Bioeconomy BW

Fungi – an introduction

After animals and plants, fungi are the third largest kingdom of eukaryotic organisms. Most people see them as plants because they typically grow in soil and do not move around like animals in the search for food; supermarkets sell edible mushrooms such as white mushrooms and shiitake. But no fungi are capable of carrying out photosynthesis themselves; the fungal energy metabolism is driven by organic molecules of dead and sometimes also living organisms. Indeed, DNA comparisons have shown that fungi are more closely related to animals than to plants. According to these comparisons, the lineage that led to humans (and all other animals) separated from the lineage that led to truffles (and all other fungi) later than the lineage that gave rise to green plants. Mutation rate estimates ("molecular clock") suggest that this happened about 800 million years ago in the Precambrian. Both the first fossil land plants and the earliest fossil fungi date back to around 400 million years ago.

Although fungi are also found in oceans and fresh water, the majority of them live on the land, where they are virtually omnipresent and where they have tapped a huge variety of food sources. It is estimated that there are about 1.5 million different species of fungus, of which less than one tenth has been described scientifically.

A digestive organ turned inside out

Fungi break down their food outside their bodies by excreting enzymes and they absorb nutrients in dissolved form through their cell membranes. This is similar to the food uptake method in the small intestine of human beings. The effective digestion and uptake of food needs an absorption surface that is as large as possible. In the intestines, this is achieved by so-called villi and the brush border of epithelial cell microvilli. A normal field mushroom can achieve a large absorption surface through a kilometre-long net of intertwined hyphae. The entirety of the thread-like hyphae is referred to as the mycelium. What is normally perceived as fungus is only a small part of the fungal organism, i.e. the fruiting body where the spores are formed. In contrast to animals and plants, fungi do not produce embryos, but instead they grow from tiny unicellular spores that are produced in huge quantities either sexually or asexually. With our every breath, we take up airborne fungal spores.

For many people, fungi are less important than plants and animals in terms of the role they play. However, due to their ability to convert organic dead matter into mineral resources, they play an important role in the global substance flow. They also constitute a much greater mass than the entire mass of animals, amounting to about one fourth of the earth's entire biomass. In a pine forest in Michigan, USA, a honey fungus (Armillaria bulbosa) was found whose mycelium, which originated from a single spore, covered an area of 37 ha and weighed around 11 t. The fact that this mycelium was indeed part of a single organism could be proven by the genetic analysis of samples taken at

Wood mushrooms (Lactarius spec.)
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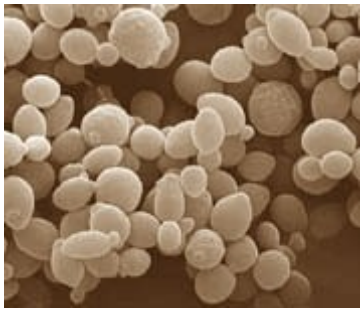
different sampling sites.

False and true fungi

Not all fungi form mycelia. Some fungi, yeasts for example, are unicellular organisms that reproduce asexually through cell division or budding, and grow as a diffuse mass. The transition from unicellular to multicellular organisms (and also the reverse) has happened repeatedly in the fungus kingdom.

In the past, many different chlorophyll-free organisms that grew and subsisted like fungi were classified as fungi. In the meantime, molecular markers and genetic analysis in particular have led to a systematic that reflects natural relationships more correctly. There is a general agreement that the so-called ray fungi (actinomycetes) are unrelated to fungi despite the fact that they have mycelia consisting of cell threads and form actinospores. Actinomycetes are prokaryotes (and hence nowadays called Actinobacteria). The best-known representative of actinomycetes, Streptomyces, is one of the most important antibiotics producers after Penicillium and related true fungi. What was previously classified as slime mould (including Dictyostelium and Physarum, popular model organisms for the development of unicellularity) is now no longer classified as fungus and instead is split into a separate heterogeneous group.



Baker's yeast (Saccharomyces cerevisiae), a unicellular ascomycete
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The position of oomycetes is still a matter of controversy. Oomycetes comprise important plant pests such as Phytophthora infestans which leads to potato blight, or Plasmopara viticola, the downy mildew of grapevines. In contrast to true fungi, the cell wall of oomycetes contains cellulose like that of green plants, and they form spores that can move around in water with flagella. The less well-known chytrids, which form mobile reproductive cells (asexual zoospores and sexually produced

gametes), have a kind of intermediate position in that they can contain chitin and sometimes also cellulose. True fungi, however, do not contain cellulose but instead they have chitin as the major constituent of their cell wall. They do not have flagellar stages and sexual reproduction is not the result of the fusion of gametes, but rather of the conjugation of different hyphae. These hyphae are not referred to as female and male hyphae, but as minus and plus due to the lack of morphological differences. The conjugation of hyphae gives rise to the fungal fruiting body where spores are produced through meiosis.

Zygomycetes or pin moulds are true fungi; a common example being black bread mould (Rhizopus stolonifer) or strawberry spoilage fungi. The large group of "higher fungi" is divided into two groups, which differ in particular through their fruiting bodies in which the spores are formed:

I. Ascomycetes or sac fungi: This is the largest fungal group, which includes popular edible mushrooms such as truffles and morels as well as many other species that can be both beneficial as well as harmful for humans, including Claviceps that grows on the ears of rye and other cereal plants (alkaloids), the moulds Aspergillus (aflatoxins, statins), Penicillium (antibiotics) and Tolypocladium (cyclosporin) as well as the yeast Saccharomyces used for making beer, wine, cakes and bread. Ascomycetes include a large number of specialist fungi, which are also able to break down the most resistant substances of the animal and plant kingdom, such as cellulose and lignin contained in wood, keratin contained in hair and nails and collagen contained in bones and connective tissue. This fungal group is also of major importance for the industrial biotechnological production of enzymes and organic compounds such as citric acid or amino acids, not forgetting the fungi used for the maturation of cheeses such as Brie, Camembert, Gorgonzola or Vendôme.

Mycorrhiza on cereal crops

II. Basidiomycetes or club-shaped mushrooms. This phylum includes the majority of edible and poisonous mushrooms as well as hallucinogenic mushrooms such as Psilocybe or Amanita, which are either extremely popular or extremely feared fungi, depending on the point of view. Some fungi of this phylum serve as the source of potent substances for the pharmaceutical and agricultural industries. The substance class of strobilurines, which is used for plant protection, was initially discovered in small Collybia fungi that grow on pine cones. Basidiomycetes also include dreaded plant pests such as rust or smut fungi. Numerous species form stable symbioses with the roots of trees and bushes (mycorrhiza), which is required by plants for their nutrient supplies from the soil.

On the subject of fungi, lichens, which are associations of fungi and algae, also need to be mentioned. They are possibly the most developed form of a symbiotic association and are of huge ecological importance as the primary settlers of inhospitable areas of the world.

Many fungi do not reproduce sexually (or at least have not been observed to do so). Due to the lack of a fruiting body, they cannot be classified as ascomycetes or basidiomycetes. These fungi are therefore grouped as deuteromycetes or Fungi imperfecti (imperfect fungi).

Medical importance of fungi

Of the 150 or so known human pathogenic fungi, many are classified as Fungi imperfecti, including Candida albicans which is the major cause of genital infections in humans, and the causal agents of skin, hair and nail mycoses (dermatophytes). While these human pathogenic fungi are mainly experienced as unpleasant rather than dangerous, they can pose a great danger to people with a weakened immune system.

Not only fungal infections, but also dead fungal cells or their components represent foreign antigens and can lead to allergies and represent a risk to human health. Fungal antigens are the most frequent allergens for humans. Poisoning does not just develop in its acute form, for example following the consumption of death caps. About 2,500 mycotoxin-producing fungi are known, which is a higher number than fungi that can cause infections. There are known mycotoxins with organotoxic, mutagenic and teratogenic characteristics where little is so far known about their role in the development of liver cirrhosis, for example. Science still has a long way to go in fungal investigation.

Dossier

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