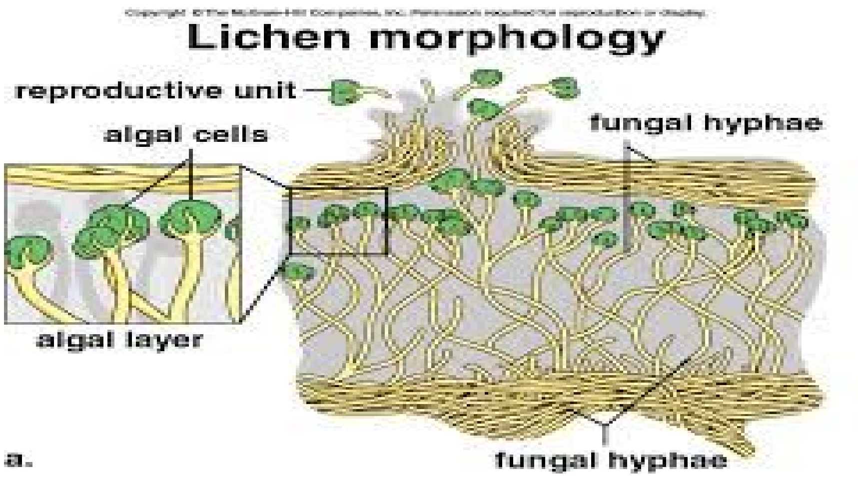
Ecology of Fungi

Introduction

Fungi, together with bacteria, are the principal decomposers in the biosphere. They break down organic materials and return the substances locked in those molecules to circulation in the ecosystem. Fungi are virtually the only organisms capable of breaking down lignin, one of the major constituents of wood. By breaking down such substances, fungi release critical building blocks, such as carbon, nitrogen, and phosphorus, from the bodies of dead organisms and make them available to other organisms. In breaking down organic matter, some fungi attack living plants and animals as a source of organic molecules, while others attack dead ones. Fungi often act as disease causing organisms for both plants and animals, and they are responsible for billions of dollars in agricultural losses every year. Not only are fungi the most harmful pests of living plants, but they also attack food products once they have been harvested and stored. In addition, fungi often secrete substances into the foods that they are attacking that make these foods unpalatable, carcinogenic, or poisonous. The same aggressive metabolism that makes fungi ecologically important has been put to commercial use in many ways. The manufacture of both bread and beer depends on the biochemical activities of **yeasts,** single-celled fungi that produce abundant quantities of ethanol and carbon dioxide. Cheese and wine achieve their delicate flavors because of the metabolic processes of certain fungi, and others make possible the manufacture of soy sauce and other fermented foods. Vast industries depend on the biochemical manufacture of organic substances such as citric acid by fungi in culture, and yeasts are now used on a large scale to produce protein for the enrichment of animal food. Many antibiotics, including the first one that was used on a wide scale, penicillin, are derived from fungi. Some fungi are used to convert one complex organic molecule into another, cleaning up toxic substances in the environment. For example, at least three species of fungi have been isolated that combine selenium, accumulated at the San Luis National Wildlife Refuge in California's San Joaquin Valley, with harmless volatile chemicals—thus removing excess selenium from the soil.

Two kinds of mutualistic associations between fungi and autotrophic organisms are ecologically important. **Lichens** are mutualistic symbiotic associations between fungi and either green algae or cyanobacteria. They are prominent nearly everywhere in the world, especially in unusually harsh habitats such as bare rock. **Mycorrhizae,** specialized mutualistic symbiotic associations between the roots of plants and fungi, are characteristic of about 90% of all plants. In each of them, the photosynthetic organisms fix atmospheric carbon dioxide and thus make organic material available to the fungi. The metabolic activities of the fungi, in turn, enhance the overall ability of the symbiotic association to exist in a particular habitat. In the case of mycorrhizae, the fungal partner expedites the plant's absorption of essential nutrients such as phosphorus.



Fungi show a wide range of behaviours and interactions. There are numerous interactions, both between different species of fungi and also between fungi and other organisms. Over time there may be a change in the species present in any area. Certain species are quick colonizers of disturbed areas – but are then replaced by others. Some species develop rapidly, reproduce quickly and then die whereas others are longer lived. Then there are those which are found in limited habitats whereas others can turn up almost anywhere.

The three fungal lifestyles

While there is no single fungal lifestyle, one thing common to all fungi is that (unlike the green plants, for example) they do not make their own food. Fungi get their nutrients from existing organic matter and there are many sources of organic matter in the world - leaf litter, dung, soil, animals, dead wood and living plants - to name just a few. Fungi use them all.

A fungus that feeds on dead organic matter is a **saprotroph**. Fungi that get their nutrients from living organisms do so in a variety of ways but can be put into two broad categories. Where there is no benefit to the other organism, the fungus in question is a **parasite**. If there is some benefit to both the fungus and the other organism, the fungi are **mutualistic**. Note that in mutualistic associations, the benefits need not be equally shared. You will often see the word symbiotic used to describe associations between different organisms and that word literally means "living together". It's a general term covering all types of associations, with no implication about the nature of the association. Hence, parasitic and mutualistic are two examples of symbiotic associations

Fungi form two key mutualistic symbiotic associations

Lichens

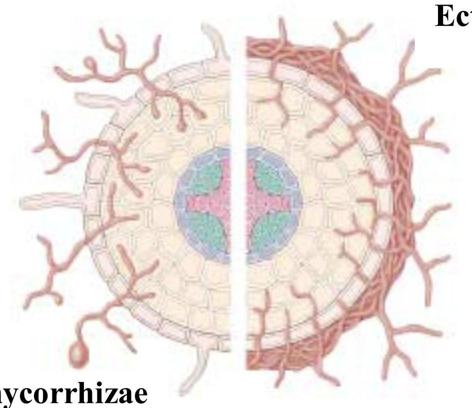
Lichens are symbiotic associations between a fungus and a photosynthetic partner. They provide an outstanding example of mutualism, the kind of symbiotic association that benefits both partners. Ascomycetes (including some imperfect fungi) are the fungal partners in all but about 20 of the approximately 15,000 species of lichens estimated to exist; the exceptions, mostly tropical, are basidiomycetes. Most of the

visible body of a lichen consists of its fungus, but within the tissues of that fungus are found cyanobacteria, green algae, or sometimes both . Specialized fungal hyphae penetrate or envelop the photosynthetic cells within them and transfer nutrients directly to the fungal partner. Biochemical “signals” sent out by the fungus apparently direct its cyanobacterial or green algal component to produce metabolic substances that it does not produce when growing independently of the fungus. The photosynthetic member of the association is normally held between thick layers of interwoven fungal hyphae and is not directly exposed to the light, but enough light penetrates the translucent layers of fungal hyphae to make photosynthesis possible. The fungi in lichens are unable to grow normally without their photosynthetic partners and the fungi protect their partners from strong light and desiccation. The durable construction of the fungus, combined with the photosynthetic properties of its partner, has enabled lichens to invade the harshest habitats at the tops of mountains, in the farthest northern and southern latitudes, and on dry, bare rock faces in the desert. In harsh, exposed areas, lichens are often the first colonists, breaking down the rocks and setting the stage for the invasion of other organisms. Lichens are often strikingly colored because of the presence of pigments that probably play a role in protecting the photosynthetic partner from the destructive action of the sun’s rays. These same pigments may be extracted from the lichens and used as natural dyes. The traditional method of manufacturing Scotland’s famous Harris tweed used fungal dyes. Lichens are extremely sensitive to pollutants in the atmosphere,
and thus they can be used as bioindicators of air quality. Their sensitivity results from their ability to absorb substances dissolved in rain and dew. Lichens are generally absent in and around cities because of automobile traffic and industrial activity, even though suitable substrates exist.

Mycorrhizae

The roots of about 90% of all kinds of vascular plants normally are involved in mutualistic symbiotic relationships with certain kinds of fungi. It has been estimated that these fungi probably amount to 15% of the total weight of the world’s plant roots. Associations of this kind are termed **mycorrhizae** (from the Greek words for “fungus” and “roots”). The fungi in mycorrhizae associations function as extensions of the root system. The fungal hyphae dramatically increase the amount of soil contact and total surface area for absorption. When mycorrhizae are present, they aid in the direct transfer of phosphorus, zinc, copper, and other nutrients from the soil into the roots. The plant, on the other hand, supplies organic carbon to the fungus, so the system is an example of mutualism.

There are two principal types of mycorrhizae : **endomycorrhizae,** in which the fungal hyphae penetrate the outer cells of the plant root, forming coils, swellings, and minute branches, and also extend out into the surrounding soil; and **ectomycorrhizae,** in which the hyphae surround but do not penetrate the cell walls of the roots. In both kinds of mycorrhizae, the mycelium extends far out into the soil.



Endomycorrhizae

Endomycorrhizae are by far the more common of these two types. The fungal component in them is a zygomycete. Only about 100 species of zygomycetes are known to be involved in such relationships throughout the world. These few species of zygomycetes are associated with more than 200,000 species of plants. Endomycorrhizal fungi are being studied intensively because they are potentially capable of increasing crop yields with lower phosphate and energy inputs. The earliest fossil plants often show endomycorrhizal roots. Such associations may have played an important role in allowing plants to colonize land. The soils available at such times would have been sterile and completely lacking in organic matter. Plants that form mycorrhizal associations are particularly successful in infertile soils; considering the fossil evidence, the suggestion that mycorrhizal associations found in the earliest plants helped them succeed on such soils seems reasonable. In addition, the most primitive vascular plants surviving today continue to depend strongly on mycorrhizae.

Ectomycorrhizae

Ectomycorrhizae involve far fewer kinds of plants than do endomycorrhizae, perhaps a few thousand. They are characteristic of certain groups of trees and shrubs, particularly those of temperate regions, including pines, firs, oaks, beeches, and willows. The fungal components in most ectomycorrhizae are basidiomycetes, but some are ascomycetes. Several different kinds of ectomycorrhizal fungi may form mycorrhizal associations with one plant. Different combinations have different effects on the physiological characteristics of the plant and its ability to survive under different environmental conditions. At least 5000 species of fungi are involved in ectomycorrhizal relationships, and many of them are restricted to a single species of plant.