FUNGAL MUTUALISMS AND EARLY LIFE ON LAND

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It is difficult to adequately document the benefit derived for each of the bionts in living mutualistic symbioses, and therefore even more problematic in the context of fossil organisms. Nevertheless, both nutritional and physical examples of mutualism can be convincingly documented from the fossil record. Both examples come from the Lower Devonian Rhynie chert, the lagerstätte that has unquestionably provided the most significant data base about the biology and evolution of early terrestrial plants, and other organisms. One form of mutualistic symbiosis now known to exist in the Rhynie chert ecosystem are endomycorrhizae. Today these associations are represented by zygomycetous fungi that have evolved a unique physical and biotrophic interaction with a large number of land plants. In this type of mutualism the fungus obtains a carbon source by means of intercellular shrub-like haustoria termed arbuscules, while the benefit to the plant is increased nutrient uptake, better resistance to drought and high soil temperatures, and protection against certain soil pathogens. The ability to demonstrate fossil arbuscules in several Rhynie chert plants indicates that this type of symbiosis is ancient, and supports the thesis that fungi were a critical partner in the terrestrialization of the land. Lichens in the Rhynie chert represent another example of terrestrial mutualisms. Modern lichens are associations between fungi (mycobiont) and a cyanobacterium or green alga that represents the photobiont. What is unusual about the lichen symbiosis is that together the partners form a unique thallus and also produce a special compliment of chemical compounds. In the fossil lichen the photobiont is a cyanobacterium. The thallus consists of a fungal mat that contains small pockets on the upper surface. Within the pockets are solitary cells or cell clusters, each surrounded by a gelatinous sheath. Photobiont cells are invested by fungal hyphae indicating that in this mutualism there was a nutritional exchange in the direction of the fungus, while the cyanobacterial partner gained protection, perhaps against desiccation. Stages in the development of the lichen suggest that photobiont cells became "used up", and that this fungal/cyanobacterial interaction was probably weakly parasitic. Examples of some modern endolithic algae and fungi provide as model system that offers one scenario as to the early evolution of lichen mutualists, and their role in the colonization of the earth.