11. Coexistence of algae, fungi and vascular plants

11.1 Mycorrhizae – Coexistence of vascular plants and fungi

The symbiotic relationship between fungi and the roots of vascular plants is called mycorrhiza. Hyphae transport inorganic nutrients—mainly carbohydrates—from the soil to the plants, while the fungi profit from organic substances provided by the vascular plants. Mycorrhizae occur in most of the terrestrial plants.

Ectomycorrhizae

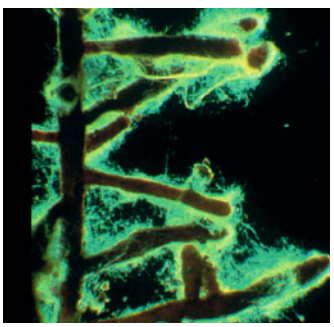
Fine roots are coated by a mycelium of numerous fungus species. The hyphae penetrate the intercellulars between the endodermis (*syn*. rhizodermis) cells and form the Hartig net. The hyphae functionally replace the fine roots. Ectomycorrhiza is most abundant in conifers (e.g. in *Picea*, *Abies* and *Pinus)*, and in deciduous trees (e.g. *Fagus* and *Quercus)* of the temperate zones in the Northern Hemisphere.

Endomycorrhizae

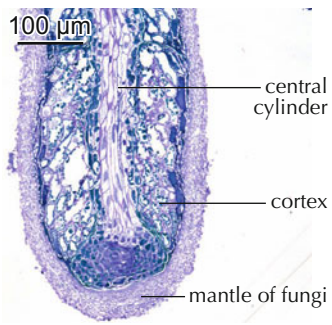
Hyphae within the cortex cells of plants characterize endomycorrhiza. The most abundant endomycorrhiza is arbuscular mycorrhiza (vesicular-arbuscular mycorrhiza, or VAM). It is found in the majority of terrestrial plants. Anatomically characteristic are globular (vesicle) or irregular, tree-like (arbuscular) terminal ends of hyphae within the living cortex cells of roots.

Mycorrhizal symbiosis is essential for orchids. Since orchid seeds don't have their own nutrient reserves, they are relying on symbiotic fungi (basidiomycetes) for successful germination. Fungi also provide organic and inorganic nutrients to orchids without photosynthetic capacity, e.g. *Neottia nidus-avis*. In this case the vascular plant acts as a parasite of the fungus (holoparasite).

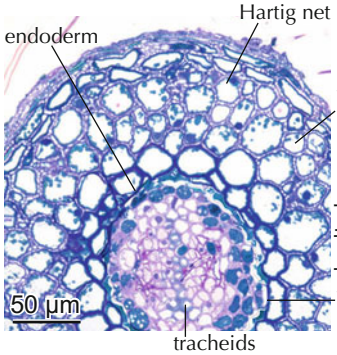
Ectomycorrhiza



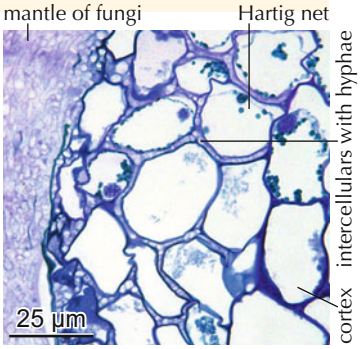
11.1 Ectomycorrhiza on *Picea* fine roots. Slide: S. Egli.



11.2 Ectomycorrhiza on a fine root of *Picea abies*. Section stained with Lugol's iodine, hyphae appear purple. Slide: S. Egli.

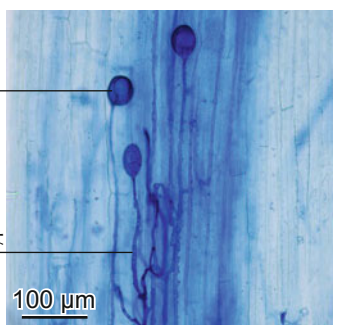


11.3 Ectomycorrhiza on a fine root of *Picea abies*. Hyphae surround the root and penetrate the rhizodermis. Slide: S. Egli.



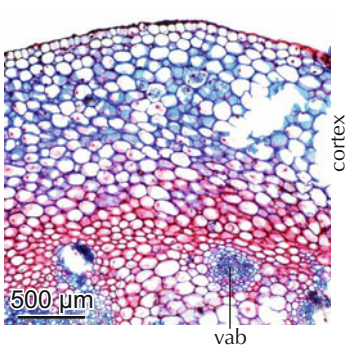
11.4 Ectomycorrhiza in intercellulars of the rhizodermis of a fine root of *Picea abies*. Slide: S. Egli.

Endomycorrhiza

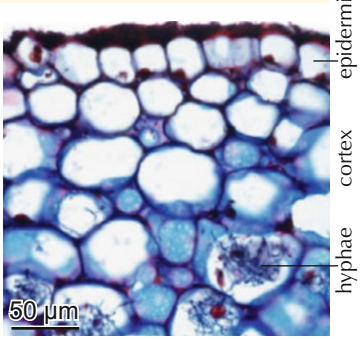


11.5 Endomycrorrhiza with globular vesicles in the roots of *Allium porrum*. Slide: S. Egli.

11.6 *Neottia nidus-avis*, a holoparasite without chlorophyll. Photo: A. Moehl.



11.7 Cross section of *Neottia nidus-avis* with vascular bundles in the center and a parenchymatous cortex.



11.8 Endomycorrhiza in living cortex cells of *Neottia nidus-avis*. Groups of hyphae surround cell nuclei.

F. H. Schweingruber, A. Börner, *The Plant Stem*, https://doi.org/10.1007/978-3-319-73524-5_11

11.2 Lichens – Coexistence of algae and fungi

Hyphae of fungi and algae live together in a symbiotic association and form a morphological and physiological unit. Partners are principally ascomycetes and cyanobacteria. More than 20,000 species occur from the tropics to the arctic, and from extremely dry to aquatic sites. Some thousand species form leaf-like, not self-supporting thalli, some form small, self-supporting and upright, horizontal or hanging stems. Fungi build the corpus and are responsible for water uptake, while the photosynthetic algae provide organic nutritive substances. The periphery is light-permeable and extremely hydrophilic. This allows short-term photosynthetic reactions of the algae by moistening the surface. Lichens produce species-specific acids, which partially crystallize. The arrangement of hyphae is related to growth forms. Upright types form a dense external tube, hanging types form a dense central cable-like strand, and leaf-like forms do not have stabilizing elements. The following images describe the principal lichen structure and some anatomical variations of different growth forms.

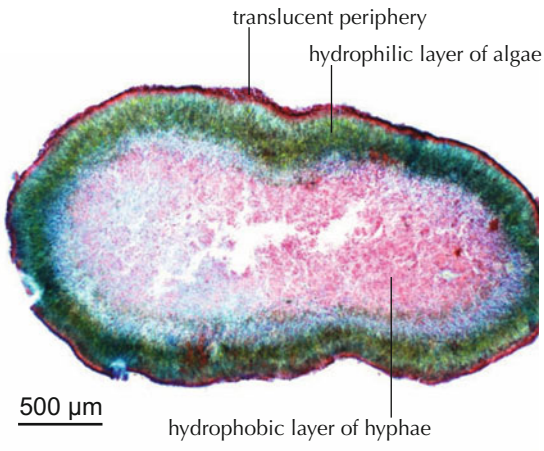
Macroscopic aspect of lichen growth forms

11.9 Upright *Cladonia* sp. with 4 cm-tall stems with reproductive organs.

11.10 Hanging *Usnea barbata* with up to 20 cm-long strands.

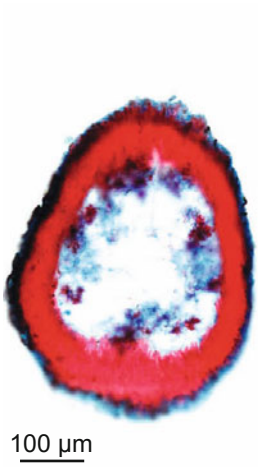
11.11 Leaf-like, not self-supporting *Hypogymnia physodes* with 3 cm-long, flat thalli.

Principal structure of lichens

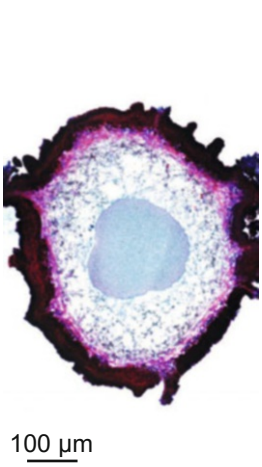


11.12 Structure of *Roccella* sp. Characteristic are the translucent periphery, the green hydrophilic layer of hyphae with algae, and the central hydrophobic layer of hyphae. Material: C. Scheidegger.

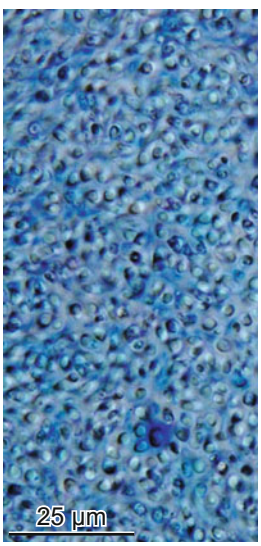
Structure of different lichen growth forms



11.13 Upright *Alectoria nigricans* with a dens tube-like stem.



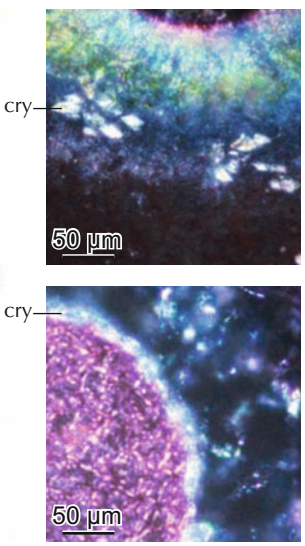
11.14 Hanging *Usnea hirta* with a dense central strand.



11.15 Thick-walled hyphae in the central strand of *Usnea hirta*.

11.16 Leaf-like *Hypogymnia physodes* without dense hyphae zones.

Crystals



11.17 Top: Large crystals in *Roccella* sp. Bottom: Small crystals around the central strand of *Usnea barbata*, polarized light.