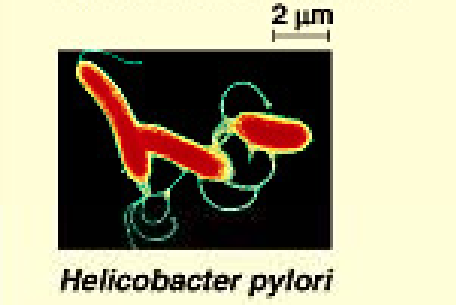
Microbial response to climate change: prokaryotes and fungi



Helicobacter pylori

1. Prokaryotes:

a. What role have prokaryotes played in historical atmospheric change?

b. What types of prokaryotes were involved in making the Earth's atmosphere?

c. What strategies do prokaryotes employ to acquire carbon? Ecological roles?

d. What role do prokaryotes play in the nitrogen cycle?

2. Fungi:

a. What strategies to fungi employ to acquire C?

b. What roles do fungi play in global material cycles (C, N, etc)?

3. The potential effects of current trends in climate change on:

a. Prokaryotes and fungi

b. Plant-microbe associations

c. Soil nutrient availability

1. Prokaryotes:

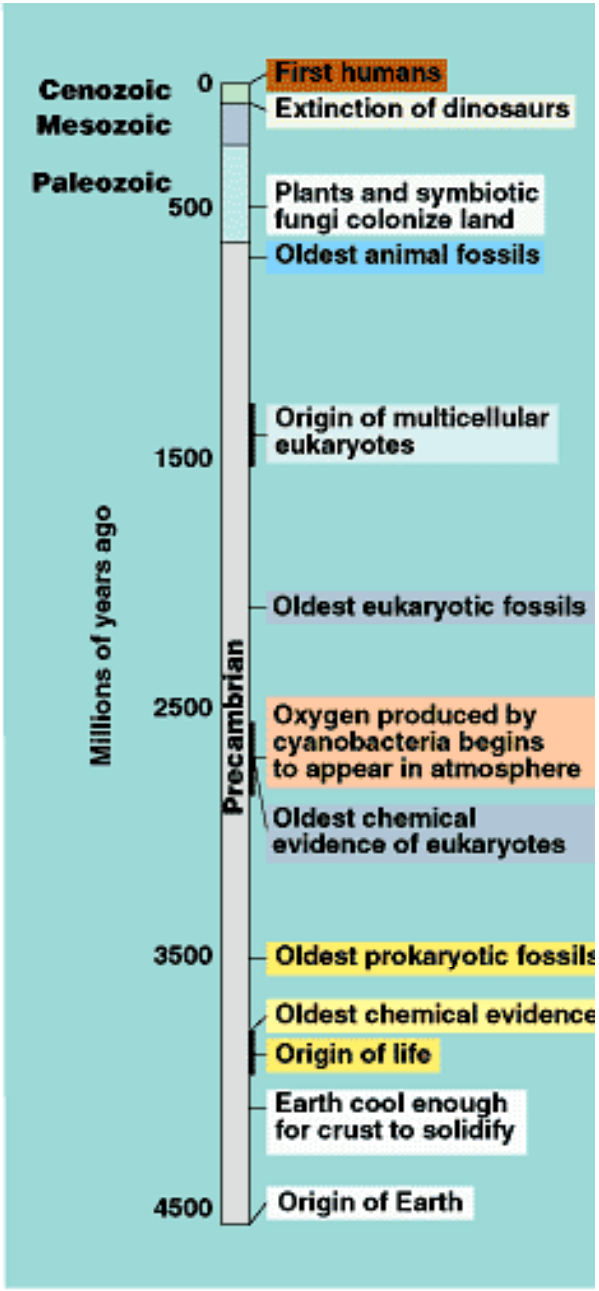
a. *What role have prokaryotes played in historical atmospheric change?*

Anaerobic to aerobic environment ~2.5 billion YA

b. *Prokaryotes involved in making the Earth's atmosphere?*

Cyanobacteria – important characteristics?

- photoautotrophs
- aquatic
- some can fix nitrogen



c. What strategies do prokaryotes employ to acquire carbon?

Autotrophs fix C from CO_2 using light (or inorganic chemicals).

Heterotrophs obtain C from organic compounds using energy from organic compounds.

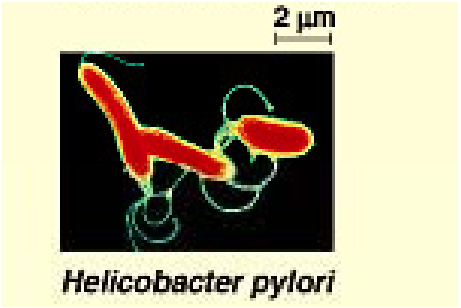
Key ecological roles:

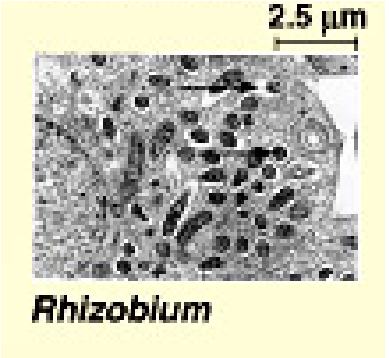
Decomposers: with fungi, they are the only organisms that release C, N etc. from organic molecules to inorganic forms in soil, water or air. (heterotrophs)

Primary producers: cyanobacteria in aquatic ecosystems (autotrophs)

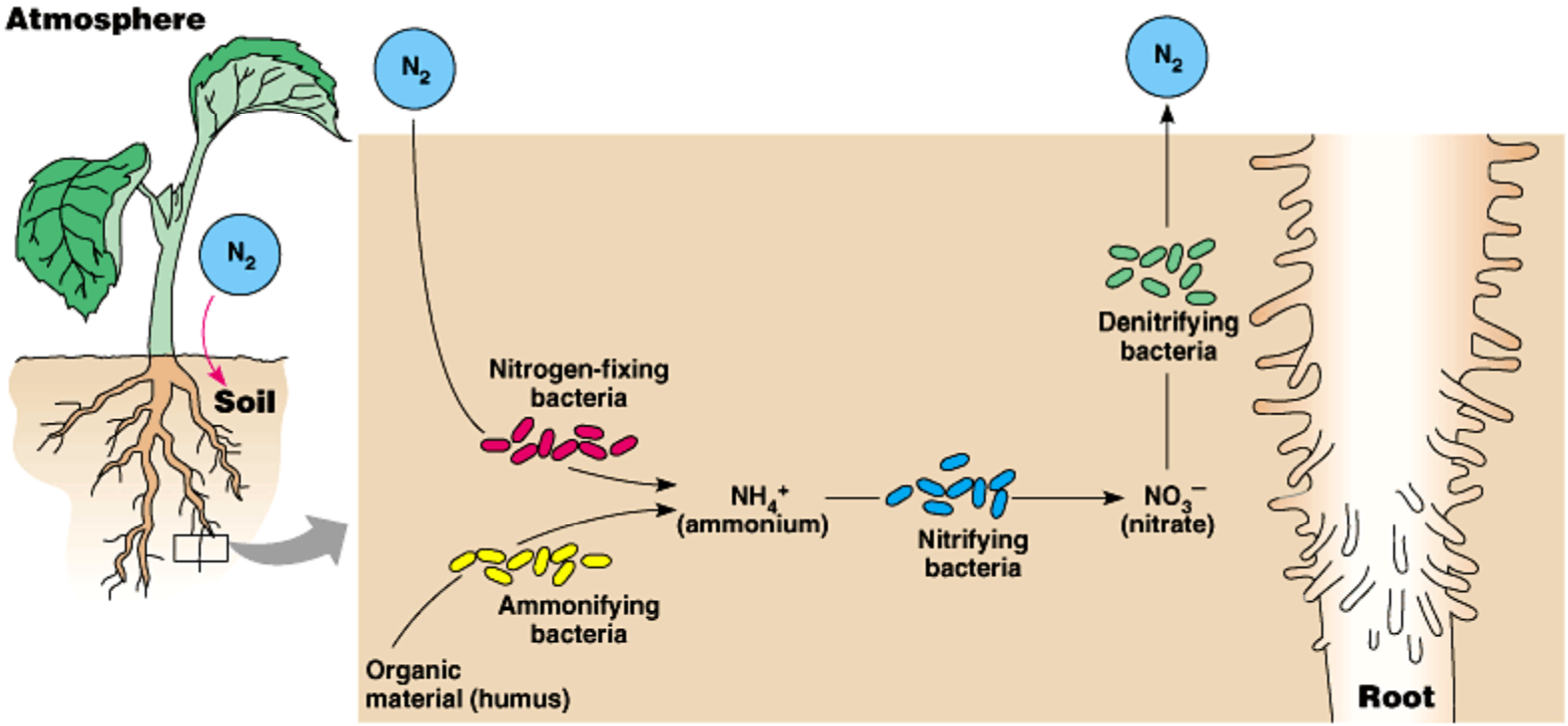
Nitrogen fixers in soil & water: only organisms that can convert atmospheric N to forms that other organisms can use (ammonia and nitrate).

Important symbiotic interactions with other organisms: e.g. parasites, commensalists, mutualists.



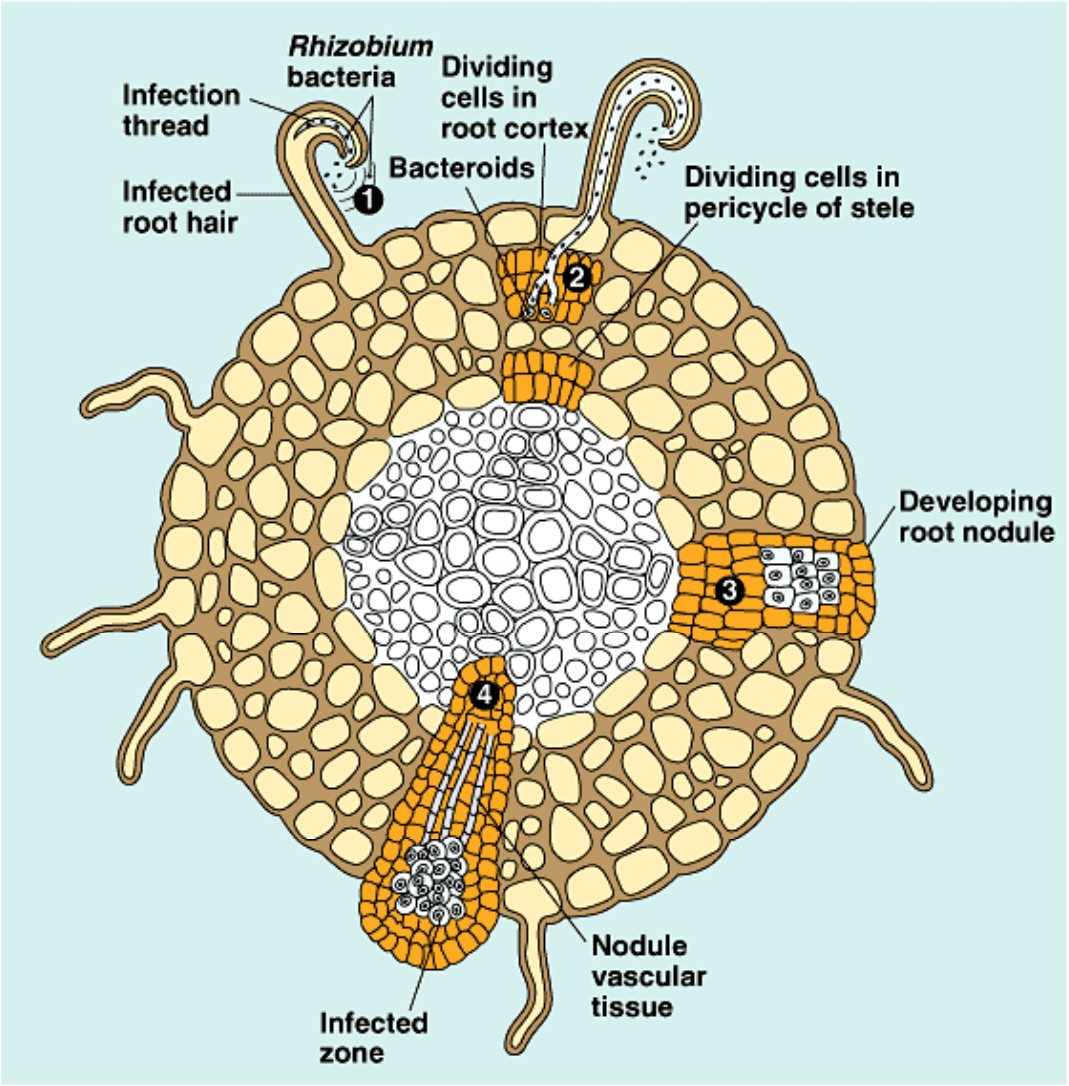


d. What role do prokaryotes play in the nitrogen cycle?



- A very important microbe-plant mutualism: nitrogen-fixing root nodules

Members of Fagaceae (pea and bean family) and *Rhizobium* (bacteria)

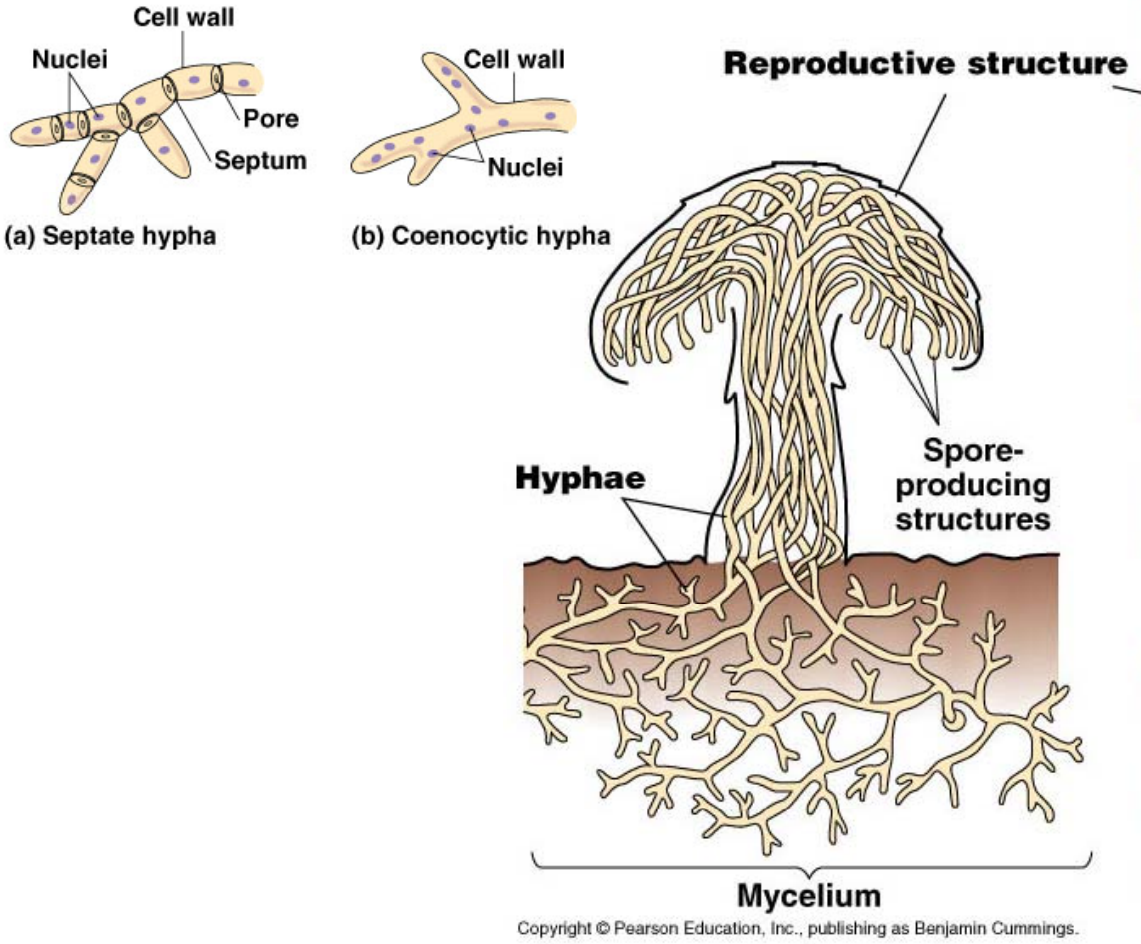


2. Fungi:

a. What strategies to fungi employ to acquire C?

All fungi are heterotrophs that acquire nutrients via absorption through mycelium:

i. Decomposers



ii. Parasites of animals, plants and other fungi

- Parasites of animals: e.g. fungal diseases of humans: athlete's foot, *Aspergillosus*

Emerging pathogens----

Sudden, simultaneous and significant frog deaths in Australia, central America and US in late 1990's - "due to chytridiomycosis".

Impaired immune systems due to ?

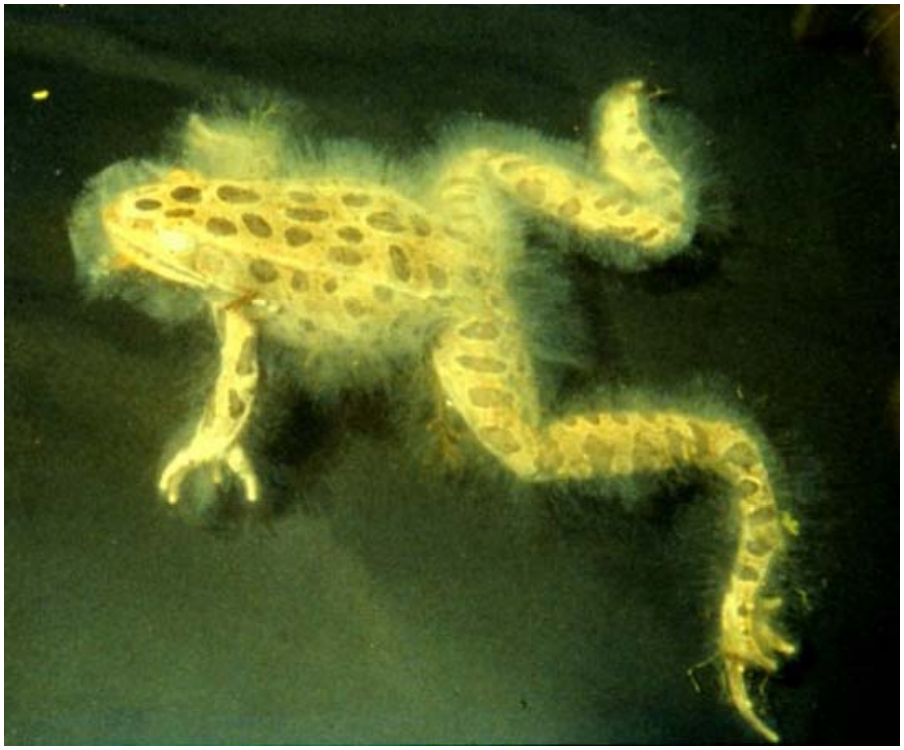
– increased temperature?

- Increased exposure to

UV light (ozone depletion)?

-Various industrial chemicals?

- Spread of pathogen by humans?



Organism described in 1999:

Batrachochytrium dendrobatidus

Longcore et al. (1999) Mycologia

91:219-227

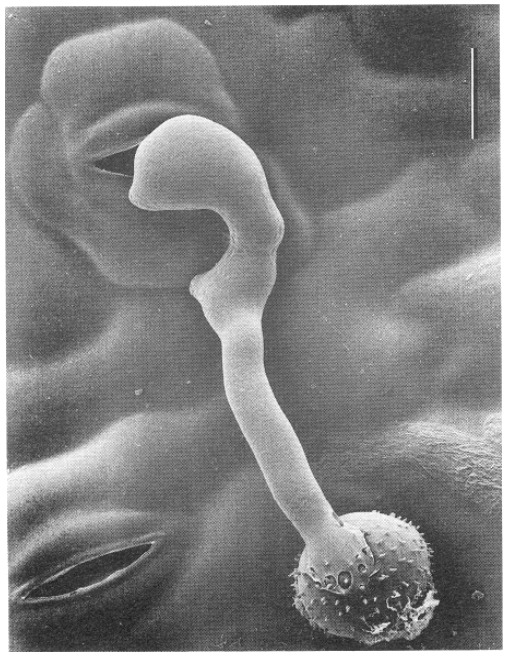
Parasites of plants:

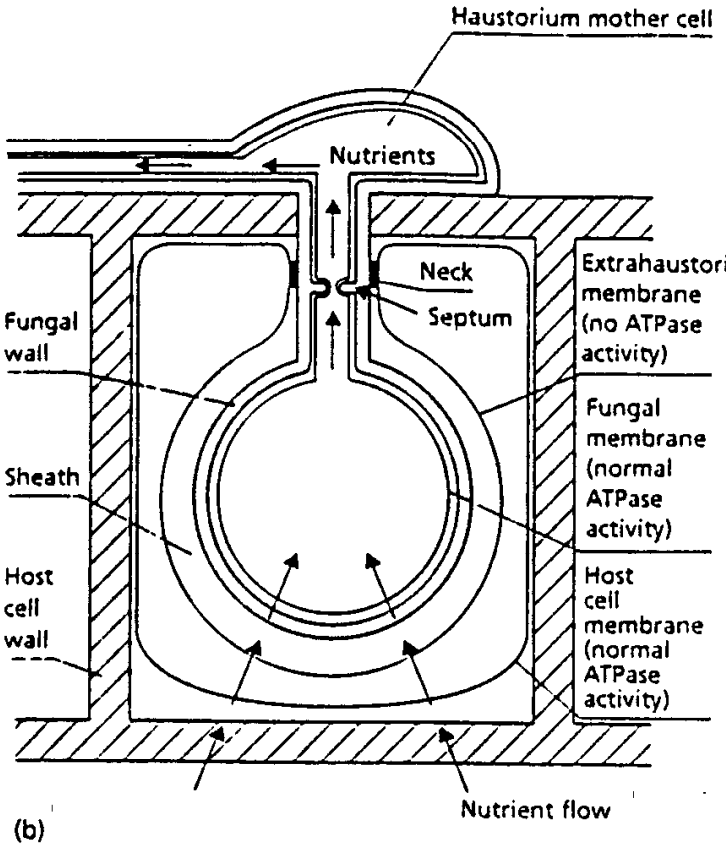
Most successful pathogens attack host during <u>environmental stress</u>

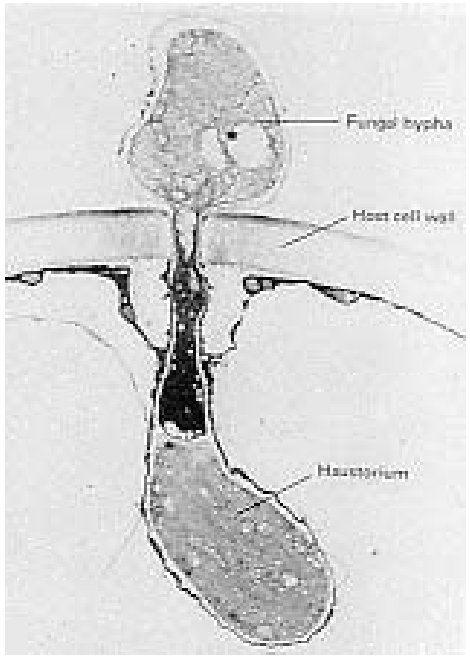
e.g. temperature, pH, oxygen/carbon dioxide, light intensity, and especially moisture

Fusarium root rot progresses in roots over time

Turf grass infected with *Pythium* after 2 weeks of saturating humidity and rain




Haustorium mother cell
Nutrients
Neck
Septum
Extrahaustori
membrane
(no ATPase
activity)
Fungal
wall
Fungal
membrane
(normal
ATPase
activity)
Sheath
Host
cell
wall
Host
cell
membrane
(normal
ATPase
activity)
Nutrient flow
(b)


Fungal hypha
Host cell wall
Haustorium

iii. Mutualisms:

lichens: fungi + algae(+ cyanobacteria) – important bio-indicators of atmospheric pollution

mycorrhizae: fungi + plant roots – essential associations with 95% of all land plants

crustose lichens on rocks – Lake Superior, MN

Morchella esculenta (morel)

Two types of mycorrhizae:

1. Ectomycorrhizae: (EM) mostly macrofungi with variety of host plants: e.g. pines, firs, oaks

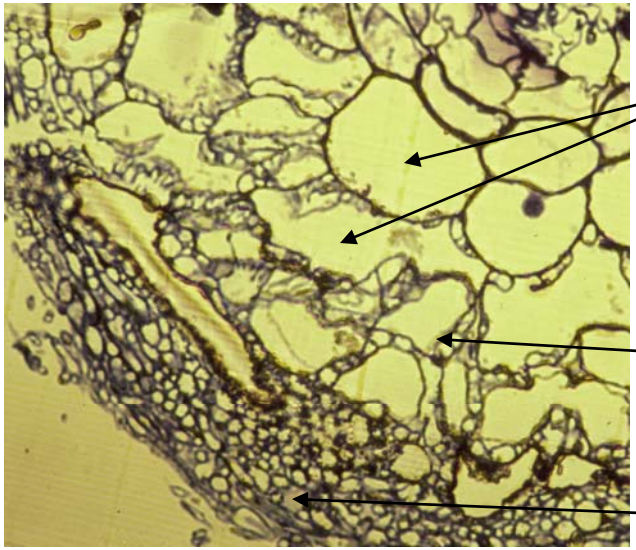
Suillus pictus

- with pines

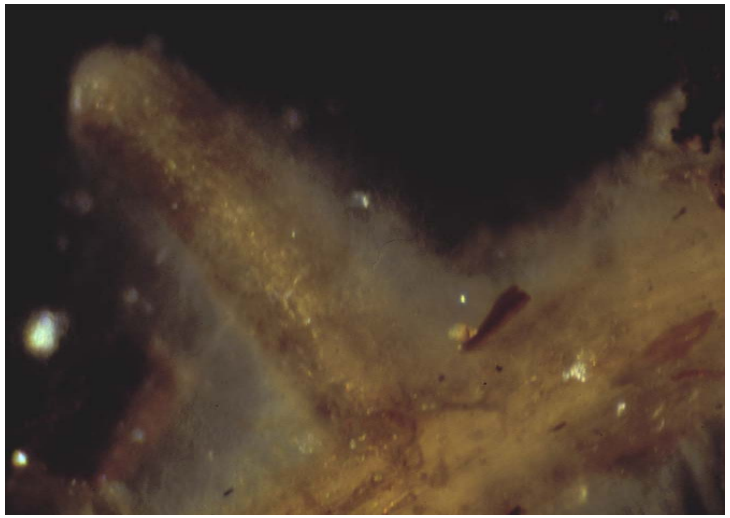
pine rootlet without EM

- note root hairs

X-section of EM rootlet



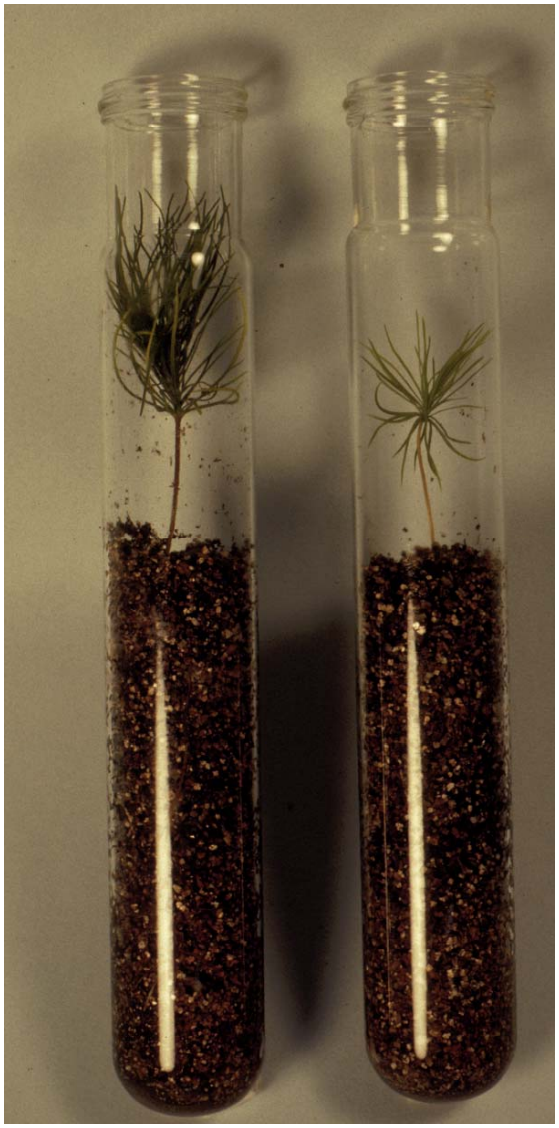
EM rootlet



Effects of EM fungi on growth of host plants

- increased uptake of P from soil, better WUE

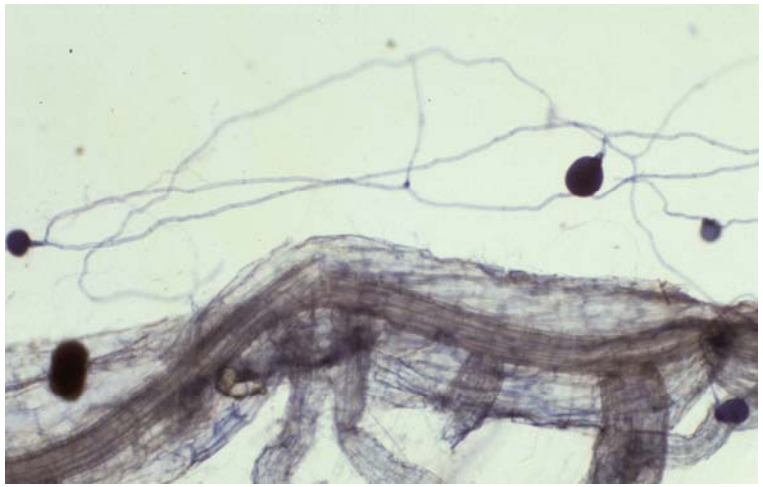
15 year old pine trees planted with (left) and without (right) EM fungi



3 month old pine seedlings inoculated with and without *Suillus pictus*

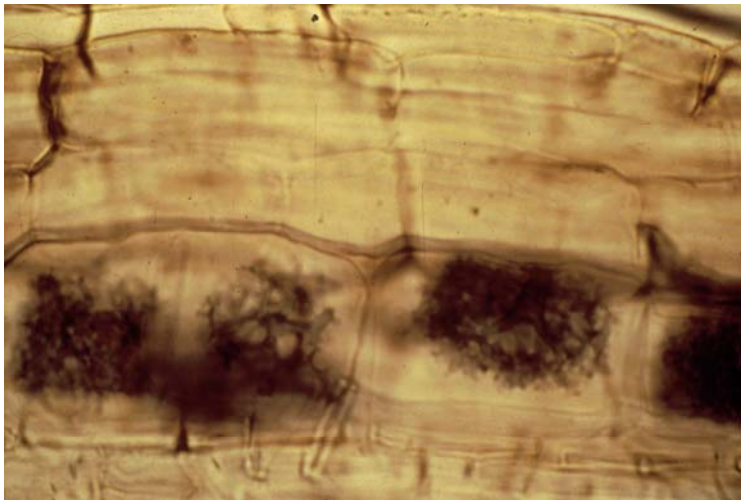
b. Endomycorrhizae = arbuscular mycorrhizae (AM)

Microfungi with 90% of all plants: grasses, forbs, maples

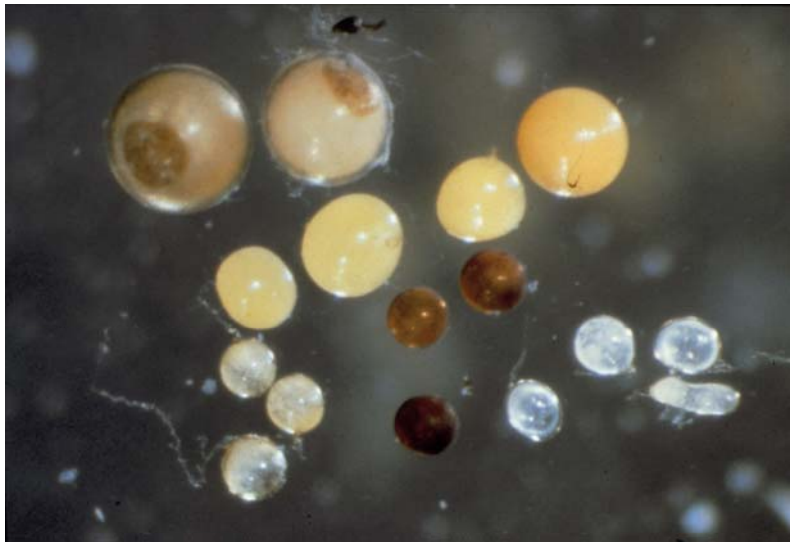


Namib Desert grass root infected with *Glomus* species

castor bean plant with and without AM association



arbuscules within plant root cells – site of nutrient exchange



AM spores isolated from Namib Desert “soil”.

b. What roles do fungi play in global material cycles (C, N, etc)?

As heterotrophs, all fungi break down organic molecules, respiring CO_2

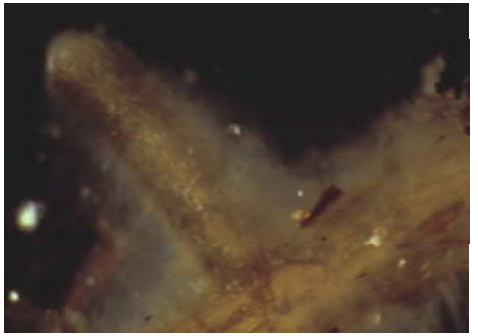
decomposers: use complex organic molecules from dead animals, plants, other microbes

- certain fungi are the sole decomposers of **lignin** (woody plants)

parasites: exoenzymes breakdown complex organic molecules, fungi absorb simple sugars, amino acids, N and P from host.

mutualists (e.g. mycorrhizae, lichens):

simple sugars from host; inorganic P & N from environment.



3. Potential effects of current trends in climate change on microbes:

a. Direct effects on prokaryotes and fungi (i.e. not mediated by host)

- temperature change: specific thermal optima for growth
- soil moisture availability (due to improved WUE of plants at higher CO_2)
- increased climatic variability: e.g. drought cycles and microbial growth, pathogen cycles

b. Plant-microbe associations (mutualisms and rhizosphere microbes)

- effects of increased CO_2 on plant growth --- likewise effect microbial growth, but …..

c. Soil nutrient availability

Increased demands on soil N and other nutrients due to enhanced plant growth, results in ?? (see Hu et al. 2001).

(see Table 37.1 for essential **macro-** and micro-nutrients)