Gorgonzola.

Aspergillus and *Candida albicans* are used for the production of the food preservative citric acid.

Carcinogenic aflatoxins produced by *Aspergillus* infecting seeds of peanuts and corn

Fungal diseases of grain, corn, and other agricultural plants including rusts, smuts, and powdery mildew

Fungal spoilage of fruits and vegetables—especially impacts poor nations with little refrigeration

Endophytic fungi result in livestock loss due to grazing on plants containing fungal toxins.

HEALTH AND SOCIAL

Source of antibiotics—penicillin and cephalosporins

Source of steroids and vitamins

Source of the immunosuppressive drug cyclosporine and anti-cancer drug taxol

Source of the cholesterol-lowering drug lovastatin

Fungal diseases of humans—including histoplasmosis, blastomycosis, sporotrichosis, ringworm, Athlete’s foot, aspergilliosis, and candidiasis

Allergies

Aflatoxins produced by *Aspergillus* are potential bioterrorist weapons.

COMMERCIAL AND INDUSTRIAL

Fungi are used to produce alcohols, glycerol, enzymes, and detergents.

Giberella fujikuroi is the source of the plant hormone gibberellic acid—used in beer-making and increasing the size of seedless grapes.

Bracket fungi are used to create a unique form of art^b.

Fungal contamination of paints, industrial coolants and lubricants, petroleum products and fuels

Fungal contamination of paints, industrial coolants and lubricants, petroleum products and fuels

^a For more information on Vegemite and Quorn myco-protein, go to <http://www.vegemite.com.au/> and <http://www.quorn.us/>.

^b To view the bracket fungi art, go to <http://www.dec.state.ny.us/website/dpae/cons/nellie.pdf/>.

2005/2006 Science Catalog

Over 400 pages of living organisms, biological materials and science teaching products.

Every product in our catalog can also be ordered online at **ctvalleybio.com**

Request a catalog by phone **800.628.7748** or online at **ctvalleybio.com/catalog.html**

Use code **NABT2** for your 20% off coupon.

20%
off your first
order from our
new catalog!

CONNECTICUT VALLEY
BIOLOGICAL
SUPPLY COMPANY

Acknowledgments

The supplies for this project were purchased through a grant from the National Institutes of Environmental Health Sciences obtained through the Outreach Center at the Vanderbilt University Center in Molecular Toxicology, Nashville, Tennessee.

The authors wish to thank the students and teachers, especially Mrs. Kathleen Schroeder, and the principal, Sister Ann Marie, of St. Rose of Lima Catholic School, Murfreesboro, Tennessee, for their participation in this project. We are also grateful to the anonymous reviewers of this manuscript for their helpful comments, suggestions, and references.

illnesses in our society due to increasing numbers of AIDS patients who are immunocompromised. Many who suffer from allergies are sensitive to molds and their spores. Fungi can cause infections such as ringworm or athlete's foot, and the indoor molds especially are gaining notoriety because of their association with sick building syndrome (Kuhn & Ghannoum, 2003; Scheel et al., 2001). In addition to impacting society by causing disease, some fungi also provide us with sources of nourishment (as on the mushroom pizza) and the endproducts of fungal metabolism can result in breads, beer, and wine, and add color and flavor to several cheeses such as Roquefort and Camembert.

Fungi may have also impacted human history. The grain, rye, is sensitive to contamination by a mold, *Claviceps purpurea* that produces a toxin. The toxin induces convulsions and hallucinations when consumed with infected grains. This is known as ergot poisoning. In 1692 in Salem, Massachusetts, 30 children and teenagers claimed to be victims of bewitchment. The victims experienced convulsions, sensations of being pinched or bitten, burning sensations, speechlessness, and sensations such as flying outside their bodies. All of these are symptoms of ergot poisoning and rye was one of the predominant crops of Salem. Additionally, the symptoms of the children began the previous November and December, a time at which there would have been ample time for growth of the fungus on unthreshed rye being stored in barns since the fall harvest. This fungal toxin may have lead to the false accusations and persecution of several individuals (Caporael, 1976). Lessons such as these not only captivate students but further stress the importance of the invisible world around them.

References

- Ball, D. M. (1993). The tall fescue endophyte. *American Scientist*, 81, 370-379.
- Becker, H. (1998). Setting the stage to screen biocontrol fungi. *Agricultural Research Magazine*, 46, 10.
- Caporael, L. R. (1976). Ergotism: the satan loosed in Salem? *Science*, 192, 21-26.
- Clay, K. & Holah, J. (1999). Fungal Endophyte symbiosis and plant diversity in successional fields. *Science*, 285, 1742-1744.
- Ferguson, B. A., Dreisbach, T. A., Parks, C. G., Filip, G.M. & Schmitt, C.L. (2003). Coarse-scale population structure of pathogenic *Armillaria* species in a mixed-conifer forest in the Blue Mountains of northeast Oregon. *Canadian Journal of Forest Research*, 33, 612-623. Available online at: http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_abst_e?cjfr_x03-065_33_ns_nf.
- Gray, N. F. (1985). Ecology of nematophagous fungi: distribution and habitat. *Annual Review of Applied Biology*, 52, 431-437.
- Kuhn, D. M. & Ghannoum, M. A. (2003). Indoor mold, toxicogenic fungi, and *Stachybotrys chartarum*: infectious disease perspective. *Clinical Microbiology Reviews*, 16, 144-172.
- Larone, D.H. (1995). *Medically Important Fungi: A Guide to Identification*. Washington, DC: American Society for Microbiology Press.
- Mileus, S. (2003). Sweet lurkers: Cryptic fungi protect chocolate-tree leaves. *Science News*, 164(24), 374.
- Raven, P. H., Johnson, G. B., Losos, J. B. & Singer, S. R. (2005). *Biology*. Boston, MA: McGraw-Hill Publishing.
- Scheel, C., Rosing, W. C. & Farone, A. L. (2001). Possible cause of sick building syndrome in a Tennessee middle school. *Archives of Environmental Health*, 56, 413-417.