Lichens

• An Incredible symbiosis!
• Fungus + Green alga and/or Cyanobacterium
• With an assortment of bacteria, yeasts
  • http://aem.asm.org/content/77/4/1309.full
  • http://www.cbc.ca/news/technology/lichen-yeast-1.3689468
• Obligate biotrophic relationship!
• Mutualistic or Parasitic?

http://www.lichen.com/invertebrates.htm
What is a lichen (thallus)?

- It is not an organism in the normal sense, but rather an obligate symbiosis -
  - Photobiont: a green alga and/or blue green bacterium – own genus and species
  - Mycobiont: the fungus (Ascomycota or Basidiomycota) – lichen genus and species refers to the fungus
• Photobiont Genera
  • 25 eukaryotic genera of algae
  • 15 prokaryotic Cyanobacteria
    – 80% lichens contain unicellular green alga (*Trebouxia*)
    – 10% filamentous green algae
    – 10% Cyanobacteria (*Nostoc*)
• Green algae \(\rightarrow\) sugar alcohol (ribitol, sorbitol, erythritol)
• Cyanobacteria \(\rightarrow\) glucose – also fix Nitrogen!
Photobionts – most reproduce by cell division or fission

- Unicellular alga, Chlorophyta, *Trebourxia* sp. (L); Cyanobacterium, *Nostoc* (R); filamentous, Chlorophyta, *Trentepholia* (lower)
Mycobionts

Introduction

• 15,000 – 20,000 lichenized fungi
  – 10,000 produce fungus ascocarp or basidiocarp
  – The rest produce conidia or reproduce by others means (isidia, soredia, fragmentation)
  – 98% are Ascomycota
  – Others are lichenized Basidiomycota

– Mycobiont -
  • Absorbs water and minerals from substrate and atmosphere
  • Builds complex thallus

Lichens are shown in green, animal pathogens in red.

Genus and species of lichens represent the fungus.
- Basidiomycota
- lichens

http://www.pnas.org/content/101/13/4507.full
Lichen Growth Forms - Ascolichens

- Foliose
- Crustose
- Fruticose
- Squamulose
- Leprose
• **Foliose lichens**: leaf-like, lobed thallus, sometimes with **rhizines**, rootlet-like structures produced by lower cortex, attaching thallus to the substrate

*Peltigera*
• Foliose - Gelatinous lichens: formed from fungus and Cyanobacterium, *Nostoc*
**Crustose lichens**: growing in or on rock, wood or soil.

- Crustose lichen
- Apothecia
• **Fruticose and Filamentous lichens**: grow away from their substrates, may be branched, shrub-like, beard-like, etc.
• **Squamulose lichens**: composed of many small upturned scales

Primary thallus of *Cladonia*
• Leprose lichens: those in which the thallus is a loose, powdery material

Lepraria
Lichen Thallus – Reproduction

1. Fragmentation
2. Isidium
3. Soredium

- **Isidia**: finger-like or branched structure that grow up from the thallus.
Soredia on the Soralium

Apothecium

What are “isidia” and “soredia”? Why don’t I have them?

Fragmentation

isidia
*Peltigera membranacea* – stratified, *Nostoc* photobiont

*Peltigera venosa* – stratified, *Trebuoxia* photobiont
Lichen thallus structure (interior), cross sections through thallus

Stratified lichen thallus

- Foliose
- Cortex
- Algal layer
- Medula
- Lower cortex
- Substrate

rhizines

- upper cortex
- algal layer
- madulla
- lower cortex
Lichen thallus structure (interior), cross sections through thallus

Gelatinous lichen thallus, non-stratified

Upper surface

fungus

Gelatinous matrix

Lower surface
More than one photobiont

Cephalodium – sometimes colonies of a blue green bacterium in or on lichen thallus; fixes Nitrogen and photosynthesis!
Physical relationship between hyphae and green algal cells

- Ascocarp of fungus
- Fungal hyphae
- Algal layer
- Soredia
- Appressorium
- Algal cell
- Fungal hyphae

Scale: 10 μm
SEM of reconstitution of a lichen \textit{(Cladonia cristatella British Soldier)} (from Raven)

(a) \textit{Trebouxia} cell surrounded by fungal hyphae

(b) Penetration by haustorium (see arrow)

(c) Mixed components developing into mature lichen
Hydrophobins

Hydrophobins (small (90 –150 amino acids secreted proteins) are of fundamental importance to the maintenance of the lichen symbiosis. It appears that they prevent waterlogging of key airspaces within lichen thalli, allow channeling of water and nutrients between the symbiotic partners and, in effect, isolate the photobiont, making it dependent on the mycobiont for its supply of water and nutrients. Also on hyphae and spores of other fungi, mushrooms, etc.

A hydrophobic rodlet layer of assembled hydrophobin (red line) lines the medullar gas spaces of a lichen, covering both the mycobiont and the photobiont.
Functional Aspects of the Symbiosis

* What does the fungus gain from the alga?

Richardson’s summary of movement of carbohydrate from *Trebouxia* to fungus

Where cyanobacteria are present, the fungus gains glucose as well as nitrogen

* What does the alga gain from the fungus?

A substrate and stable environment

Mineral nutrients
Lichen Growth

Growth rates

- Growth very slow since thallus ‘dried out’ most of the year
- Some grow fast where water is abundant
- Some grow very slowly where water is scarce
- Many foliose species have rates of radial extension between 2 and 5 mm per year but many crustose lichens grow much more slowly with rates of less than 0.5 mm per year.
Lichen Growth

Many crustose lichens grow exceedingly slowly and live for thousands of years. Representatives of a species called the map lichen (*Rhizocarpus geographicum*) have been aged in the arctic at 8,600 years, by far the oldest living organisms on the planet. They are easily aged because many species grow at constant rates. The ages of the oldest lichens on exposed rock give an approximation of the time when the rock was first uncovered. Glacial geologists use the ages of lichens to estimate the time of retreat of a glacier.
Sexual Reproduction - Fungus

• Ascocarp, asci and ascospores
  – Ascus and ascospores mature very slowly;
    • Due, perhaps, to the slow uptake of energy from phycobionts
  – Number of ascospores per ascus varies
    • Pertusaria sp.: 1 spore/ascus
    • Acarospora sp.: 100 spores/ascus
    • Many do produce the standard 8 spores/ascus
Do lichens have a life cycle?

Let’s break it down:

Lichen thallus – vegetative reproduction

Fungus – sexual or asexual reproduction

Green Alga – sexual and asexual reproduction

Cyanobacteria – vegetative and asexual reproduction
*Trebusoxia* are lichenized or free living, usually the cells of the latter are larger and do not release sugar alcohols as in lichenized species. *Trebusoxia* has a massive chloroplast with a single pyrenoid. When it is growing in the lichen association, reproduction is normally by autospores, although under wet conditions zoospores may be formed. When the alga is grown in liquid culture, zoospores are formed. Sexual reproduction is isogamous or anisogamous by the fusion of biflagellate gametes.
Nostoc
Verrucaria (Loculoascomycetes)

perithecia and pseudothecia

Bitunicate ascus, sepatate ascospores

Unitunicate ascus
Asexual reproduction - conidia

- Pycnial anamorphs: small opening (black dot) leading to flask shaped cavity with conidia
• Lichens are differently sensitive to air pollution.
  1) Fruticose:
    The most sensitive
  2) Foliose: the second
  3) Crustose: the most resistance
Lichens and air pollution

Pollutants:
- Depositional Nitrogen
- Sulfur Dioxide
- Ozone
- Acidic Deposition
- Fluorine
- Heavy Metals

http://gis.nacse.org/lichenair/?page=airpollution#metals
LICHENS AS ECOLOGICAL INDICATOR

Brief history of using lichens as bioindicator of air pollution:
- Other air pollutants, NOx, O3, heavy metals, HF, organic pollutants, caused disappearance of lichens from cities & industrial areas.
- In 1866 it was noted that lichens disappeared from Jardin de Luxembourg near Paris.
  * Smoke from burning of coal was the course.
  * SO2 from burning coal damaged to lichens.
  * Lichens have been used as bioindicator of air pollution world-wide.
Uses Of Lichens

- Because they are capable of colonizing bare rocks and other mineral substrates, lichens are important in soil formation during some ecological successions. For example, lichens are among the first organisms to colonize sites as they are released from glacial ice. In such situations lichens can be important in the initial stages of nitrogen accumulation and soil development during post-glacial primary succession.

- Lichens are an important forage for some species of animals. The best known example of this relationship involves the northern species of deer known as caribou or reindeer (Rangifer tarandus) and the so-called reindeer lichens (Cladina spp.) that are one of their most important foods, especially during winter.