

Letter from the desk of David Challinor
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Fungi are one of the five great kingdoms of living matter. The others are procaryotes, such as viruses and some single-cell bacteria that lack a nucleus; eucaryotes, or single-cell organisms with a true cell nucleus; plants; and animals. Fungi are unlike any other kingdom, although they are surprisingly more closely connected to animals than to plants. Rather than explaining the complicated nature of these ubiquitous organisms, I will discuss how they relate to other organisms, both favorably and unfavorably, and perhaps more importantly how they interact with humans. This month's letter is about the fungus among us.

The fungi kingdom is divided into those that break down dead tissue (decomposers), and parasitic fungi that attack living tissue. An example of the former can be seen when you turn over a piece of a fallen, rotting log and thin white strands of fungal mycelia are visible throughout the decomposing wood. The mycelia release the enzymes that break down the lignin (a substance related to cellulose that together with it forms the woody cell walls of trees) and other solid components of the log until it becomes a mere pile of rich organic matter on the forest floor forming an ideal rooting medium on which new seedlings can grow. The same group of fungi attack a whole range of dead animals and plants, returning their components to the soil from which future generations can benefit.

Of more concern to humans are the parasitic fungi that, when ingested, have a deleterious effect on humans. A common example is ergot, which infects rye and other grasses and can destroy whole fields when environmental conditions are right for its spread. Of all the fungi affecting humans, ergot is the most interesting. During particularly wet times (at the end of the grain growing season), ergot can attack grain, which is then ingested by people. Until modern times, the effect of consuming ergot-infested grain was not recognized -- what was observed were people who suffered from severe pain in their feet, legs, hands and arms, occasionally leading to lethal gangrene in the affected limbs. Cattle fed contaminated grain might actually lose their tails. This ill-understood condition was known as St. Anthony's Fire, but today its origin is well understood: wet grain is an ideal breeding ground for ergot. Consuming ergot-contaminated grain causes the blood vessels of the extremities to constrict painfully and, in extreme cases, this constriction can lead to gangrene. Sufferers of St. Anthony's Fire were also known to exhibit strange behaviors, and it has been suggested that ergot consumption may have been responsible for the abnormal conduct of those enmeshed in the Salem Witch Trials.

In modern times, ergot is used medicinally to control bleeding after childbirth and to mitigate migraine headaches. The last known serious ergot outbreak was in 1995 in Brazilian sorghum. Sorghum ergot is now spreading in several Central and South American countries. More recently (1997), ergot contamination has turned up in South Texas and, in a few cases, in Kansas and Georgia.

Besides grain, trees are also attacked by fungal pathogens. The accidentally introduced white pine blister rust that came to the United States in the early 1900's on imported white pine nursery stock. The importation was ironic because white pine is a native American tree, but it had been so overharvested that when lumber companies wanted to replant this species they had to go to Europe for nursery stock. Blister rust in Europe is not a major problem, because the rust only attacks 5-needle pines; there are only two varieties and both grow high in the mountains and generally above the limits of the currants and gooseberries which are the fungi's alternate hosts. In the U.S., on the other hand, eastern white pine is still an important lumber tree; in the west the two major 5-needle pines (western white and sugar) grow in forests whose floor is home to wild currant bushes. Despite a massive effort in western forests to eradicate these bushes by hand, control of the blister rust was unsuccessful. Even sprayed fungicides were ineffective, because the spray to be effective, must coat every needle of every tree and has to be re-applied after each rainstorm. Spraying is costly because beneficial fungi can be destroyed as well as the target species. Fungi have probably been around about as long as plants and fungal parasites have been adapting to different hosts and changing climate conditions all this time. It would be counter-evolutionary were parasitic fungi ever to exterminate all their hosts because they too would succumb.

Host trees can develop defenses against damaging parasites. Individual trees often appear in a population that seems to be resistant to a particular pathogen. When spotted by scientists, resistant trees are propagated in nurseries from seeds or cuttings and then planted in the field in hopes of exploiting their pathogenic resistance. A good example of this effort is the work now being done with the American chestnut tree to enable it to be reintroduced to the wild so that everyone can enjoy its favorable timber and fruit characteristics. Like the white pine blister rust, the fungus creating the chestnut blight causes only minimal damage in the European forests where it originated.

It is hard to imagine how many different kinds of fungus are continuously present on trees (and on humans, too). One estimate is that there is an average of 15 different fungal pathogens for every native tree species. In most cases, the effects of these pathogens on the trees is benign, unless the exact mix of humidity, temperature, day length, etc. occurs, causing the pathogen to explode in damaging numbers. These favorable combinations (for fungal explosion) are fortunately rare so that hosts and parasites can generally maintain a reasonable balance.

Parasitic fungi live with decomposing ones; both are essential to keeping an ecosystem actively functioning. Grass leaves, for example, are covered with fungal endophytes -- fungi whose mycelial hyphae (the long white strands) actually penetrate the cells of their host. (endo = inside; ecto = outside) Ectophytes have hyphae that grow so close to root hairs that nutrients can cross from the hyphae to the roots through their respective cell membranes. Problems with endo- and ectophytes on grass leaves occur when foreign or even "improved" native grasses are used for pasturage. Fungal endophytes on grass leaves went virtually unstudied until 1977, when scientists identified a grassleaf endophyte as the source of livestock poisonings. Domestic stock that grazed on Tall fescue suffered weight loss, lower milk production, and pregnancy problems from one endophyte confined to this grass species. A closely related endophyte lives on the leaves of perennial rye grass and also causes significant livestock losses. Sick and staggering cows attract a lot of attention, and soon scientists found the toxic alkaloids in these endophytic fungi. It turned out that the toxins actually protected the plant from insect herbivores. Other endophytes help their host plants by making their leaf pores (stomata) close sooner and tighter during droughts to save water, and root endophytes help the plant absorb more nutrients than those plants without such fungal parasites.

The Tall fescue problem, however, appears to be an anomaly resulting from selective breeding of the grass to sustain heavy grazing. The local wild fescue relative from which the tall variety was developed showed no evidence that its leaf endophytes produced any toxins at all to protect it from insect leaf eaters or mammalian herbivores. It looks as though Tall fescue is yet another example of there being a cost, often unanticipated, for every advantage. The taller, lusher fescue grass can, under certain conditions, still carry health risks for the stock that eats it.

There is much yet to be learned about leaf endophytic fungi. Such fungi do not seem to be consistent in what they do for their host plant. Some evidently can and do protect their host's leaves from insect herbivores. Others help the plant take up more nitrogen through its roots, but this seeming inconsistency between helpful qualities might make more sense when we compare these leaf endophytes with other fungi. Many of us have been attacked by athlete's foot or by Candida albicans, two common parasitic fungi. We are fortunate that in almost all cases these assaults can be controlled by over-the-counter fungicides. Understanding the conditions that cause these infections allows us to take preventive measures. Just as in the case of plants, fungi are all around us and, like Mr. Boll Weevil in the song, are always "lookin' for a home."

The "good" plant fungi such as ecto- and endomycorrhizae grow on and in the roots of many trees, thereby increasing their absorbing capacity for soil nutrients. These fungi are particularly important on nutrient-poor soil. For example, in the 1930's when shelterbelts were planted to curb erosion in the dust bowl, the trees failed to thrive until the soil in which they had been planted had been inoculated with mycorrhiza from forest soil further east. Perhaps the most beneficial fungus of all was that which produced penicillin, a drug discovered by Alexander Fleming, a microbiologist, in 1928. He found that it had incredible antibiotic properties. Penicillin is the common name of the antibiotic compound made from two fungi, Penicilium

notatum and P. chrysogenum. They are best described as a blue-green mold that grows on decaying fruits and ripening cheese. Fleming's chance discovery of the antibiotic quality of these fungi clearly revolutionized medicine, and we are still reaping its benefits today.

Humans also eat fungi in large quantities, especially the commercially produced ones used in soups and salads. Many kinds of wild fungi are assiduously but carefully collected as a few of them contain toxic alkaloids. One group of fungi actually combines with an algae to produce lichens. Others grow underground (truffles), on trees, and under certain conditions on humans.

We can reasonably expect to discover other new valuable qualities that have heretofore been locked up in plants and fungi. Fleming just happened on the antibiotic property of the fungi he was studying. His finding is an excellent example of the importance of financing research in seemingly esoteric fields. Only a few industrious and lucky scientists will ever "hit the jackpot" and find a substance such as penicillin, but institutions like the Smithsonian must continue the tradition of increasing the world's knowledge. The results of basic research will always have some value and, on rare occasions, some may even be earth shattering. We cannot afford to miss any approach to add to "the increase and diffusion of knowledge among men."

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