The Potomac
Sporophore
Spring | April 2016 Volume No. 31 | Issue No. 2
The quarterly publication of the Mycological Association of Washington, Inc. (MAW) | www.mawdc.org

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In This Issue:

Fungal Reproductive Processes (Mushroom Sex)

William Needham
First Vice President

The physiological complexity of the fungi is manifest in their diversity; there are estimated to be 1.5 million different species of which only about 69,000 have been identified. These statistics are indicative of the reproductive fecundity of the fungi in initiating and replicating a broad taxonomy and of the limitations in our understanding of their nature, which includes the physiology of the reproductive process. While the reproductive processes of the Kingdoms *Plantae* and *Animalia* are well known, the fungi of the Kingdom Eumycota (also known as Myceteae), are not. Sex refers to the division of living species according to their reproductive roles, traditionally the female as the guardian of the egg and the male as the purveyor of the sperm. This dichotomy is very distinct in animals and to a somewhat lesser extent plants; in a perfect flower both sexes are represented. Some fungi, particularly the simpler and more primitive forms, have something more or less analogous to male and female sexes. However, the more complicated forms like the basidiomycete mushrooms have a much more complex relationship that involves multiple combinations of paired individuals whose union results in reproduction. In order to comprehend mushroom reproduction and attendant "sexuality," it is necessary to establish a lexical framework on which to base the discussion.

The most important aspect of reproduction is the transmission of the DNA code from one generation to the next, as it critically establishes speciation and allows for random mutation. Reproduction is initiated by the union of the male sperm and the female egg in most animals, the pollen from the male anther and female pistil in (flowering) plants, and by several variations on the theme; the end result is the same. Both males and females carry the same number of chromosomes; the number varies according to species (23 in humans) and is usually denoted simply by the letter n; the single chromosome set cells are called haploid, derived from the Greek word for 'single'. When the two haploids combine, the result is 2n; a fertilized egg or zygote – also a double haploid or diploid. The zygote, Continued on Page 2

Going Bananas: Could Fungal Disease Eradicate a Favorite Fruit?

Thomas Roehl
Newsletter Editor

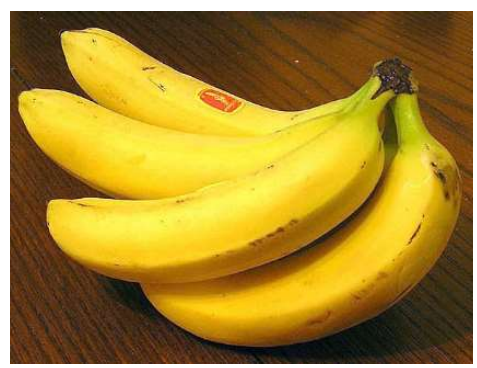
Bananas are ubiquitous in American culture. From snack food to dessert ingredient to comic fodder, this fruit fills several diverse roles. Recently, though, nearly every news outlet has featured an article suggesting that the banana's days are numbered.

The reason for this bleak outlook is that Panama disease – an old enemy of banana growers – has re-emerged with the ability to kill the previously resistant Cavendish banana. A variety of this disease has been spreading across the world for the past three decades, drawing ever closer to the main banana-exporting countries in Latin America.

The fear today is that Panama disease will be as destructive as it was in the 1950's, when it wiped out the popular Gros Michel banana variety. Although banana growers have had ample warning this time around, they have not been able to find an acceptable alternative to the Cavendish.

History of the Banana

Bananas have been cultivated for a very long time. The banana was first cultivated somewhere in Southeast Asia, where many banana relatives still grow wild. Samples of organic material found at archaeological sites suggest that banana cultivation began around 5,000 B.C.E. A Sanskrit text dating from


Generally, supermarket dessert bananas are all Cavendish bananas.

around 500 B.C.E. is believed to contain the first written reference to the banana. After spreading across Southeast Asia, Arabic peoples brought the banana to Africa. In fact, the word 'banana' comes from the Arabic word for 'fingers.' Continued on Page 9

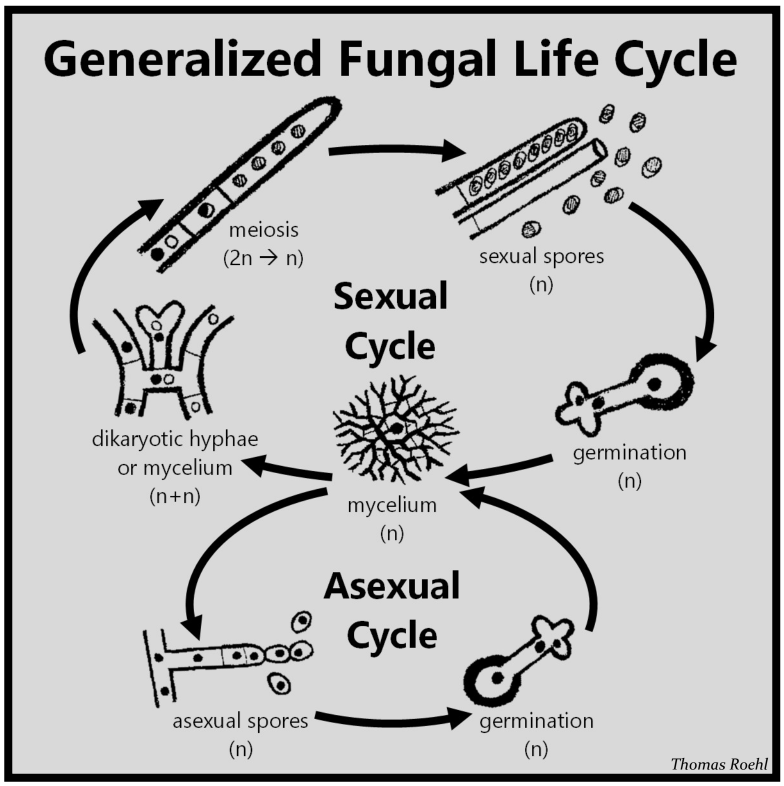
Continued from Page 1 as the only repository for all of the genetic information of the new organism, must grow without losing the code. This is accomplished by *mitosis*, the division of the nucleus into two identical daughter cells which have the same diploid 2n genetic makeup. The word was derived from the Greek *mitos* meaning thread and the Latin *osis* meaning process based on observations of the thread-like chromosomes in the nuclei. As the diploid nuclei continue to divide, the resultant cells differentiate according to the established sequence of gene expression, the eventual result a fully grown individual. Reproduction of a new individual requires that the diploid 2n cell be reduced to a haploid n cell in order for it to seek out a haploid cell of the opposite sex. The reduction of a 2n diploid to an n haploid was termed *meiosis*, from the Greek *meion* meaning less and *osis*, meaning process; since this is a homonym for mitosis, differentiating them is the *pons asinorum* of biology students. With refinements in laboratory methods and instrumentation in the late 19^{th} century, it was discovered that meiosis was a two-step process so that four haploid cells were formed. In summary, two n or haploid nuclei combine to produce a 2n diploid which grows from one cell to many with *mitosis*; the 2n diploid cell reduces to four n haploid cells by *meiosis* to complete the cycle.

The fungi can be divided into two generalized groups based on their reproductive strategies: sexual and asexual. In the mycological vernacular, sexual fungi are sometimes referred to as the Fungi Perfecti and asexual as (naturally) Fungi Imperfecti. One also occasionally finds the asexual fungi referred to as Deuteromycetes from the Greek word *deuesthai,* 'to be in need of,' and *mycetes*, or fungi. The etymological suggestion is that to be asexual is to need sex. More properly, the sexual fungus is called a *teleomorph* and the asexual fungus is called an *anamorph*. This also makes good etymological sense since *teleo* is the Greek word for 'consummation' or 'completeness' whereas *ana* means simply 'on' or 'up', implying simplicity. Both teleomorphs and anamorphs produce spores to execute the reproductive function. The spores of the teleomorphs convey a genetic component from two separate parent entities (which really should not be called male and female). Asexual spores are not called *anaspores*, though they probably should be if language were based on logic, but rather *mitospores*, to indicate that they are the product of mitotic or asexual division. Another name that one encounters for asexual spores is *conidia*, which comes from the Greek word *konis*, meaning dust; these are asexual spores that are formed outside any enclosing structure. Mushroom sex is complicated.

The anamorphs largely occupy the netherworld of the Kingdom Eumycota, which taxonomically comprises three phyla. The primitive Phylum Chytridiomycota (one species of chytrid is responsible for the recent decimation of many amphibian species in Central America and Australia – the frog die-off) comprises species which have asexual zoospores that move with a whip-like flagellum. The Phylum Zygomycota is a complex group that includes the bread molds and the soil fungi that are predominant in establishing mycorrhizal relationships with plant roots. Zygomycetes propagate by both teleospores and mitospores; they are classified by the unique sexual phase that results from a physical conjugation (the Greek word for union is *zygoma*) of two separate fungi. However, it is the third and most physically obvious Phylum Dikaryomycota, which comprises the cup-like Subphylum Ascomycotina and the true mushroom Subphylum Basidiomycotina, which have exasperatingly enigmatic reproductive systems. The ascomycetes and the basidiomycetes can have both an anamorph and a teleomorph, in which case the two taken together may be called a *holomorph*. Some species exist only as anamorphs, some (so far as is known) exist only as teleomorphs, and some have part of the life cycle as anamorph and part as teleomorph.

Deciphering the complexities of the holomorph, which can involve multiple hosts and multiple physical forms, is a seemingly Sisyphean task, though it has been worked out for a few species – where there is some agronomic significance. A case in point is the basidiomycete species *Puccinia graminis* subspecies *tritici*, more commonly known as wheat rust. The life cycle starts when a spore germinates on a barberry (genus *Berberis*), a popular garden shrub (the Japanese barberry, *B. thunbergii* has escaped cultivation and become an invasive species). After germinating, the fungus forms a brown pustule that doesn't harm the barberry, but which emits asexual spores. These spores germinate on wheat plants (genus *Triticum*) and form anamorphs that create more spores that can cause massive wheat crop damage by infesting acres of (amber waves of) grain. During the late summer, the fungus shifts to the production of spores that are dispersed in search of the barberry. Because of this, a barberry eradication program was initiated by the U. S. Department of Agriculture in 1918 that continued until 1975, destroying an estimated 100 million plants. There are likely thousands of holomorphs (an anamorph and a teleomorph) that have yet to be fully characterized, if even known to exist. The fungal world is complex.

Since anamorphs are asexual, there is no question about sex; there is none. When a mitospore comes to rest in a provident environment, it germinates to create a filamentous tendril called a hypha (from the Greek *hyphos*, meaning web) that grows in what is called the assimilative mode. Assimilation is the process by which food is changed from the form in which it is found into the form in which it can be used; it is the fungal equivalent of plant vegetative growth. As assimilative growth continues, the bundles of hyphae eventually form a tangled "web" called a mycelium, which comes from a combination of Greek words that translate loosely as "folded warty fungus." In the case of the fungi, assimilation is most generally in the form of the secretion of enzymes from the hyphal tip that break down the plant or animal nutrients into a form that can be used by the fungus for growth. The hypha extends, becoming ramose to exploit new resources, until the host is expended and growth ceases. Reproduction occurs when there is sufficient energy available for the production of spores, and, most importantly, when the food source is depleted. The process of spore formation among anamorphs is generally straight forward. In the simplest case, structures called conidiophores grow directly on the hypha and produce conidia, the mitospores of the anamorph. In some cases, a simple, specialized spore-bearing body called a *sporangium* will be created. In either case, prodigious quantities of spores are produced, and this is the key to the success of the fungi. The miniscule size of the spore permits airborne transmission over great distances and their ubiquity helps to ensure that at least one will be successful. For the asexual anamorphs, this is all that it takes. It is much harder for the sexual fungi. One may well posit that it makes no sense to invoke the complexities of sexuality when asexuality is so fecund. It is important to keep in mind that asexuality brooks very little – if any – variation, whereas variation is the province and provenance of sexuality. Organisms can adapt to changing environmental conditions efficiently and effectively only with the evolution that sexuality provides. And the environment is always changing.



Sexual reproduction in the dikaryomycotan fungi is simultaneously very simple and very complicated. According to Nicholas Money in *Mr. Bloomfield's Garden*, "sexual behavior in mushroom-forming fungi spans monogamy and civility, to group sex and slaughter." Bryce Kendrick in *The Fifth Kingdom* has a more nuanced view in noting that "reproduction in fungi frequently involves sex, though their sexual behavior is sometimes obscure." The hidden sex of spore-producing species has a turbid history; mosses, ferns, algae and fungi were at one point classified as in a subkingdom called Cryptogamia (literally "hidden life"). Before the invention of the microscope, spores were essentially invisible; the reproduction of any of the cryptogams was accordingly shrouded in the aura of thaumaturgic intrigue. For example, the absence of visible seeds in ferns led to some interesting interpretations as to the nature of fern propagation. As the fern was clearly a plant, then it must have a seed, and, by syllogistic logic, since the "fern seed"could not be seen, it was claimed by some early herbalists that it must be invisible. This ultimately led to a widely held belief that the invisibility of the fern seed conveyed invisibility to the Continued on Page 4

William Needham

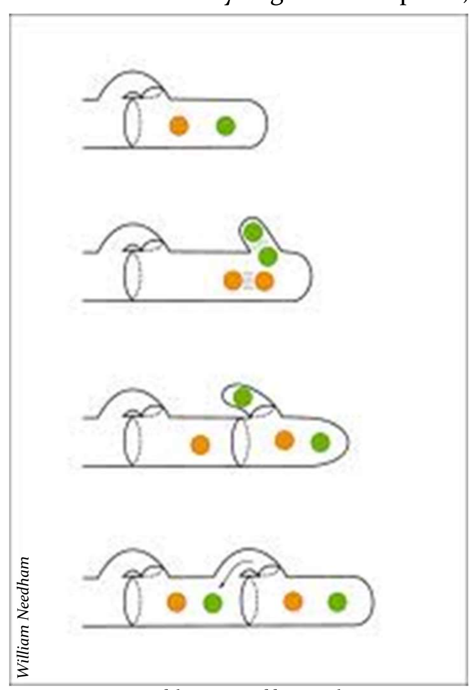
Schizophyllum commune, the Common Split Gill, has over 21,000 possible sexual pairings!

Continued from page 3 bearer of the seed, but only if the seeds were collected at midnight on Midsummer Night's Eve, June 23, also known as the eve of Saint John, the shortest night of the year. Mushrooms, whose reproductive mechanisms were even more obscure than those of the ferns, were seen as even more mysterious, a perspective enhanced by their seemingly chthonian appearance overnight, sometimes in fairy ring circles.

The simple part of mushroom sexuality is that they do not have any specialized sex organs. Any of the filamentous hyphae can engage in sexual union if approached with a sexually compatible hypha from another individual. The complicated part is that there may be many different pairing combinations that are sexually compatible, just as there will be many that are not. When the hyphae from two incompatible forms make contact, the result is a fungal battle for territory, the two strains defending their borders with melanin barriers; trees that are subject to fungal hegemony have patterned wood whose whorls and shadings afford an aesthetic effect employed by wood carvers. When the hyphae of two sexually compatible individuals make contact, the reproductive process begins. The complexity is in the breadth and extent of sexually compatibility. The multiple sexes of the basidiomycete fungi were first discovered by the German botanist Karl Johannes Kniep during the First World War through the evaluation of the fungus *Schizophyllum commune*, known as the common split gill. The choice of this fungus was not serendipitous; *S. commune* is distributed worldwide and grows throughout the year, a consequence of its high spore germination rate and its ability to thrive in a fairly broad range of environmental conditions. Kniep found that, unlike animals and plants that have one set of genes for each of the male and female genders, most fungi have two sets of genes which are called 'mating type factors'; he called them A and B, a designation that has persisted. Over the last century, work with *S. commune* has revealed that there are about 340 A factors, and 64 B factors, which results in something like 21,000 possible "sexual" pairings. There have been estimates made for other fungi, but it should be recognized that the only way to determine if two types are compatible is to pair them to see what happens, a daunting and painstaking laboratory assignment. For most mushrooms, the number of mating factors, or sexes, is a matter of conjecture. It is likely, however, to be significantly more than two.

So, what happens when two hyphae like each other? They mate. What this means for fungi is that the two hyphae merge to form a single cell; the union to form into a single cytoplasm is called *plasmogamy*. Since each of the two "sexes" are haploid (n), this results in two nuclei inside one cell (n + n). This is not the same as diploid (2n) because the nuclei remain distinct and separate. The cell with two different nuclei is called a *dikaryon*, from which the Phylum name Dikaryomycota originates; *karyon* is the Greek word for nut and in the lexicon of biology, it is the nucleus of a cell. The double nucleus dikaryotic hypha can and does continue to grow by assimilation, but in a manner that is one of the most unusual aspects of fungal physiology. Starting with the first frame of the drawing, each of the two compatible nuclei divides by mitosis, retaining their haploid genetics so that two of each type is created – depicted in the second frame. One of the nuclei pairs separates so that one nucleus is at the tip of the hypha and the other, sister nucleus is at the back. The second nuclei pair also separates, but in this case one moves into a bulbous growth that protrudes from the side of the hypha while the other stays behind. As a new cell wall forms between the two sets of nuclei as shown in the third frame, the bulbous region clamps onto the hyphal wall on the other side of the septa, forming what is prosaically called a clamp connection. The clamp connection opens to allow the two separate nuclei to form an identical dikaryon and then closes so that at the end of the process in the fourth frame there is a dikaryon in each of the two separated cells. Laboratory observation has revealed that most basidiomycetes produce a new clamp connection about once every hour and that the mitotic division that creates the paired nuclei takes about 3 minutes. A sexually compatible dikaryon can continue to grow using clamp connections indefinitely as long as there is a nutritive source. Note that a 2n diploid has not yet been formed and meiosis, and therefore sex, has not yet occurred, just a lot of foreplay.

When environmental conditions are amenable for the successful dispersion of the sexually engendered spores,



William Needham

Diagram of the process of forming clamp connections. See text for details.

William Needham

Fruiting bodies of the Scarlet Cup (*Sarcoscypha coccinea*, left) and the Orange Earth Tongue (*Microglossum rufum*, right)

the reproductive cycle begins. It is the mechanics of the sexual process that differentiates the Subphylum Basidiomycotina from the Subphylum Ascomycotina; the former produce 4 spores on a structure called a *basidium* and the latter produce 8 spores in a structure called an *ascus*; the subphylum names are derived from the names of the two different spore containments. The conversion of the dikaryon into sexual spores by meiosis does not occur until the fungus is ready, a determination based on some means of determining temperature and moisture that registers the propensity for the spores to germinate if created.

In the ascomycetes, the dikaryon undergoes a nuclear transition from n + n to the diploid 2n which rapidly undergoes meiosis to create four nuclei that divide by mitosis to create the 8 spores. The ascomycetes, which include the succulent edible morels and truffles, are mostly small, brightly colored cups like the Scarlet Cup (*Sarcoscypha coccinea*) or irregular stalks like the Orange Earth Tongue (*Microglossum rufum*); their taxonomy is established by the manner in which they release their spores from the ascus.

The basidiomyctes are the largest and most complex organisms of the Kingdom Eumycota; they are evident for their visible mushroom fruiting bodies. The reproductive machinations of basidiomycetes are essentially the same as those of the ascomycetes - a 2n diploid forms and divides by meiosis to create 4 haploid spores, stopping short of the final octal mitosis of the ascomycetes. The key difference is that in the basidiomycetes, a nascent, hypogeal reproductive fruiting body called the *primordium* is formed by the mycelium. It is only at the point of reproductive imminence that meiosis occurs. Club-shaped basidia develop at the ends of select hyphae and produce haploid spores (usually four in number). Each spore is separately housed at the end of a small projection so that it is ready for dispersal. Fungi thus spend almost all of their lives as haploids contrasted to animals and plants that live almost wholly as diploids The spore producing surface is called the *hymenium*; for gilled mushrooms it is on both sides of the adjacent gills, for mushrooms with pores, it is the surface of the vertical tubes. The fully formed hypogeal mushroom primordium is now reproductively and physiologically ready to break the surface of the ground and open to expose its spore-laden gills to the winds of chance dispersion. The impetus for this reproductive consummation is environmental. Mushrooms make their epigeal appearance soon after a rain as the conditions for spore germination are likely to be good. They also appear when their food source is threatened, which may occur due to disease, death, fire, or, when that source is nutritionally depleted. If the spores germinate and find a mate, then fungal life goes on.

$200 MAW Education Funding

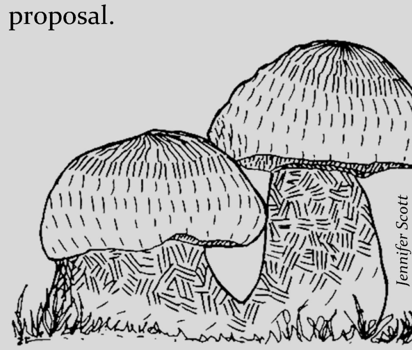
MAW has funds available to support an education project! This year's budget includes about **$200 set aside for education programs**. If you have an idea to support a fungus-related education activity, **submit your proposal to the MAW Board of Directors**.

If your proposal is accepted, MAW will allocate funds for your project and reimburse or purchase project-related materials and services. MAW will also encourage its members to participate in supporting your project.

Previous MAW education projects have included:

- Judging state High School science fair entries of mycological interest
- Elementary School mushroom identification visits to support Virginia and Maryland Standards of Learning
- Distributing Field Guides to students with a demonstrated interest in fungi
- MAW member identification visits to local civic associations

Please email Bruce Boyer at **namatrustee@mawdc.org** for more information and/or to submit your proposal.



Jennifer Scott

Meeting File

February 2 – William Needham's "Mycology 102"

Thomas Roehl
Newsletter Editor

On February 2, MAW First Vice President William Needham discussed the basics of fungal ecology and cellular biology. Although officially titled *Introduction to Fungi of the Kingdom Eumycota*, William likes to refer to this lecture as *Fungi 102* because it builds on previous experience with mushrooms and introduces listeners to fungi on a cellular level.

Fungi, William explained, are eukaryotic, heterotrophic, absorptive organisms that use spores for dispersal. Eukaryotic means that they have highly-differentiated cellular components, like those found in plant and animal cells. Fungi are heterotrophic because they extract food from their surroundings instead of producing food themselves. Finally, they are absorptive because they digest food externally.

Since fungi do not produce their own food, they have developed three strategies for extracting food from their environment. Saprobic fungi decay dead organic matter, parasitic fungi attack living tissues, and mycorrhizal fungi exchange their resources for food from plant roots. All three of these strategies have been around for a very long time because, as William pointed

Thomas Roehl

William Needham answers questions from listeners during the March meeting.

out, "there is very credible evidence that fungi and plants evolved together."

The main cellular unit of the fungus is the hypha, the name of which comes from the Greek word for 'web.' A hypha is "a filamentous tendril made of chitin." Chitin provides fungal cells with structure but also makes up the exoskeletons of bugs. This demonstrates that fungi are more closely related to animals than to plants.

Fungi are extremely important organisms. They play a key role in decomposition, are responsible for many devastating diseases, have cultural impacts in food and medicine, and form mycorrhizae.

William explained that mycorrhizal fungi are probably the most important fungi because "90% of all healthy plants have mycorrhizae." So important are mycorrhizae to healthy plants that when grown without their mutualistic fungi, plants are only half as large. Some plants do not form mycorrhizae, but these are generally considered weeds.

Switching gears, William noted that the fungi were historically split up into four main groups (phyla): Ascomycota, Basidiomycota, Zygomycota, and Chytridiomycota. Although DNA evidence has further separated these phyla, they are still useful in discussing cellular characteristics of fungi.

William provided a brief overview of each phylum's characteristics, cellular biology, and reproductive processes.

Upcoming Events:

May 3 – Monthly Meeting: Peter McCoy, author of *Radical Mycology*, will discuss using fungi for bioremediation and cultivating mushrooms.

Mid May – NAMA 2016 Foray registration opens. Registration fills up fast, so make sure to reserve your spot early! Look for more information in MAW emails and during monthly meetings.

May 20-21 – BioBlitz at Rock Creek Park: MAW will help collect and identify mushrooms during this two-day event. Contact Connie Durnan at **vicepresident2@mawdc.org** for more information or to volunteer.

June 7 – Monthly Meeting

July 5 – Monthly Meeting

Unless otherwise noted, monthly meetings will be held on the first Tuesday of the month at 7:00 PM in the Kensington Park Library, 4201 Knowles Avenue, Kensington, MD. Attendees are encouraged to bring mushrooms for sharing and identification. Members of the public are welcome to drop in.

Opk

Save the Date:

Sept. 8-11 – NAMA Foray at the NoVA 4-H Center in Front Royal, VA. To volunteer to help at this event, contact Bruce Boyer at **namatrustee@mawdc.org**.

Sept. 23-25 – MAW weekend foray at Camp Sequanota in Jennerstown, PA

Oct. 9 – MAW Mushroom Fair

Finally, he offered a brief narrative of the use of mushrooms, from when they were first used as food and medicine to how they are used today.

March 1 – Dr. St. Leger Introduces Insect-Killing Fungi

Thomas Roehl
Newsletter Editor

Raymond St. Leger, Ph.D., a Distinguished University Professor in the Department of Entomology at the University of Maryland, brought the often overlooked world of entomopathogenic fungi (fungal pathogens of insects) to light during the MAW meeting on March 1.

St. Leger started off the meeting with an eye-catching video of "zombie ants." Certain fungi in the genus *Ophiocordyceps* infect ants and induce them to climb up onto leaves. The fungus then kills the ant, fruits from the ant's head, and releases spores onto unsuspecting ants below.

Zombie ants are perhaps the most exciting example of entomopathogenic fungi, but they are not alone in this category of fungi. St. Leger estimates that there is a one-to-one ratio of insects to entomopathogenic fungi. In fact, fungal infection is the number one reason that insects die.

This scenario has important implications for humans. For example, compounds from entomopathogenic fungi have proved useful in medicine. Entomopathogenic fungi can also be used in biocontrol of insect pests.

Much of St. Leger's research focuses on using fungi to solve the problem of malaria. With insecticide resistance increasing, it is important to find alternative methods to combat the disease.

One strategy uses bioengineered fungi that infect mosquitos to kill the parasite. These fungi infect but do not kill the mosquitos. Genes designed to kill the malaria parasite can be inserted into the fungus, thus preventing the spread of malaria. Unfortunately, people dealing with malaria would rather have the mosquitos killed. This highlights the need to work with locals to develop effective malaria solutions.

Currently, St. Leger is working on trials of a mosquito-killing fungus in Burkina Faso. In these trials, spores of a mosquito-killing, transgenic fungus are sprayed onto black blankets. The transgenic fungi have proved to work faster and last longer than the original fungi. If used in conjunction with insecticides, it could help prevent the spread of malaria and block the development of resistance to both fungi and insecticides.

April 5 – NIH Scientists Explain Fungal Genetic Databases

Thomas Roehl
Newsletter Editor

The MAW meeting on April 1st featured three guest speakers from the National Institutes of Health (NIH): Dr. Ben Busby, Dr. Conrad Schoch, and Dr. Barbara Robbertse. The trio explained their work on creating and curating fungal genetic databases for the National Center for Biotechnology Information (NCBI).

Schoch, the Fungal Taxonomist at NCBI, is responsible for verifying names of fungal DNA sequences that are added to the NCBI databases. He started off the meeting by explaining that the NCBI maintains a variety of online databases (for example: GenBank) that store genetic information for many organisms, including fungi. To ensure the information in these databases is useable, the names and sequences of organisms must be accurate.

An accurate identification relies on three factors: a name, a type specimen, and a genetic sequence. For each named fungus, a collection should be designated as the "type specimen." If the morphology and DNA of another specimen matches the type specimen, then they belong to the same species.


Thomas Roehl
Dr. Raymond St. Leger enthusiastically discusses entomopathogenic fungi during MAW's March meeting.

Many fungal DNA sequences being added to the NCBI databases do not have an associated name or specimen. In these cases, other entries with a verified name and type specimen can be used to help identify the unknown sequence. This system relies on accurate reference sequences to function properly.

Some NCBI databases, such as RefSeq, are curated. These use the same data as the archival databases, but are checked for mislabeled sequences. Dr. Robbertse, who is a curator for RefSeq, took over the presentation to describe curation in detail.

A curator for RefSeq must pay attention to many details in order to verify an entry. To be trusted, an entry must have a source specimen on file, must not be identical to an entry listed under another name, and must not be spliced together from two separate species. Additionally, the names in the database must be continually updated, since fungal nomenclature changes frequently.

Dr. Busby wrapped up the presentation by explaining sequencing, the types of databases at NCBI, and the tools that can be used to analyze the information they contain. NCBI databases include information on DNA, RNA, protein sequences, entire genomes, epigenetics, and more. BLAST and its derivatives are tools that quickly compare sequence fragments in a database. People can learn more about NCBI's databases from the information and tutorials on NCBI's website (**http://www.ncbi.nlm.nih.gov/**).

Fungi in the News

Thomas Roehl
Newsletter Editor

Editor's Note: This article contains summaries of the biggest fungus-related news stories from the first quarter of 2016. Visit the link following each topic below for a closer look.

Fungi Could Survive on Mars

Fungi from Antarctica recently survived 18 months in a Mars-like environment. The fungi – which normally live inside Antarctic rocks – were kept on a platform on the International Space Station that was designed to approximate Martian conditions. In some of these fungi, as many as 60% of their cells were still viable at the end of the experiment. This lends researchers hope that life could exist on other planets. Read more at: **http://phys.org/news/2016-01-antarctic-fungi-survive-martian-conditions.html**

WNS Spreads to West Coast

White Nose Syndrome (WNS), a disease deadly to bats and caused by the fungus *Pseudogymnoascus destructans*, was confirmed to have killed a little brown bat found near Seattle, Washington, in March. This marks the first occurrence of the disease on the West Coast of the United States. Officials fear WNS could devastate western bat populations, as it has done in the eastern U.S. WNS is primarily spread from bat to bat, but can also be carried on clothing and boots. Therefore, always follow proper quarantine procedures after visiting areas inhabited by bats. Read more at: **http://www.usgs.gov/newsroom/article.asp?ID=4496#.VwAMhof50jg**

Food Made from Plastic Waste

An Australian business has come up with a novel way to solve the problem of plastic waste: use fungi to turn it into food that humans can eat. Read more at: **http://www.smithsonianmag.com/smart-news/chow-down-plastic-eating-fungus-180958127/**

Fungal Packaging at Ikea

In an effort to make its shipping activities more environmentally-friendly, furniture giant Ikea is considering replacing polystyrene with biodegradable, fungus-based packaging. Read more at: **http://www.telegraph.co.uk/news/earth/businessandecology/recycling/12172439/Ikea-plans-mushroom-based-packaging-as-eco-friendly-replacement-for-polystyrene.html**

Gut Fungi Can Help Boost Biofuel Production

Fungi living in the guts of herbivores such as goats are specialized for breaking down plant material and turning it into fuel. Scientists analyzed the wide array of enzymes produced by these fungi and discovered that those enzymes could be used to produce biofuels more efficiently. Read more at: **http://www.forbes.com/sites/jamesconca/2016/02/26/can-goat-poop-overpower-fossil-fuels/**

Fungi to Be Sent to Space in Medicine Development Hope

Medicines derived from fungal compounds, such as penicillin, have changed the world in the past. In the hopes of discovering new medicines from fungi, NASA will send strains of *Aspergillus nidulans* to the International Space Station this April. The fungi will spend between three and seven days exposed to the intense radiation and microgravity outside the station in the hope that they will produce novel compounds with medical applications. Read more at: **http://www.latimes.com/science/sciencenow/la-sci-sn-fungi-medicines-space-20160329-story.html**

NASA Maps Mycorrhizal Networks from Space

Using a satellite that can differentiate between tree species, NASA was able to indirectly map networks of mycorrhizae. Trees associate with either arbuscular mycorrhizal fungi or ectomycorrhizal fungi, but rarely both. The satellite data mapping tree types can therefore be used to estimate the extent of these two fungal networks. Each type responds differently to rising temperatures, so this map could help scientists improve the accuracy of climate change models. Read more at: **http://www.jpl.nasa.gov/news/news.php?feature=6241**

Bread Mold May Aid Battery Production

The bread mold *Neurospora crassa* has been used by scientists to produce a manganese composite material. The composite was found to have electrical properties suitable for use in capacitors and batteries. Read more at: **http://phys.org/news/2016-03-bread-mold-rechargeable-battery.html**

Early Fungal Fossils Found

British scientists have identified the earliest known fossil of a terrestrial organism. The fossilized fungus, which was alive around 440 million years ago, likely contributed to the development of early soil. This later allowed plants and animals to colonize dry land. Read more at: **http://www.bbc.com/news/science-environment-35698463**

New MAW Website

MAW recently updated the look of its website! The new website can be found at **www.mawdc.org** or at **www.mawdc.wildapricot.org**. Log in or create an account now to:

- Pay dues
- View event details
- Update email address
- Update street address

To ensure you receive foray notifications, MAW news, and the latest edition of *The Potomac Sporophore* in a timely manner, make sure the email and street addresses listed for your account are up-to-date.

Fungus Destroying Bananas Worldwide

Continued from Page 1

With the advent of refrigeration, bananas could be transported across oceans. As a result, exporting bananas became a profitable enterprise during the 1870's. Large banana plantations were established in Central and South America, turning this tropical fruit from a delicacy to a food staple for millions of people in the United States and Europe by the early 20th century.

During the late 19th and early 20th centuries, the Gros Michel variety dominated international markets. Compared to bananas found on supermarket shelves today, the Gros Michel tasted better, did not bruise as easily, lasted longer, could be transported more easily, did not need to be artificially ripened, and was resistant to a greater variety of diseases. Unfortunately, this banana variety had absolutely no resistance to Panama disease.

Panama disease was first noticed in Australia in 1876. There, Gros Michel bananas began dying inexplicably. The lower leaves would turn yellow from the outside in and then wilt and die. This spread up the plant until the entire plant died. On the inside, the plant turned brown and began rotting, starting with the outer layers. Since most bananas grown for export were

Bananas are the world's largest herb and are technically not trees.

produced on plantations in the tropical Americas, the Australian problems were not very alarming.

From Australia, Panama disease spread to Indonesia and then to Central and South America, reaching Cuba by 1910. The disease slowly worked its way throughout the banana-growing regions of the Americas for the next 40 years. In the 1950's, the disease reached epidemic proportions: entire plantations were destroyed by Panama disease.

In an attempt to get away from the disease, plantations were often abandoned and started up in new areas. Regrettably, Panama disease was not fully understood and these new plantations quickly went the way of their predecessors. In 1965, the Gros Michel banana was declared commercially extinct.

The banana industry was saved by a stroke of luck: the Cavendish variety was found to be resistant to Panama disease and was seen an acceptable alternative to the Gros Michel by international markets. Because the Cavendish was considered inferior to the Gros Michel, its adoption was rather slow. Only in the 1950's – when all other options had been exhausted – did banana companies begin widespread cultivation of the Cavendish banana.

The Modern Banana Industry

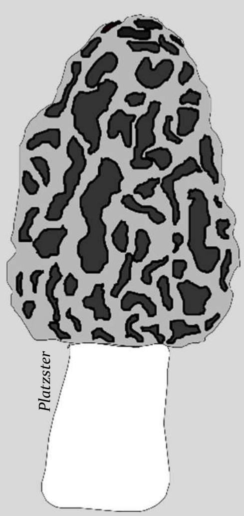
Today, the Cavendish banana dominates export markets. There are over a thousand varieties of bananas, but those are mostly cultivated for local markets and individual use. None of these bananas are seen as a viable alternative to the Cavendish on the international market. The Cavendish makes up 47% of modern banana production but over 90% of banana exports.

Asia produces the most bananas, but a majority of these are consumed locally. The tropical Americas are the world's top exporters of bananas. The United States of America is the top banana importer, with Americans consuming about Continued on Page 10

Your Recipe Here

Do you have a favorite recipe that you would like to share with other MAW members? Submit your recipes for publication in *The Potomac Sporophore*! To submit a recipe for the next edition, email Thomas Roehl at **editor@mawdc.org** before the July monthly meeting.

Fried Morels



Morels have a strong flavor that works best in simple dishes. The most basic way to cook morels is fried in butter.

Ingredients:

- Morels: as many as possible
- Butter: enough to cover morels
- Salt and pepper

Directions:

1. Cut morels in half lengthwise and clean
2. Melt butter in skillet
3. Add morels and cook until done
4. Season with salt and pepper to taste

Recipe contributed by: Connie Durnan

Continued from Page 9 12kg of bananas per person per year (which is more than apples and oranges combined).

Bananas are a very important source of income for many developing countries, particularly those in Latin America. Additionally, millions of people around the world rely on bananas as an important part of their diet. Take Uganda for example: Ugandans consume an average of 240kg of bananas per person each year!

However, the future of the banana is not clear thanks to the re-emergence of Panama Disease.

Banana Biology

To understand the problems plaguing bananas, it will help to learn a little bit about banana biology.

Modern bananas (including plantains, which many cultures do not distinguish from bananas) descend from two ancient species: *Musa acuminata* and *M. balbisiana*. Many banana varieties result from crosses between the two species, but the two most important varieties (Gros Michel and Cavendish) contain genes from only *M. acuminata*.

Bananas are great for eating because they have no seeds. There are two reasons for this.

First, bananas can form fruit without being fertilized through a process called *parthenocarpy*. Without pollination, seeds will not form. Thanks to parthenocarpy, bananas produce fruit even though they don't create any viable seeds.

Second, bananas are triploid, which means they have three sets of chromosomes. During meiosis, each gamete (pollen or eggs, in the case of plants) will receive at least one set of chromosomes. The extra set of chromosomes will be randomly split up between two gametes during the final step of meiosis. To produce a viable seed, a pollen grain and egg must fuse to create a zygote with at least two complete sets of chromosomes. Plants do very well with multiple sets of chromosomes, but they must be complete sets. The probability that any given pollen grain and egg will be able to create a zygote with three complete sets of chromosomes is very small.

Wild bananas do form black, pea-like seeds, which can be found distributed in the flesh in the middle of the banana (thus making the banana technically a berry). The brown specks at the center of seedless bananas are the remnants of unfertilized ovules, which would have produced seeds had that been possible.

Although it can reach heights of 15 meters, the banana is not a tree. Instead, it is the world's largest flowering herb. The trunk of a banana plant is actually a 'pseudostem,' which is a tightly-packed spiral of leaves. The pseudostem connects to the roots through a structure called a 'corm,' which is a tight, fleshy bundle of roots. The corm allows the banana to reproduce asexually by sending out suckers. Each sucker is connected to the corm via roots and can form a new corm, pseudostem, and root system.

Reproducing asexually by suckers is a very useful ability. Since bananas cannot reproduce through seeds, farmers have to propagate their crops using corms. Corms can be dug up and brought to new areas, thus quickly expanding banana production. Once the banana produces fruit, the pseudostem dies. To make new pseudostems, all a farmer has to do is cut down the old stalk and all but one of the suckers. The sucker will then grow into a new plant, thus propagating the banana plant indefinitely. This makes it very easy to recover from natural disasters like hurricanes.

A banana corm. To grow a new plant, a corm is simply dug up and replanted elsewhere.

An unintended consequence of reproduction by suckers is that every plant on a plantation is genetically identical. This means that all the plants are susceptible to the same diseases. As a result, if one plant becomes infected by a disease, all the plants will soon be infected by the same disease.

Panama Disease

Panama disease is caused by the fungus *Fusarium oxysporum* f. sp. *cubense*, commonly referred to simply as '*Fusarium*.' This fungus attacks the banana's vascular system. In plants, vascular tissue is responsible for transporting water, sugar, and other nutrients between the leaves, roots, and other parts of the plant.

Fusarium gets into the banana through wounds in the roots or corm. From there, the fungus grows along the xylem and phloem channels that make up the plant's vascular tissue. Thus, *Fusarium* spreads along roots and leaf stems, slowly making its way towards the center of the plant.

Morel Season is Here!

Need help identifying or finding morels? Join MAW on a foray this April and May! Look for foray notifications by email.

For more help, read "Morels and How to Find Them" by former MAW member Tim Geho – available on MAW's website at **http://mawdc.wildapricot.org/other-resources**.

2016 NAMA Foray

Don't miss out on the biggest foray event of the year! The North American Mycological Association (NAMA) foray will feature over 300 amateur and 30 professional mycologists leading forays, classes, cooking demonstrations, and more. This year's foray will be held at the Northern Virginia 4H Center in Front Royal, VA. You must be a member of NAMA to attend. Contact Bruce Boyer for more info or to volunteer.

As it grows, the fungus kills the banana plant's vascular cells (and any other nearby cells) and absorbs their nutrients. The end result is that the plant's water and food supply gets choked off. Because of this, the initial symptoms of Panama disease resemble those of a plant without an adequate water supply: the leaves turn yellow and wilt.

It is easy to see where the fungus has been at work when the pseudostem is cut open. Cells infected by the fungus turn reddish-brown and smell strongly of garbage. Additionally, uninfected roots become weak and die because they cannot get enough sugar from the leaves.

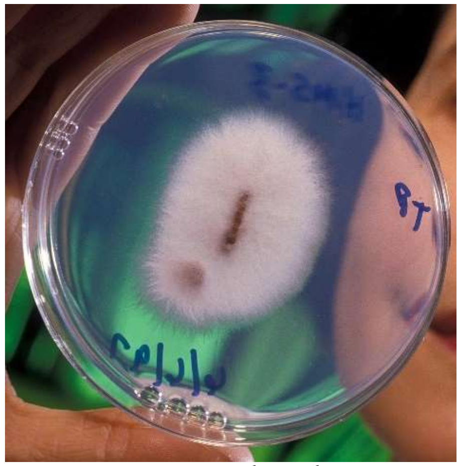
Fusarium is primarily a soil-borne pathogen. It produces resilient, asexual resting spores that can persist in the soil for decades. The spores germinate when new banana roots grow near them, thus infecting all banana plants in the area for years to come.

Spores can be easily transported from one area to another with soil stuck to shoes, farm equipment, and even transplanted banana corms. This was not known in the 1950's, so farmers who started new plantations inevitably brought the disease with them when they moved to virgin soil.

Panama disease may also spread through airborne spores, but this is less frequent.

An Emerging Disease

Unfortunately for the banana industry, *Fusarium* has evolved a way to infect the Cavendish variety. *Fusarium* has a number of different varieties called 'races.' Race 1 is the variety that devastated the Gros Michel plantations in the 50's. The modern outbreak, however, is caused by the variety designated Tropical Race 4 (TR4).



Fusarium oxysporum grown on a culture medium.

TR4 was first observed infecting Cavendish bananas in Taiwan in the late 80's and was found on bananas in Malaysia by the early 90's. During the next decade, the disease spread throughout Southeast Asia. It then made the jump to Australia in the late 00's. In 2013, the fungus was reported from Jordan and Mozambique.

From there, it seems likely that the fungus will spread across Africa and eventually make it to Latin America. This would be extremely detrimental to food security and income for millions of people living in those areas.

A Future for Bananas?

So far, banana breeding programs have failed to produce a viable alternative to the Cavendish, meaning that the banana industry may not be able to recover this time around.

The fungicides that are already used to control other banana pathogens are harmless to the soil-dwelling TR4. There are chemicals that can be applied to the soil to kill *Fusarium*, but these are so toxic that they are banned in most countries.

Currently, the only preventative measures available are strict quarantines. Australia has tried to prevent the spread of TR4 using quarantines, but with limited success. Last year, the fungus escaped the quarantine and found its way to Australia's largest banana-producing center.

So what can be done to save the banana? Sadly, not much.

Efforts to cross-breed the Cavendish with a more resistant variety or related, wild species are extremely slow. Since the Cavendish is triploid, it rarely produces viable seeds when properly fertilized. Traditional cross-breeding therefore produces only a few viable seeds a year. On top of that, the seeds must then be grown to see if they received the right set of desirable traits. Modern genetic techniques have helped speed up this process in other plants, but we do not know enough about TR4 to apply those techniques to bananas.

To add to the problem, consumers are currently wary of genetically modified food. Consequently, banana companies do not think a GMO banana would be commercially viable and genetic modification techniques are being ignored.

Proper quarantine procedures and sanitization techniques can help slow the spread of the fungus, but today's level of globalization means that the disease's advance is likely inevitable.

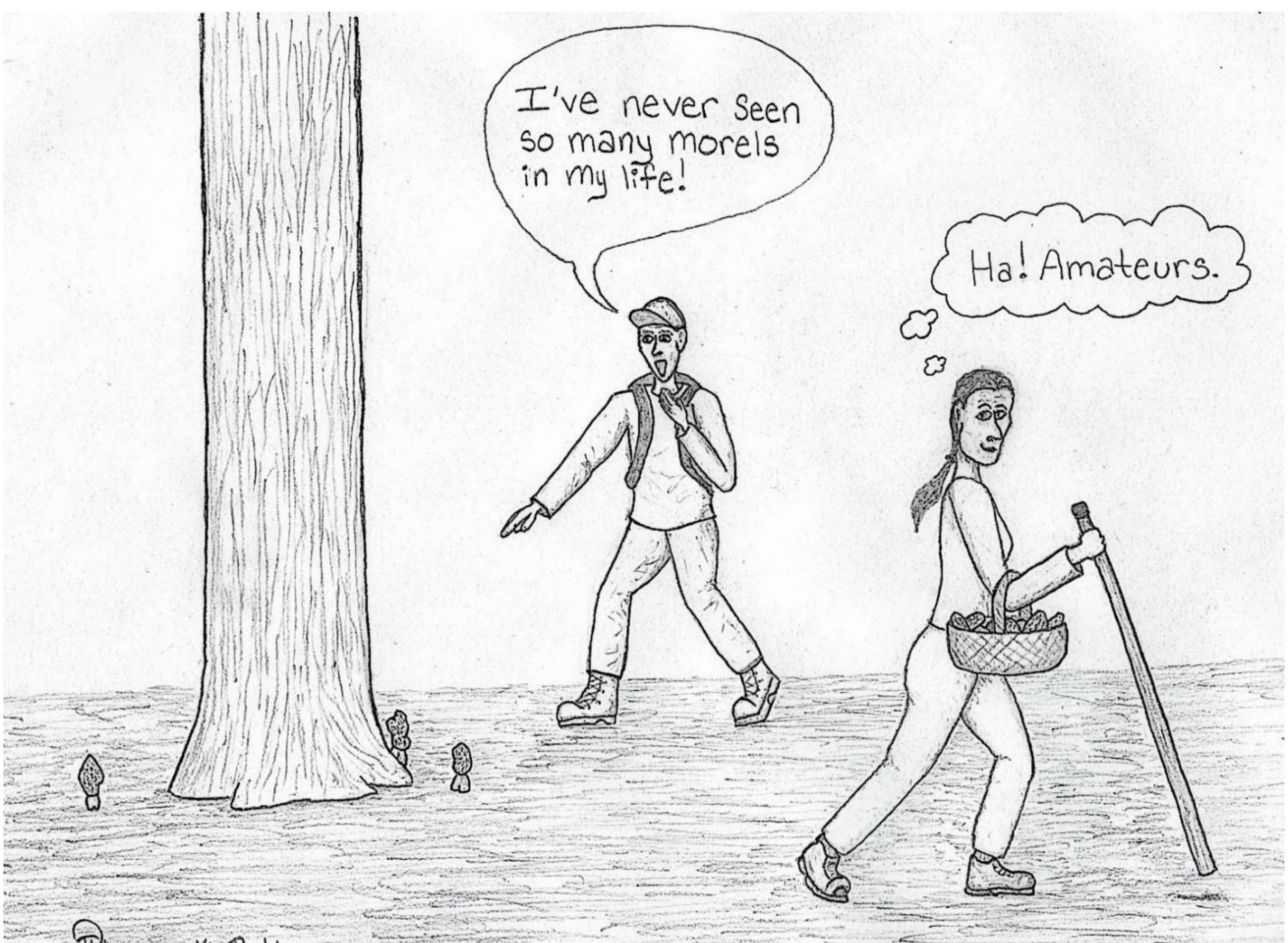
With any luck, however, the banana's immense appeal will encourage researchers and banana companies to find a way to preserve America's favorite fruit.

Is Something Missing?

Is there something that you wish had been included in this month's *Sporophore* but wasn't? Submit:

- ❑ Ideas
- ❑ Articles
- ❑ Photos
- ❑ Recipes
- ❑ Suggestions

for publication in the *Sporophore* to the editor at **editor@mawdc.org**.


I've never seen so many morels in my life!
Ha! Amateurs.
Thomas Roehl and Kim Roehl