The aerial portion of plants—flowers, fruits, leaves, stem—capture the imagination of most naturalists. However, plants lead a subterranean double life full of complex, bizarre interactions equally worthy of our attention. Chief among these is the relationship between plant roots and symbiotic fungi, known as mycorrhizae.

Translated from Greek, *mycorrhiza* means, literally, “fungus root” and refers to a portion of the plant root (usually the smallest, finest roots) where plant and fungal tissue mingle intimately to form a new organ. The purpose of this organ is to provide a forum for cooperation, where plant and fungus can benefit themselves by helping each other.

The best way to understand this form of biological cooperation is to use an economic metaphor. Plants and fungi, being separated by more than one billion years of evolutionary history, have arrived at very different solutions to the problem of making a living. Plants have developed specialized tissues and an architecture designed to maximize capture of light energy and transformation of carbon dioxide through photosynthesis into metabolically useful sugars. However, plants need nutrients, such as
nitrogen and phosphorous, and water from the soil to support their photosynthetic activities. Fungi lack this autotrophic (self-feeding) capacity but have developed a growth form (microscopic filaments, called “hyphae”) and enzymatic capacities ideal for penetrating dense substrates, such as soil or wood, degrading them, and extracting useful nutrients. Much as countries specialize in the production of certain goods and trade for others they do not have or cannot produce cheaply, certain lineages of fungi and plants have discovered how to engage in a mutually beneficial exchange of soil nutrients and photosynthetic sugars. And this exchange is the purpose of a mycorrhiza.

Mycorrhizae take on many forms and involve a wide range of disparate plant and fungal lineages. The different types of mycorrhizae are generally distinguished based on the morphological structure of the mycorrhizal organ and on the identity of the plants and fungi involved. In most cases, however, the symbiosis involves a root where plant and fungus cohabitate, and from which fungal hyphae radiate outward into the soil to scavenge for nutrients and water. Perhaps the two most common types of mycorrhizal symbiosis are those referred to as “arbuscular mycorrhizae” and “ectomycorrhizae.”

Arbuscular mycorrhizae have two primary distinguishing morphological features. The first of these is the tendency for fungal hyphae to penetrate the cell wall of the root cells they inhabit. For this reason, arbuscular mycorrhizae have also been referred to as “endo” (or inside) mycorrhizae. The second is the tendency of these mycorrhizae to form a highly branched structure that interfaces with the plant cell membrane. This branched structure is called an “arbuscule,” from the Latin for “bush,” and is the primary site of exchange of nutrients and sugars between the plant and fungal partners. From the arbuscule, fungal hyphae forage short distances out into the soil, in the range of centimeters, and scavenge primarily mineral forms of nitrogen and phosphorus that are essential for plant growth. These fungi reproduce by forming microscopic, ornamented spores directly in the soil or inside the plant root. Due to the small size of their hyphae and spores, these fungi are difficult to observe without the assistance of a microscope.

Although these fungi may be hard to see, they are present underfoot in almost any walk outside. Arbuscular mycorrhizal symbiosis is incredibly widespread in nature, and some 90% of plant families have been shown to affiliate with these fungi. The fungi themselves come from a single, ancient lineage. In fact, arbuscular mycorrhizal symbiosis may have played an important role in helping plants move out of the water and colonize...
land. As evidence, fossil plants have been found containing arbuscule-like structures dating back to approximately 400 million years ago when plants first began colonizing the land.

Although not nearly as common in terms of numbers of plant species involved, ectomycorrhizal symbiosis occurs in plant families that are among the most dominant and important in our temperate forests, including pines, firs, oaks, aspens, willows, alders, and birch trees. These mycorrhizae are distinguished by the formation of a distinct mantle of fungal hyphae that completely envelops the outside of the plant root, thus the name “ecto” (outside) mycorrhizae. Unlike arbuscular mycorrhizal fungi, ectomycorrhizal fungi do not penetrate the plant cell wall; rather they fill the spaces in between the root cells with fungal tissue known as the Hartig net. These fungi forage much larger distances through the soil, often meters from the host root, and can form dense aggregations of hyphae that are visible to the naked eye just beneath the duff in pine or fir forests. When it is time to reproduce, these fungi produce dense aggregations of hyphae that develop into large, spore-producing mushrooms. These fungi are often responsible for producing the choicest edible mushrooms, such as porcinis, chanterelles, matsutakes, and truffles. Their inability to grow and reproduce without a living host tree also explains why these mushrooms cannot be mass cultivated and are so expensive at market. The mushrooms of these ectomycorrhizal fungi are often the largest and most conspicuous seen in a walk through the forest. One clue to the identity of an ectomycorrhizal mushroom is its tendency to grow directly out of the ground, rather than on decaying wood or leaf litter as most saprotrophic mushrooms grow. Some of the common genera in our area are the russulas, cortinarius, boletes, and amanitas.

Because of its subterranean nature, it is easy to underappreciate the importance and obligate nature of mycorrhizal symbiosis. However, in most cases neither plant nor fungus can grow and compete in the natural environment without establishing a mycorrhizal symbiosis. A number of scientific studies have shown that mycorrhizal fungi have significant impacts on the growth, fecundity, and species diversity of the plant communities they inhabit. As some indication of their importance, scientists have estimated that approximately 10–15% of net photosynthesis (think about 10–15% of your net income) is allocated to these fungi.

Although our knowledge of mycorrhizal symbiosis has grown in recent years, there is still much to be learned. Technological advances, such as the use of DNA barcodes for identifying fungi and the use of chemical tracers for following nutrient fluxes, have paved the way for new and exciting studies on mycorrhizal symbiosis in the coming years.

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