Mycorrhizas — The Source of All That is Good?

By Steve Trudell

I don't recall the first time I heard of mycorrhizas. It might have been in one of Ken Wells's lectures 23 years ago in the abbreviated introduction to fungi I received while making the transition from geology student to botany student at UC Davis. I know it wasn't in the general botany class I had taken a few years earlier. Nevertheless, for most of my years as a mushroom hunter and photographer, my understanding of mycorrhizas was pretty much limited to:

—Mycorrhizas are mutually beneficial associations between fungi and plant roots.

—In a mycorrhiza, the plant receives essential nutrients from the soil via the fungus, while the fungus receives food, largely in the form of sugar, from the plant.

—Some of the fungus-plant associations are specific enough that another person could tell what trees I had been hunting under, merely by looking at the mushrooms in my basket.

Several years ago, however, I began to learn that there is far more to mycorrhizas than this limited view. In fact, now I am fond of telling people that mycorrhizas are responsible for all that is good in the world — an exaggeration perhaps, but less of one than you might guess.

Beginning here, I will try, through an irregularly appearing series of articles, to pass along some of the fascinating knowledge about mycorrhizas that I have gleaned over the years as I moved from mushroom hunter to avid reader about mycorrhizas, to (hopefully!) bonafide mycorrhizal researcher.

Where We're Headed

In the remainder of this installment, I will summarize the basic nature and importance of mycorrhizas, setting up a big-picture framework for subsequent, more detailed pieces on specific facets of mycorrhizology. Along the way, we will take side-trips to review some of the biological, chemical, and ecological background necessary to appreciate fully what mycorrhizas are and what they do. So here we go!

The Big Picture — Four Important Concepts

Mycorrhizas are:

—Ancient, on the order of 400 million years old.

—Taxonomically, morphologically, anatomically and functionally diverse.

—Ubiquitous in terrestrial environments.

—Essential components of terrestrial ecosystems, playing critical roles in determining the structure, biodiversity, and functioning of those systems.

Realization of the truth of these four statements continues to be slow in coming, even among professional botanists and ecologists. For them, accepting that "lowly" fungi play major roles in ecosystems goes against much of what they have learned and requires a fundamental shift in the way they view the world.

For the overwhelming majority of the population, however, the explanation for mycorrhizal ignorance is simple — who knows anything about, or even cares about, fungi or what goes on underground? So prepare yourself to enter the ranks of a tiny enlightened minority. If you persevere, you'll come away knowing much that most university scientists don't!

So, what are mycorrhizas anyway? Although I'll provide a commonly accepted definition to get us started, keep in mind that, as we proceed in this series, we'll find that there are some fundamental problems with it.

What Are Mycorrhizas?

The term is derived from the Greek words for fungus and root. One definition couched in suitable scientific jargon is: "a mutualistic symbiosis between plant and fungus, localized in a root or root-like structure, in which energy moves primarily from plant to fungus and inorganic resources move from fungus to plant" (Michael F. Allen, *The Ecology of Mycorrhizae*, Cambridge University Press, 1991). Mycorrhiza is one type of fungus/plant symbiosis (others include *pathogenic* invasions, lichens, and leaf and stem *endophytes*.

Let's take that definition apart and make sure we understand what it means. There are six main concepts in it:

1. Mutualistic symbiosis
2. Plant
3. Fungus
4. Root or root-like structure
5. Energy
6. Inorganic resources

We'll examine each in turn.

Mutualistic Symbiosis

A symbiosis essentially is a composite organism, being an intimate living-together of individuals belonging to two or more different (usually *very* different) species. An example familiar to many mushroomers is that of lichens.

In most lichens, a green alga lives within a body structure, called a thallus, made up of fungal hyphae. Generally speaking, the algae and fungi that form lichens do not live alone in nature — they are found almost exclusively in the company of their respective lichen partner.

Depending on the specifics of a symbiotic relationship, each partner can benefit, suffer, or be unaffected by the activities of the other(s). The

case where both, or all, participants realize a net benefit from the relationship is called a mutualistic symbiosis, or mutualism.

Plant

Although we are used to thinking of mycorrhizas in relation to forest trees, members of all green plant groups form mycorrhizas, including ferns, mosses, liverworts, horsetails and club mosses. The commonality among these organisms is that all have belowground parts and virtually all make their own food through the process of photosynthesis.

In photosynthesis, the plant captures energy in the form of light, usually from the sun, and obtains carbon, to be used in constructing its body and essential chemical components, from carbon dioxide gas in the atmosphere. Chief among the products of photosynthesis (these products are called photosynthates) is a simple sugar called glucose.

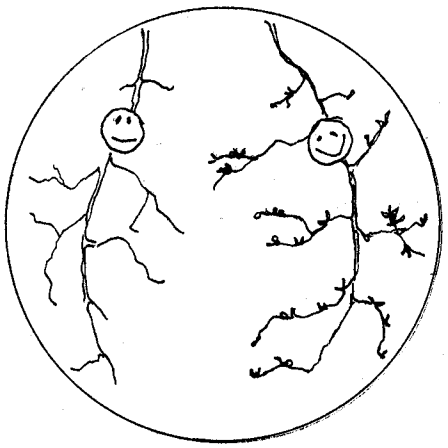
Fungus

Mushroom-hunters are familiar with many of the mycorrhizal fungi characteristic of *north temperate* forests — especially *basidiomycetes* such as chanterelles, boletes, and amanitas. Additionally, a small percentage of *ascomycetes*, such as the truffles, some helvellas, and possibly even morels, also form abundant mycorrhizas in these forests.

Less known by mushroom-hunters is that the most common fungi in mycorrhizas worldwide are *zygomycetes*, relatives of black bread mold and the hair-like fungus *Phycomyces* that appears during damp weather on the droppings left in the backyard by our dogs.

Root or Root-like Structure

We all are familiar with roots. However, not all underground plant parts are roots. For instance, plants such as ferns, ginger and certain irises are anchored primarily by underground stems called rhizomes. Many of the so-called lower plants, such as mosses and liverworts, also have simple underground anchoring structures that many botanists do not consider to be true roots (so they are called rhizoids instead). Mycorrhizas occur in rhizomes and rhizoids as well as in true roots.



Energy

Through photosynthesis, green plants obtain energy from sunlight, and store some of it as sugars and other chemicals. Thus, plants are energetically self-sufficient as long as they have a source of light. Humans and other animals, on the other hand, must eat pre-made food and then break it down through digestion and other processes to obtain energy.

Although fungi don't ingest their food in the same way that we animals do, they also must obtain energy from what they "eat." So when we speak of mycorrhizal fungi obtaining energy from plants, we mean that the fungus is receiving energy-rich compounds such as sugars from them. The fungus then "burns" these compounds to release the energy stored in their chemical bonds as well as to provide structural building blocks.

Inorganic Resources

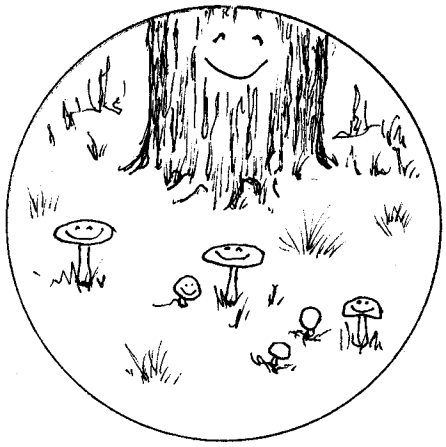
Plants need more than sunlight and carbon dioxide to build their bodies and pursue active lives. They also need water and other substances that are often called nutrients or minerals, all of which are obtained from the soil. There is a long list of nutrients required by plants, but most are needed in only tiny amounts.

Those needed in fairly large quantity are nitrogen, phosphorus, and potassium — the N-P-K that you see referred to on most fertilizer containers (N, P, and K are the chemical abbreviations for nitrogen, phosphorus, and potassium, and the set of numbers, such as 20-10-5, refers to the amount of each in the fertilizer blend). Because nitrogen and phosphorus often are scarce in soils in relation to the amounts needed by plants, it is no surprise that many mycorrhizal fungi are active in providing plants with access to these critical resources.

Wow! There's a surprising lot of information packed into that relatively short definition. So perhaps this is a good place to stop, and to let you know what you can look forward to in future installments.

Next time we'll look at the different types of mycorrhiza — what they

A.B. Frank coined the word mycorrhiza in 1885 by combining, logically enough, the Greek words for fungus and root. Traditionally, in English at least, mycorrhiza has been used for the singular form and mycorrhizae for the plural. However, the -ae plural is Latin in origin, not Greek, and so according to purists its use is incorrect. As a result, there currently is a movement away from use of the -ae form, toward use of "mycorrhiza" for both singular and plural (as is done with the word species), or use of "mycorrhizas" for the plural form.



ent types of mycorrhiza — what they look like, who the partners in them are, and where they tend to live. Following that, we'll delve into topics such as

—How mycorrhizas function

—How we study mycorrhizas

—Rock-eating and other activities of mycorrhizas in ecological cycles

—Mycorrhizal networks and other roles of mycorrhizas in plant ecology

—What you can tell about the mycorrhizal fungi in an area by the mushrooms you find there

—Practical uses of mycorrhizas in agriculture, forestry, land restoration, and home gardening

—Prospects for cultivation of edible mycorrhizal mushrooms

If there is something mycorrhizal you are particularly curious about and that doesn't seem to be included in this list, please let me know and I'll try to touch on it somewhere along the line.

Steve Trudell can be reached at Ecosystem Science Division, College of Forest Resources, Box 352100, Univ. of Washington, Seattle WA 98195-2100 or by email sent to mycecol@u.washington.edu.

Glossary

Anatomy: The structure of an organism, usually referring to the level of organization observable with a typical light microscope.

Ascomycetes: One of the major groups of fungi, characterized by sexual spores formed within a sac-like cell called an ascus. Examples include cup fungi, morels, elven saddles, and truffles.

Basidiomycetes: One of the major groups of fungi, characterized by sexual spores formed on the outside of a club-shaped cell called a basidium. Examples include gilled mushrooms, boletes, chanterelles, corals, puffballs and jelly fungi.

Biodiversity: The total variety of organisms occurring within a given area.

Ecosystem: All of the organisms within a given area and the physical environmental factors (such as climate, air, rock materials and soils) with which they interact.

Endophyte: An organism that lives within a plant; mycorrhizal fungi are root endophytes (with an external phase in the surrounding soil). Other fungi live within the stems and/or leaves of most plants.

Morphology: The structure of an organism, usually referring to the level of organization observable with the unaided eye, a hand lens or a dissecting microscope.

Zygomycete: One of the major groups of fungi, characterized by large, thick-walled, sexual spores usually not contained within a fruiting body.