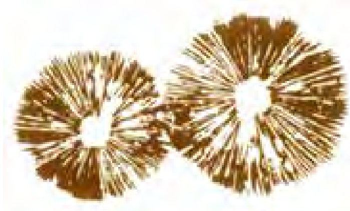
SPORE PRINTS



BULLETIN OF THE PUGET SOUND MYCOLOGICAL SOCIETY
Number 535 October 2017

FIELD TRIPS: WHAT TO DO, WHAT TO EXPECT

Wren Hudgins
Chair, Field Trip Guiding Committee

We are starting our Fall field trips on Sept. 23, and PSMS members may have differing expectations, especially new members, regarding the experience. First, there is a lot of good information on our website, so be sure to read that. Field Trip Chair Brian Luther has been fielding a lot of questions, one by one, so I thought I'd send out some general information that might answer the next dozen questions before they are asked.

Who Can Come: Unless specified otherwise, no reservations are necessary for any trip. Trips are for members and are considered a member benefit. On occasion in the past, we have let members bring one non-member guest, once, as sort of a free trial, to see if they like the experience enough to join. If you are in that situation, ask Brian if it's OK to bring one friend once.

General Schedule: Members generally arrive at the trip site between 8 and 9 am. We have volunteer hosts who come early, set out breakfast items, and make coffee. Brian often makes a fire, and that first hour of the day is very pleasant and relaxing. Somewhere around 9:30 am Brian gives a short talk in which he goes over collecting gear, thanks the trip hosts, and sets the time for the potluck. Then someone (usually me, but not for the first two trips this Fall) gives a short safety talk and organizes attendees into guided groups if they want a guided experience.

Field Trip Guides: We have some experienced members who are willing to forego their own hunting (thank them) to lead a group of beginners into the woods. If there are more members wanting a guided group than we have guides to take them out, then preference will go to those who have never had a guided experience. Arriving late guarantees you won't be going out with a guide. Although there can always be last minute changes, the guides at the first trip will be Sweta Agrawal, Shannon Adams, Merly Pacaba, Jamie Ardeña, and Dan Paull

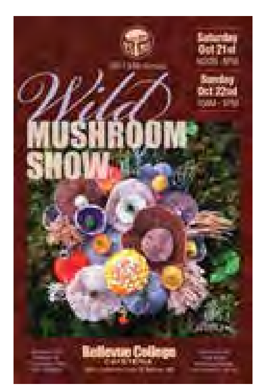
There will be a chance to sign up with one of the guides, but not everybody gets to do that every trip. The guided groups will typically be out for 2.5 to 3 hours, sometimes driving from the trip site and sometimes walking. No one guide is better than another. No one has a stash of secret spots that they will reveal to you. We can recognize promising terrain, but we can't promise there will be mushrooms there. We can talk about what we hope to find, the correct habitat, hunting strategies, etc. These trips are planned a year in advance, and we have no idea about rainfall, which is a major factor in the timing of mushroom fruiting. *There is NO GUARANTEE of finding edible mushrooms*.

What Do We Guarantee? We'll promise some mushroom education and an enjoyable social experience if you stay for the potluck after hunting. The potluck is often set for about 4 pm or 4:30 pm so that folks can enjoy the socializing and the food and still get home at a reasonable hour. Most field trips are close enough to the Seattle area that the whole experience can be had in one day. Some trips are pretty far for a one-day trip.

So What Are Your Responsibilities?

1. Read the material we write about the field trips. We went to some trouble to write it.
2. Dress appropriately for the weather. Even if it's not raining, you may be walking through wet brush.
3. Bring safety gear (Google "the ten essentials") and water. Walkie talkies are helpful and navigation gear (compass, GPS) is very helpful.
4. If you want to go out in a guided group, bring a whistle as you will not be permitted into a group without one. We have a limited number of whistles we can give out to forgetful members, one per forgetful member, per lifetime.
5. Bring a basket or bucket or some container in which to carry mushrooms and a knife to cut them with. Do not use plastic sacks.
6. Groups often split up in the woods, and some members stray so far away that they get separated from their group leader. We'll do our best to get you into the woods and back out again safely, but ultimately it's YOUR responsibility to know where you are and to be able to get yourself safely back. If you can't manage this responsibility, then it's best not to go out in one of our groups (and I'd question the wisdom of going into the woods at all).

Almost everyone has a good time, mushrooms or no mushrooms, but we do get occasional complaints about the paucity of edible mushrooms, which is one reason I'm writing this.



Spore Prints

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CALENDAR

Oct. 10	Membership Meeting, 7:30 pm, CUH
Oct. 10	Watercolor class, noon–4 pm, CUH
Oct. 13	Field Trip (see website members' section)
Oct 13–15	Ben Woo Foray, Camp Berachah Ministries/ Black Diamond
Oct. 16	Board Meeting, 7:30 pm, CUH
Oct. 21–22	Annual Wild Mushroom Show, main cafeteria, Bellevue College
Oct. 24	*Spore Prints* deadline
Oct. 28	Field Trip (see website members' section)

BOARD NEWS

Luise Asif

Derek Hevel, Kim Traverse, and Milt Tam are organizing the **PSMS Fall Show**, October 21 & 22. Shannon Adams will coordinate collection of samples. Help is needed for the show; please *sign up to volunteer* with Luise Asif, fasif@hotmail.com, or on the website. The **Ben Woo Foray** on October 13–15 was full by August. James (Animal) Nowak has lined up an exciting list of speakers. Now that the rains have come, the **Bridle Trails Survey** will resume; the schedule is being prepared. Derek has prepared a detailed protocol which is easy to follow. The **Field Trip committee** under Wren's leadership is working on procedures to ensure that all have a very positive experience. Here, again, volunteers are needed to host.

MEMBERSHIP MEETING

Tuesday, October 10, 2017, at 7:30 pm at the Center for Urban Horticulture, 3501 NE 3lst Street, Seattle

Gary Lincoff

Our speaker for October is Gary Lincoff, past president of the North American Mycological Association, who will enlighten us on why "Mushrooms ARE the key, not just something to "key out." His talk goes beyond names and edibility to connect the dots, to show how everything around us—wildflowers and trees and mountains and dirt—is connected to mushrooms, and how we are more intimately related to them than we ever imagined!

Gary Lincoff is the author and editor of several books and articles on mushrooms, including *The Audubon Society Field Guide to North American Mushrooms*. He teaches courses on mushroom identification at the New York Botanical Garden, has led mushroom study trips and forays around the world, and is a featured "myco-visionary" in the award-winning documentary "Know Your Mushrooms." Gary's most recent book is *The Complete Mushroom Hunter*.

WATERCOLOR PAINTING WORKSHOP
(Instructor: Denis R. Benjamin)

Center for Urban Horticulture
Friday, October 20
12 noon–4 pm
Cost: $30

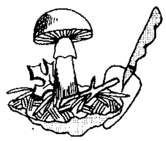
This half-day workshop is designed for those who would like to learn how to capture the beauty of mushrooms in watercolor. It is especially intended for beginners, but more experienced artists are also encouraged to attend this community paint-in. We will cover all the basics of watercolor painting, including papers, paints, basic techniques, lighting, staging your subject, etc. Everyone will paint at least one mushroom from live material during the class. Those who have paints and brushes are encouraged to bring them. We will provide paper, palettes, a limited selection of paints and brushes, and other materials (pencils, erasers, etc.) at an additional materials cost of $20. Watercolor painting will give you new ways to view and observe mushrooms. Even those who claim that they can't draw a stick-figure will be surprised at what they can really do. To provide everyone the attention needed, enrollment will be limited to the first 12 who register. You can sign up for this workshop on the PSMS website.

Denis Benjamin is a retired pathologist and former PSMS member. Self-branded as the "Cowtown Curmudgeon," he currently lives in Dallas, but his love of the Pacific Northwest and our local mushrooms brings him back to our forests year after year. An accomplished essayist and speaker, he has also taken to watercolors, where he has become quite expert in creating images of mushrooms as an art form. He contributed a watercolor painting last year for use as our Fall Wild Mushroom Show poster, which was widely acclaimed as one of the best posters we've designed.

Denis Benjamin

COLLECTING FOR THE SHOW

Marian Maxwell and Derek Hevel



We need YOUR mushrooms for display at the Wild Mushroom Show October 21–22! This year's lack of rain makes the plea more urgent. Beginning in mid-October, bring **every mushroom** you can find. We are also reviving earlier efforts to support mycological science with more info from collectors.

Here are some collecting guidelines for accomplish both efforts:

Where to Collect: Find mushrooms on your own or with an organized collecting group Thursday or Friday (Oct. 19–20). Please email Derek Hevel (see below) if you would like to drive or forage with a collecting group. Trip information will be announced via email.

How to Collect: Before you go, stock up on plastic containers, foil, and wax bags to hold your specimens. Get the entire mushroom, even structures under the ground. Protect them all the way to the show because they will have to stay fresh and intact through Sunday. Geotrophic mushrooms like Amanitas that orient their gills to the ground can be stood upright in empty milk cartons. Bring in even the most common mushrooms, since others often assume someone else will. Gather the delicate inky cap families on Friday or Saturday morning. Store smaller specimens separately in yogurt containers or the like, and mist (but not soak) them to keep them fresh and colorful.

Bring Duff/Moss/Etc. for Displays: It helps to include a few leaves from the nearest trees or grass snippets for the grass-inhabiting varieties, both for ID and for display. For general display use, please include some additional organic matter (duff, grass, leaves, bark) with what you bring to the show.

Record Collection Details: Put all your finds from one location in one container and add a paper label with your name, phone number, and location. A slip of paper is enough! You can keep your secret edible locations to yourself since we are trying to feed science, not our stomachs. We ask for your name and phone number on the chance that a researcher may request further info, but the written location alone is invaluable.

Drop Off Your Mushrooms: Show receiving is Friday night after 5 pm and Saturday morning at the tent outside the Bellevue College cafeteria (look for the signs). After drop-off, please allow the previously approved sorting and categorizing team to manage your specimens.

If you have collecting questions, please contact Derek Hevel at dhevel@yahoo.com. For general inquiries and questions about sorting or display at the show, please contact Marian Maxwell at pastpsmspres@yahoo.com (phone 425.235.8557).

MICE FOUND ABLE TO WARD OFF FUNGAL LUNG INFECTIONS BY CAUSING FUNGUS TO KILL ITSELF

Bob Yirka

https://medicalxpress.com/, Sept. 8, 2017

(Medical Xpress) - A team of researchers from the U.S., Germany, and Israel has found that mice are able to ward off fungal lung infections because their immune systems cause fungal spores to die. In their paper published in the journal *Science*, the team describes the means by which they discovered how mice are able to ward off fungal lung infections and what their findings might mean for human patients.

Fungi are all around us, so much so that most people breathe in approximately 1000 fungal spores every single day. But the means by which people ward off fungal infections in the lungs has not been understood. In this new effort, the researchers looked to mice to better understand how they ward off fungal infections in their lungs.

The researchers modified a strain of *Aspergillus fumigatus* (a fungus commonly associated with causing pneumonia in people) to change color when cell death instructions kicked in. Mice, humans, and many other creatures (including fungi) have cells with a built-in self-destruct mode—it is how we maintain a new supply of cells. Once a cell reaches a certain age or is damaged, a signal launches a sequence of events that results in apoptosis, or cell death. After death, it is cleaned from the body. By causing the fungus spores to change colors when this process was activated, the researchers observed that it occurred shortly after immune cells arrived and began interacting with them. This resulted in the death of the spore, preventing an infection from occurring.

The researchers also found that *A. fumigatus* had a gene (AfBIR1) whose function was to inhibit cell death. Causing the gene to be more active in mice led to more lung infections, while doing the reverse led to fewer infections. This finding, the researchers note, might offer a treatment for people with compromised immune systems who are typically more susceptible to fungal lung infections. Developing a drug that suppresses AfBIR1 in fungi infecting humans could conceivably save many lives.

THE IMPACT OF ELEVATED CO_2 ON A WIDESPREAD ECTOMYCORRHIZAL FUNGUS

http://www.co2science.org, Sept. 18, 2017

Ectomycorrhizal (EM) fungi play an important role in soil biogeochemical cycles and substantially influence net ecosystem primary production. Yet, despite their importance in this regard, little is known about how EM fungi might respond to both natural and anthropogenic changes in climate.

Seeking to provide some knowledge in this regard, McCormack *et al*. (2017) set out to study a widespread and abundant EM fungus, *Cenococcum geophilum*, which maintains a near-global distribution, having been observed in "essentially all forested biomes ranging from high latitude boreal forests, temperate forests, as well as wet and dry tropical forests." Specifically, they used minirhizotron camera systems to examine the spatial and temporal changes in *C. geophilum* in a loblolly pine stand in central North

cont. on page 4

Elevated CO_2 Impact, *cont. from page 3*

Carolina over a 12-year period (1999–2010) in response to elevated CO_2 and nitrogen treatments. CO_2 enrichment (+200 ppm above ambient) was provided using Free-Air-CO_2-Enrichment (FACE) technology and was initially administered 24 hours per day, except when air temperatures fell below 5°C or when wind speeds exceeded 5 ms^{-1}. Midway through the experiment in 2003, CO_2 enrichment was limited to daylight hours only. Nitrogen fertilization was applied to half of the ambient and CO_2-enriched plots at a rate approximately an order of magnitude larger than background deposition rates.

Results of the analysis revealed that nitrogen fertilization strongly decreased *C. geophilum* production while CO_2-enrichment increased it. Averaged across their entire study, McCormack *et al*. report there was "roughly 50% greater production of *C. geophilum* ectomycorrhizas with elevated CO_2 compared to control plots but this difference was only significant during the second half of the study despite large initial decreases." Nitrogen fertilization, in contrast, reduced production by 83% compared to background levels. McCormack *et al*. also report that there was no significant interaction between elevated CO_2 and nitrogen fertilization on the persistence (lifespan and disappearance) of *C. geophilum* ectomycorrhizas.

In light of the above findings, it would appear that, given the near-global distribution of this EM fungi and its importance in stimulating ecosystem productivity, the positive impact of elevated CO_2 on *C. geophilum* production (~50% increase for a 200 ppm rise) represents a welcomed benefit for the future of Earth's forests.

McCormack, M.L., C.W. Fernandez, H. Brooks, and S.G. Pritchard. 2017. Production dynamics of *Cenococcum geophilum* ectomycorrhizas in response to long-term elevated CO_2 and N fertilization. *Fungal Ecology 26*: 11–19.

RESEARCHERS IDENTIFY NATURAL COMPOUND THAT APPEARS TO SHUT DOWN CANCER CELLS' ENERGY SOURCE

Victoria Ritter

http://gearsofbiz.com/, Sept. 16, 2017

The Warburg Effect describes a phenomenon in which cancer cells voraciously consume glucose for energy—something scientists have long known, yet have had little success exploiting as a way to stunt tumor growth.

Now researchers at Duke Cancer Institute have not only untangled an unusual wiring system that cancer cells use for carbohydrate metabolism, but also identified a natural compound derived from a fungus that appears to selectively shut down this system in laboratory studies.

"The Warburg Effect has been known for decades, but the underlying mechanisms are not well understood," said Jason Locasale, assistant professor in the Department of Pharmacology & Cancer Biology at Duke and senior author of a study published Sept. 14 in the journal *Cell Metabolism*. "We started with the idea that if you understand how it works, you should be better able to control it, and we think we might have some insight on that, as well."

Locasale and colleagues, including lead author Maria Liberti, studied cancer cells to determine how their metabolism changes so dramatically from that of normal cells, which use oxygen to break down sugar. Cancer cells, instead, use fermentation, which is less efficient and therefore uses more sugar.

The researchers found particular points where carbohydrate metabolism is controlled differently in cancer cells undergoing the Warburg Effect, and they homed in on an enzyme, identified as GAPDH, that controls the rate at which glucose is processed in cancer cells.

And while the Warburg Effect is strong in many cancers, it's absent or weaker in others. By measuring the GAPDH enzyme, the Duke team was able to develop a predictive model to measure how extensively cancer cells are under the influence of the Warburg Effect. Where the effect is strongest, the tumors could potentially be vulnerable to a therapy that targets the process.

"We've seen with genetics that cancers can be targeted based on whether certain mutations are present, and it could be that selectively targeting tumors based on their metabolism could have a similar impact," Liberti said.

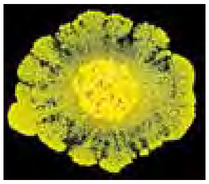
Armed with their findings, the researchers then scoured the literature to see if there were any known compounds that might block the GAPDH enzyme. One molecule called koningic acid, or KA, seemed to have potential. It was discovered 30 years ago as part of a search to find drugs that lower cholesterol. That quest led to statins, and KA was abandoned.

The molecule is produced by a sugar-eating fungus [*Trichoderma koningiopsis*] that colonizes sugar-rich environments such as sweet potatoes. The fungus generates KA to ward off bacteria that might try stealing its sugar source. Suspecting that KA might be a natural molecule that targets organisms or systems involved in accelerated glucose metabolism, the researchers tested the molecule in cancer cells and mouse models.

They found that KA does, indeed, selectively inhibit the GAPDH enzyme, curbing the ravenous glucose consumption in tumors undergoing the Warburg Effect and leaving normal cells alone.

Locasale said their findings warrant further study, notably to determine whether KA's effects can be reproduced in additional animal and cell studies and whether other drug-like molecules might work along the same energy pathway.

"These findings not only show that KA's efficacy is linked to the quantitative extent of the Warburg Effect, but that this also provides a therapeutic window," Locasale said. "This could provide another way to attack cancer beyond the genetic makeup of the tumor. That's encouraging."



Physsarum polycephalum.

MYXOMYCETE POEM

G.W. Martin

Bulletin, Boston Myco. Club, Spring-Summer 2017

Come everybody, gather round;
get ready for a treat;
The subject of my discourse is
THE MYXOMYCETE

I grieve to say the history
with scandal will be rife,
For every Myxo is compelled
to lead a double life.

At first, in piles of rotten leaves, in sodden logs or stumps,
Pretending to be animal, it crawls and creeps and clumps,
Then, ere it shifts to fungous form, it seeks the outer air,
And if your eyes are keen enough you're sure to find it there.

As animal, the shape it takes we call plasmodium;[1]
Bacteria and yeasts and spores serve as its pabulum;[2]
It eats them all and goes its way and waxes fat and strong,
Nor ever wonders whether such behavior may be wrong.

Its lack of moral scruple is without a doubt complete;
No conscience has been noted in the Myxomycete.[3]
Anon its fruiting stage begins. Before our startled eyes
It hastens to transform itself into a fungus guise.

With curious excitement all its veins become suffused,
Its nuclei meiotically divide and are reduced[4]
Into aethalium, sporange, or curved plasmodiocarp.
The change is sudden, quick, abrupt, distinct, decisive, sharp.[5]

It gleams as iridescent orbs[6] *or waves as feathered plumes,*[7]
Or livens up a bit of bark with particolored blooms,[8]
Or turns a dingy fallen leaf into a beauty-spot;[9]
But some of them, I must confess, are not so very hot.[10]

The firm peridium dries and splits and through each tiny tear
Each passing breeze releases spores by clouds into the air,
Until some capillitial tufts, an empty stalk or two,
Are all that's left to mark the place whereon the slime mold grew.

But now the spores have dropped by scores in humid cul-de-sacs;
There each small cell begins to swell and soon the spore wall cracks;
Out slips a protoplasmic globe which squirms a bit and then
Develops a flagellum and thus swims beyond our ken.[11]

It eats, divides, and eats again, but soon there comes a time
When food tastes flat, and life like that seems scarcely worth a dime.
Each lonely little swarm-cell seeks to find a fitting mate,
And round and round they dance in pairs, nor ever hisitate.[12]

They closer press, the clasp grows tight, and soon the two are one.
The nuclei fuse, flagella are retracted, and it's done.[13]

This is the new plasmodium. The cycle now repeats;
It joins with others, crawls around, and eats and grows and eats,
And in its time it fruits again, and so the tale is told
Of this, as every living thing, forever new, though old.[14]

The morals of my tale are neither many nor profound,
And since they are the common sort that everywhere abound,
I will not waste your time and mine by trying to expound —
Just help yourself to what you want and pass the rest around.

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1. Cienkowski, L. *Jahrb. wiss. Bot. 3*: 400–441. 1863.
2. Howard, F. L. *Am. J. Bot. 18*: 461–477. 1932.
3. Piffenpuffer, A. *Morality in Lower Organisms*. N. Y. 1891.
4. Wilson, M. and E. J. Cadman, *Trans. R. Soc. Edinb. 55*: 555–608. 1928.
5. Fairly so at any rate..
6. Cf. *Lamproderma columbinum* (Pers.) Rost.
7. Cf. *Stemonitis fusca* Roth.
8. Cf. *Badhamia utricularis* (Bull.) Berk.
9. Cf. *Diachea leucopodia* (Bull.) Rost.
10. E.g. *Brefeldia maxima* (Fr.) Rost, which looks like something you may step on in the cow pasture if you don't watch out. The genus was named by Rostafinski to perpetuate his feeling toward Brefeld.
11. Jahn, E. *Ber. deutsch. Bot. Ges. 22*: 84–92. 1904.
12. Silcox, Ella Leila. Love life in the Protista. Phila. 1895.
13. Wilson and Cadman, 1.c.
14. "Dust thou art, to dust thou shalt return."—G. W. Martin

HARVARD BIOTECH WIZ GRABS $55M TO CREATE DRUGS OUT OF FUNGI

John Carroll

https://endpts.com/, Sept. 18. 2017

It's hard not to enjoy talking with Greg Verdine about the new biotech companies he sets up. "What I am really passionate about is discovering new types of molecules that do things that can't be done by standard small molecules and antibodies," he told me in the lead-up to today's formal launch of LifeMine Therapeutics with a $55 million A round. "I want to go after undruggable targets, get drugs that people consider now aren't doable. The question is where you go looking for this."

The answer for Verdine, this time, is fungi.

"Fungi have been duking it out with their neighbors in the soil for a billion years," says Verdine, "stealing the lunch of their coworkers, competing, and fending off invaders using small molecules as competitive substances." And it all fits very closely with human proteins, giving it a good shot at working in humans.

It helps that evolution doesn't obey the same rules that guide medicinal chemists, and now Verdine's new company will rely on sequencing to follow this strange path in search of some radical new breakthroughs in cancer—a field that has attracted billions of dollars to back a new generation of therapies.

To do this, he says, the team has to "grow up fungi individually, isolate and sequence the DNA, and take the DNA and analyze it for biosynthetic gene clusters, an instruction set to make a natural product."

cont. on page 6

$55M to Study Fungi, *cont. from page 5*

Verdine blends multiple roles in biotech: Professor, venture partner at WuXi Healthcare Ventures—which seeded this new startup—and now a double CEO, with his dual role running Fog Pharma made easier by having both companies housed in the same building in Cambridge, MA.

Over the years Verdine has been one of the most prolific startup artists in the business, a go-to figure in the industry who's helped kick a slate of biotechs into existence, ranging from Enanta to Tokai, Aileron, and Warp Drive Bio, which he also helmed for a time.

Right now the team at LifeMine is made up of a dozen scientists and five DNA specialists, where they are focusing on programs and targets for the pipeline as they build the platform along the way. By mid-2019, Verdine expects the crew to expand to about 40 staffers.

It's still early days, though.

"We've left ourselves 3.5 years to enter the clinic," says Verdine.

That requires some very patient money, which Verdine lined up from WuXi Healthcare Ventures with a syndicate that includes Foresite Capital, Google Ventures (or GV, with Krishna Yeshwant joining the board), Arch Venture Partners, Boyu Capital, Blue Pool Capital, MRL Ventures Fund, and Alexandria Venture Investments.

Those blue chip VC names are mixing with some money out of two prominent Chinese investors, aside from the transpacific WuXi operation: Boyu—an influential private equity group led by co-founder and partner Sean Tong—and Blue Pool.

At this stage of his life, Verdine is positioned at exactly the right place, and exactly the right time, for a pricey space shot into the biotech universe. The stars have aligned—again.

MUSHROOM-SHAPED TREEHOUSE CROWNED SHED OF THE YEAR

Ben Leo

https://www.thesun.co.uk/. Sept. 17, 2017

Benedict Swanborough, of Chiddingfold, Surrey, scooped up a £1000 cash prize and beat almost 3,000 rivals for building a two-story Mushroom Shed. Swanborough, 47, hand-built the winning, wacky shack after daughter Elsie handed him £500 of her own savings and asked him for a treehouse shaped like a mushroom.

Benedict Swanborough and daughter Elsie display award outside their mushroom shed.

Swanborough and Elsie inside mushroom shed.

Swanborough got "carried away" and eventually spent more than double Elsie's budget on her dream, two-story Mushroom Shed.

The shed boasts a trap door, a stained glass window, and even a glass floor section which looks out onto a stream below at the bottom of the garden. He incorporated a "Deathly Hallows" design in brickwork outside the front door to Elsie's magical hangout to reflect her love of Harry Potter.

A circular hammock chair hangs from the exterior so that Elsie, now 13, can relax and take in the views.

And during treetop sleepovers she can gaze at the stars through a glass section in the roof. Inside, fungi paraphernalia includes a carved giant wooden mushroom on the floor and a wall chart entitled "Les Champignons" showing different types of mushrooms.

Swanborough's pride and joy saw off shedloads of rivals—almost 3,000—in Cuprinol's Shed of the Year competition.

Those finalists included old fashioned police and fire stations, a hedgehog hospital, and an underground man cave. Other memorably quirky entries included a miniature cathedral, a replica cinema, a whiskey tasting center, a flight simulator, and an entire train carriage.

The annual contest shows how sheds are now far more than mere humble havens from the family home for their fanatical and often eccentric owners.

A jubilant Swanborough sprayed champagne from the balcony of his shed as Elsie looked on proudly.

DIVERSITY, ECOLOGY, AND EVOLUTION OF MYRMECOPHILOUS *OPHIOCORDYCEPS*

John Burghardt

NIJA News, May–June 2017

João P.M. Araújo, our speaker on March 12, came to us from Minas Gerais, Brazil, by way of Penn State University, where he earned a Ph.D. in biology. João has a passion for fungi, especially for members of the *Ophiocordyceps unilateralis* complex, which use "zombie ants" for spore dispersal. João has collected and studied members of this group from tropical regions in the Brazilian Amazon, West Africa, and North America, and has named more than a dozen new species. The term "Myrmecophilous" ("ant-loving") in the title refers to organisms living in close association with ants, including pathogenic ones. Before zeroing in on *Ophiocordyceps unilateralis*, the talk provided background on the diversity, ecology, and evolution of fungi that are parasitic on insects, i.e., "entomopathogenic."

Although we seldom concern ourselves with fungi that don't produce mushrooms, it's worth highlighting the diversity of fungal parasites on insects. They have evolved in five of the major groups of fungi, as well as the closely related non-fungal group Oomycetes. Fungi have conquered diverse insect hosts, at all stages of development (egg, larva, pupa, adult), all across the world.

Oomycetes are a distinct lineage of fungus-like organisms. They are primarily plant pathogens, but twelve species in six genera are parasites on insects, especially mosquitoes.

Fungi that are parasitic on insects come from five major groups:

Microsporidia are spore-forming unicellular parasites once considered protozoans but now known to be fungi. They comprise 143 genera, of which 69 attack insects. Microsporidia attack 14 orders of insects, the broadest range of all the major groups of fungi.

Chytrids are an early, primarily aquatic, sister lineage of Ascomycetes and Basidiomycetes. They reproduce asexually through zoospores that propel themselves through the water with small tail-like structures. Several genera of Chytrids have only one species that attacks insects, but one genus, *Coleomyces*, has 63 insect-attacking species. The great majority of chytrid infections affect the insect genus *Diptera* (which includes black flies, mosquitoes, and other flies).

Entomophthoromycota, a recently recognized phylum of fungi, are mainly pathogens of insects. They have specialized spore-producing cells that obtain energy directly from sunlight. Spores are usually discharged forcibly. In contrast to Ascomycetes and Basidiomycetes, which switch from a parasitic to saprobic lifestyle after death of the host, this group includes several species that produce spores only before the death of the host.

This brings us to the two large groups of fungi that include mushrooms:

Basidiomycetes parasitic on insects are members of two genera of rusts, *Septobasidium* and *Uridinella*, affecting scale insects and one corticioid genus, *Fibularhizoctonia*, affecting termites. *Uridinella* attack single insects, whereas *Septobasidium* attack whole colonies. *Fibularhizoctonia* infects termites by making sclerotia that the termites mistake for their eggs.

Ascomycetes include many entomopathogenic fungi, especially in the order Hypocreales. Several orders include just a few species. Pleosporales includes several *Podonectria* species that infect scale insects, including the type species *Podonectria coccidola* (Ellis and Everhart, which appears to have been named from Florida). Myriangiales includes several species that infect scale insects. Most members of the genus *Ascophaerales* are saprophytes of the products of bees (honey, cocoons, nesting materials, or wax), but a few species of the genus are known to cause "chalk brood," a pathogen infecting larva that ingest spores.

The Hypocreales include a number of important genera of entomopathogenic fungi, such as *Cordyceps*, *Tolypocladium*, *Hypocrella*, *Ophiocordyceps*, *Moelleriela*, *Samulesia*, and *Torrubiella*. These genera attack insect species from 12 different orders of insects.

The Hypocreales appear to have played a role in the evolution from endophytes living in the tissue of plants to insect-pathogenic fungi that derive plant-based nutrition from insects. A large number of Ascomycete species in the Hypocreales order are pathogens of Hemipterans (true bugs). Insects arose very early in evolutionary time. Flowering plants arose about 100 million years later than insects. The co-diversification of flowering plants and insects prompted Hemipterans to diversify their mouth parts in ways that enabled them to draw fluids from the tissues of plants. At the same time, ancestors of the Hypocreales were living within flowering plant tissues as endophytes. To exploit this new source of nourishment from flowering plants, the fungi switched from a plant-host to an insect-host ecology. This is one of five to eight host-jumping events between Plant, Animal, and Fungus among members of the order Hypocreales.

The fungi of the *Ophiocordyceps unilateralis* complex were the stars of the show. They have evolved an elegant reproductive strategy that involves manipulating the behavior of the host ant. A phylogenetic tree of over 80 species in the genus *Ophiocordyceps* showed 45 species that attack ants. Of these, 13 species comprise the *O. unilateralis* complex. Their reproductive strategy was shown in a stunning time-lapse video. It went as follows:

(a) Spores are dispersed from a dead ant above the forest floor, and fall to the ground beneath the dead ant. The spores are designed to fall within a small area and to stay put where they land.

(b) Two weeks later, small fruiting bodies of the fungus appear on the forest floor, creating a minefield for healthy ants as they forage. Fungal fruiting bodies attach themselves, unnoticed, to the bodies of the healthy foraging ants.

(c) Over the next ten days, the fungus penetrates the exoskeleton of the ant and begins to put out small threadlike fungal structures on its surface.

(d) About ten days after infection, the fungus induces the infected ant to leave its colony and seek out an ideal micro-climate for development and dispersal of the fungal spores. The ant climbs to a very specific location on a leaf and bites into the edge or vein of the leaf.

(e) At this point, the ant dies, holding fast with its locked jaws to the leaf. The fungus switches from a parasitic to a saprobic nutritional mode, and the fungal structures continue to grow within and outside the ant cadaver.

(f) Two to eight weeks after the ant's death, a fungal fruiting body emerges from the back of the ant's head. Ascospores are launched from this structure.

(g) Between 24 and 72 hours after the spores are launched, they germinate and form secondary spores, adding to the minefield which will infect more healthy foraging ants.

The life history of *O. unilateralis* is an interesting example of behavioral manipulation of one species by another. In this case, a fungus manipulates an animal in ways that increase the ability of the fungal species to survive. Behavioral manipulations of arthropods by fungi are very diverse and have evolved independently several times. Scientists are applying new techniques and their relatively deep knowledge of ants to begin answering the interesting question of how a species without a brain comes to manipulate a species with a brain to increase its own fitness to survive.

A fascinating glimpse into the ways fungi, animals, and plants depend on each other.

PLASTIC-EATING FUNGUS DISCOVERED IN ISLAMABAD GARBAGE DUMP

The Dawn/Asia News Network, Sept. 21, 2017

Pakistani and Chinese researchers have discovered a fungus that feeds on plastic in a rubbish dump in Islamabad.

A study titled "Biodegradation of Polyester Polyurethane by *Aspergillus tubingensis*," authored by nine researchers from Pakistan and China who stress the need for "new, safer, and more effective ways to degrade waste plastic," found that the fungus *Aspergillus tubingensis* can break down non-biodegradable plastic in weeks by secreting enzymes that pull apart individual molecules.

Lead author of the study, Dr. Sehroon Khan from the World Agroforestry Centre/Kunming Institute of Biology, was quoted by the World Agroforestry Centre as saying that her team had been looking for ways to degrade waste plastic that "already existed in nature."

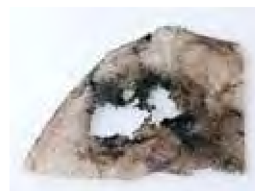
"We decided to take samples from a rubbish dump in Islamabad, Pakistan, to see if anything was feeding on the plastic in the same way that other organisms feed on dead plant or animal matter," she said.

The study says that *A. tubingensis* was tested in liquid, soil, and Sabouraud Dextrose Agar (SDA) plate—which is primarily used for the isolation of dermatophytes, other fungi, and yeasts—in order to discover the ideal conditions for it to be most effective.

Khan and her team discovered that while the fungus decomposed plastic in all three media, bio-degradation was highest when it was cultured on an SDA plate, followed by liquid and soil, respectively. According to the World Economic Forum, the fungus lives in soil, but researchers say that it can also survive on plastic surfaces. On its own, the plastic can take decades to decompose and is dangerous as it can carry carcinogens as well as other lethal pollutants.

The discovery of *Aspergillus tubingensis* may prove to be a solution to this threat. The fungus can be used in waste treatment plants to treat plastic particles that have polluted water supplies as well as soil.

This discovery is the most recent in the field of mycoremediation, a process that uses fungus to degrade polluting substances.



Aspergillus tubingensis eating plastic.

Note: The field trip on Oct. 7 has been cancelled.

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