Living with strangers

A Natural History of the Finger Lakes

CAU 2024

Where we're going

1. Mitochondria

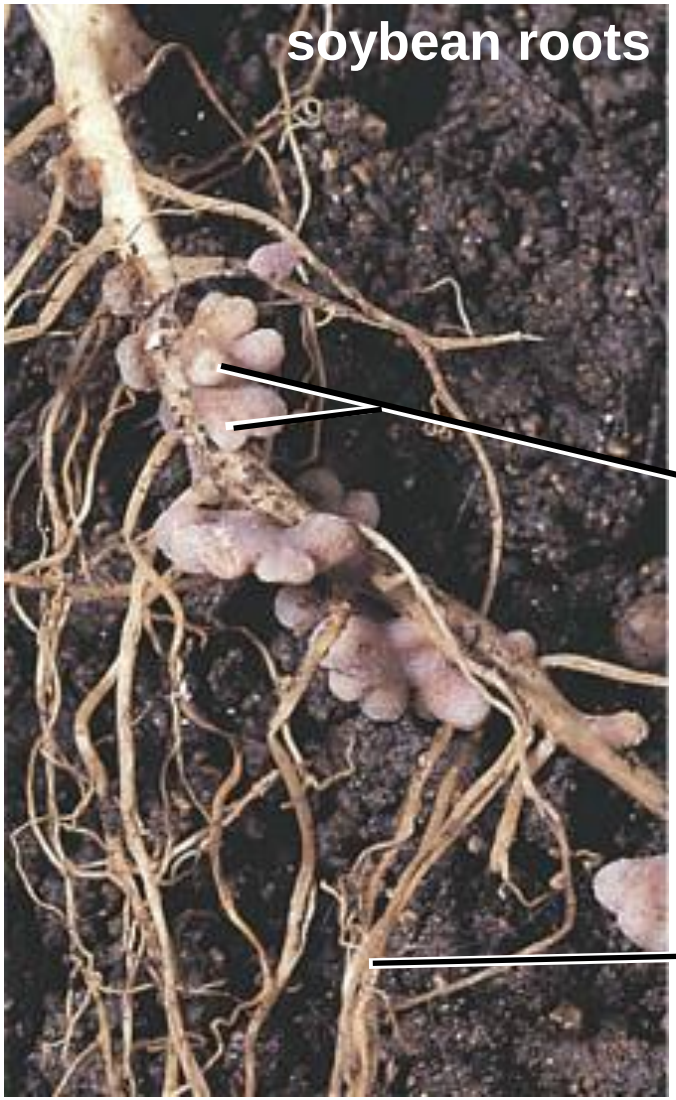
2. "internal" symbionts
   - Root nodules
   - Mycorrhizae
   - Poly DNA virus

3. Alimentary tract symbionts
   - termites

4. Other creatures
   - photosynthetic partners
   - other nutrition


Mitochondria are derived
from α-proteobacteria

Root nodules on legumes



anaerobic root nodules with *Rhizobium*

Roots

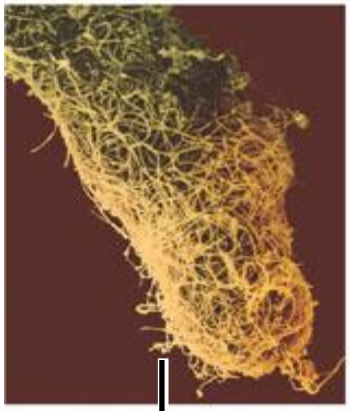
Rhizobium bacterioids within vesicle

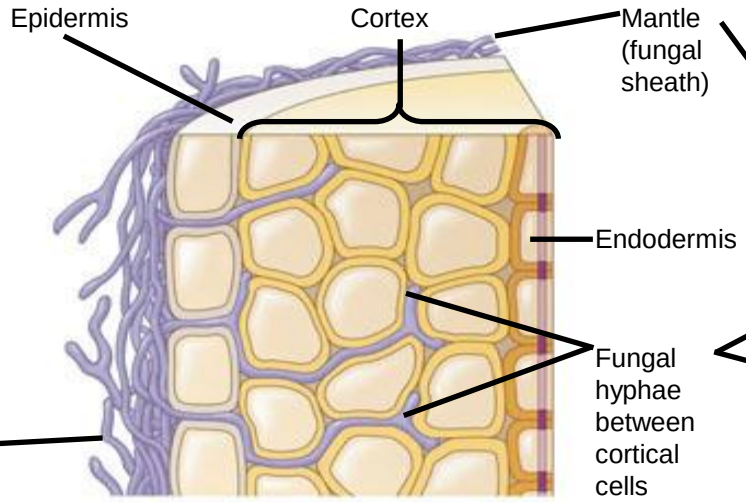
Soybean nodules contain leghemoglobin

It binds O_2 and acts as a buffer keeping O_2 away from nitrogenase, but available for bacterial respiration to make ATP

Mycorrhizae = fungi + roots

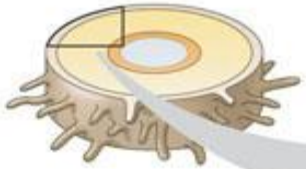
Ectomycorrhizae form dense sheath, extracellular

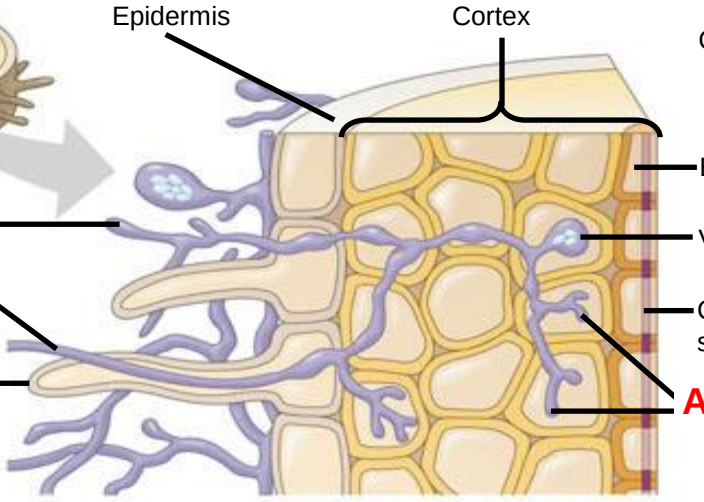


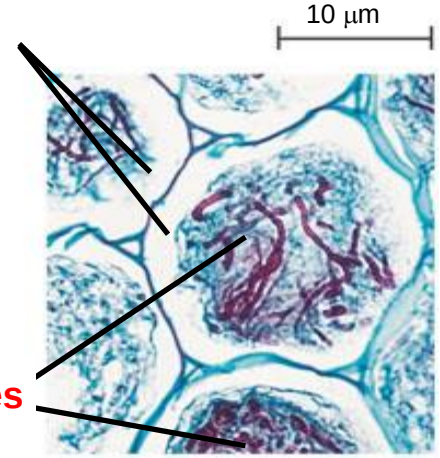


(colorized SEM)

Endomycorrhizae ("arbuscular mycorrhizae") penetrate only cell wall







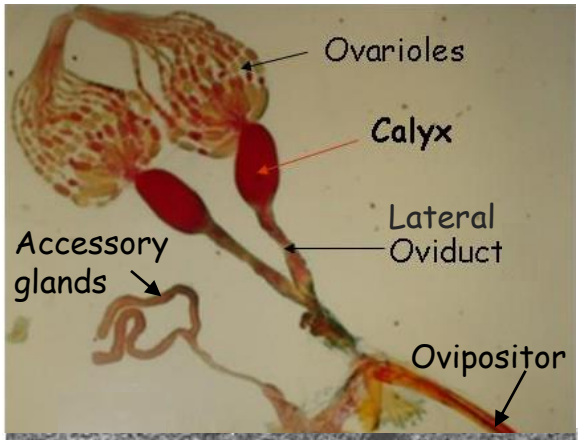
(LM, stained specimen)

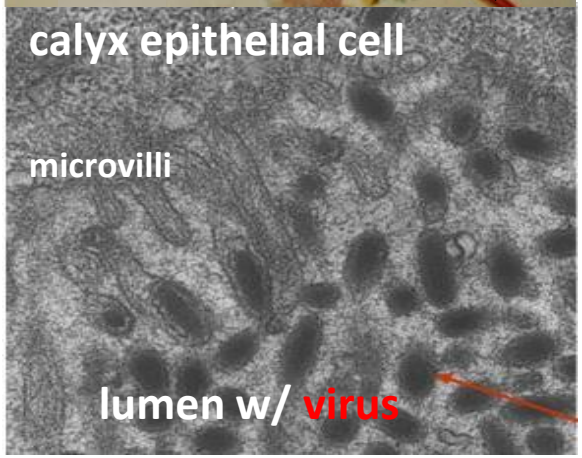
Ghost pipe (*Montropa uniflora*, Ericaceae) parasitizes ectomycorrhizae of *Russula* fungus on various hardwoods, e.g., beech, and conifers

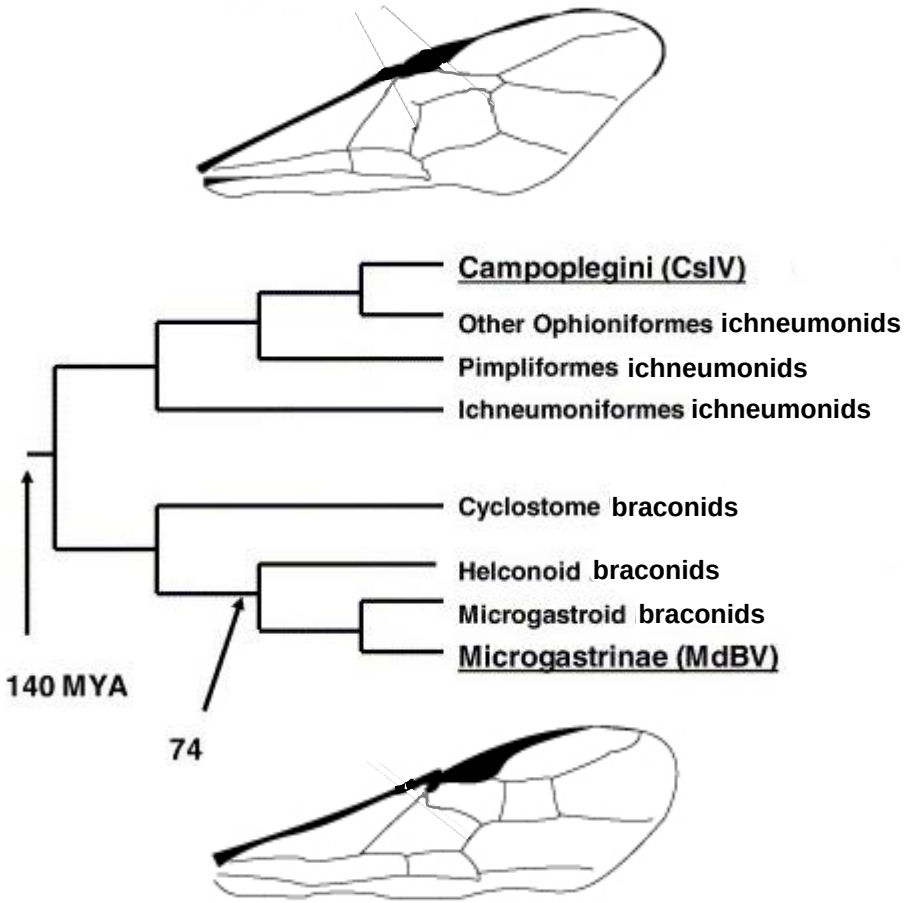
Ghost pipe associated with root mass of its host

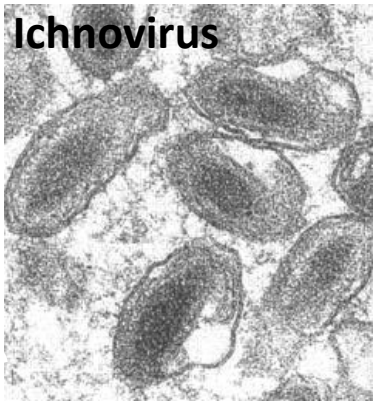
polyDNA viruses

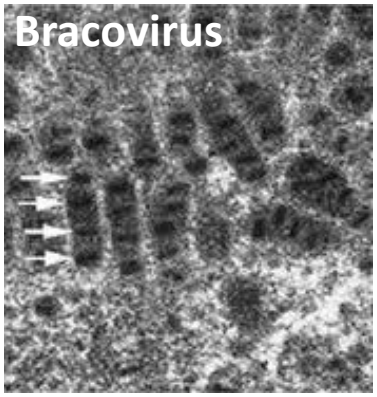
Independently evolved in two families of parasitic wasps
(different morphology, very little sequence similarity)











[Webb et al. 2006. Virology 347:160-174]

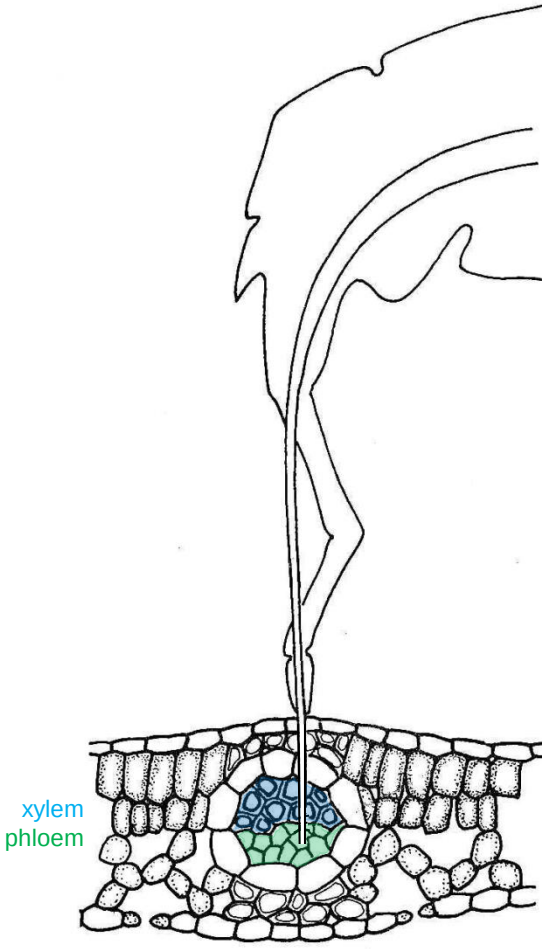
Some wasps have even incorporated the virus DNA into cells that line their ovaries

Campoletis sonorensis
[Ichneumonidae]

Wasp pupa and remains of parasitized caterpillar

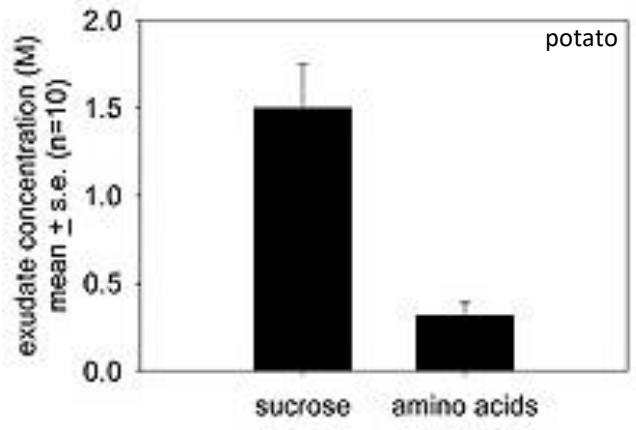
[Fleming & Summers, 1991. PNAS 88:9770]

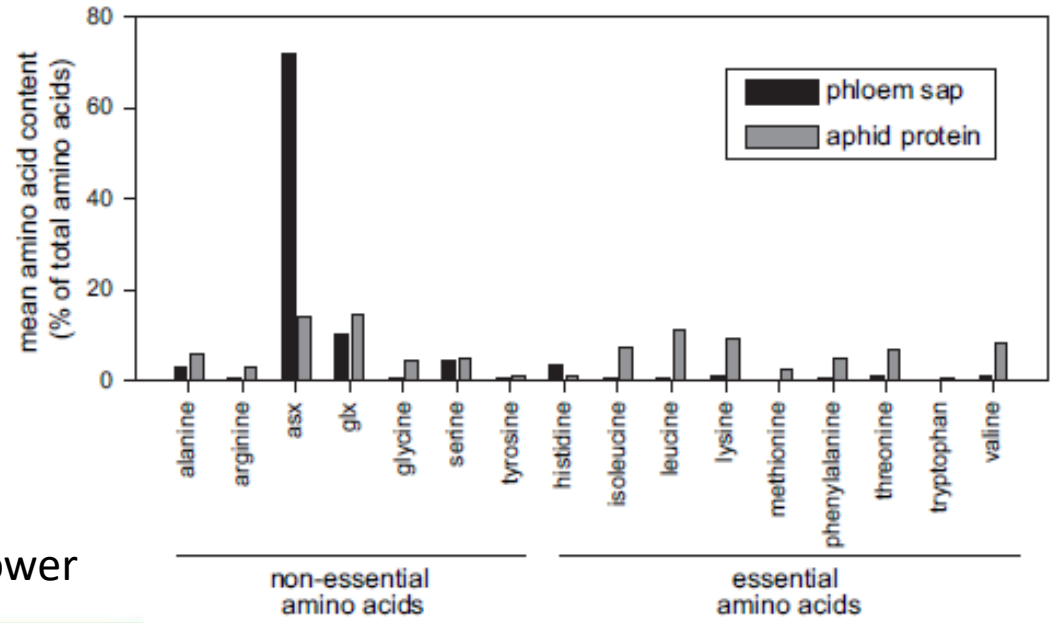
Intracellular nutritional symbionts are especially common in insects that feed on plant vascular tissues



Phloem and xylem sap are very unbalanced diets

phloem sap is high in sugar and low in essential amino acids





[Douglas, 2006. Jour Exp Bot 57:747-753]

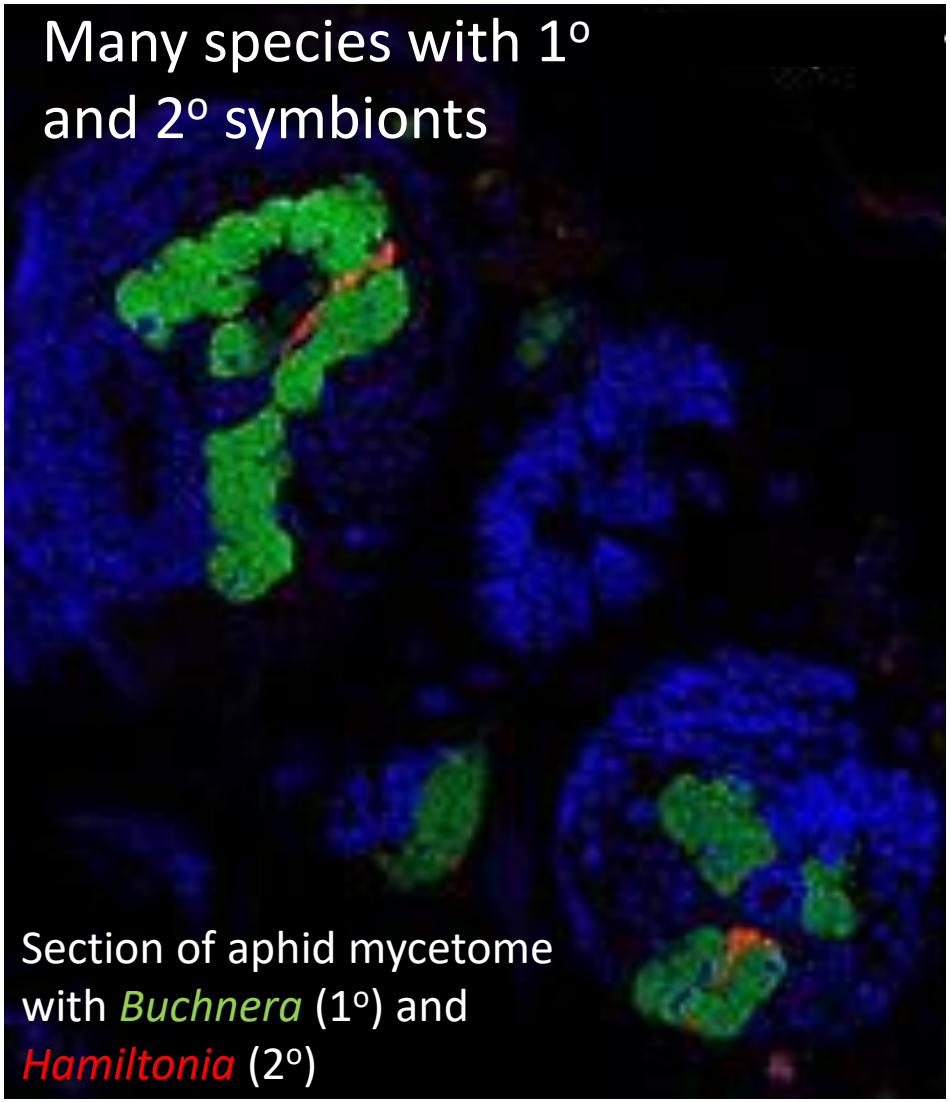
xylem concentrations are even lower

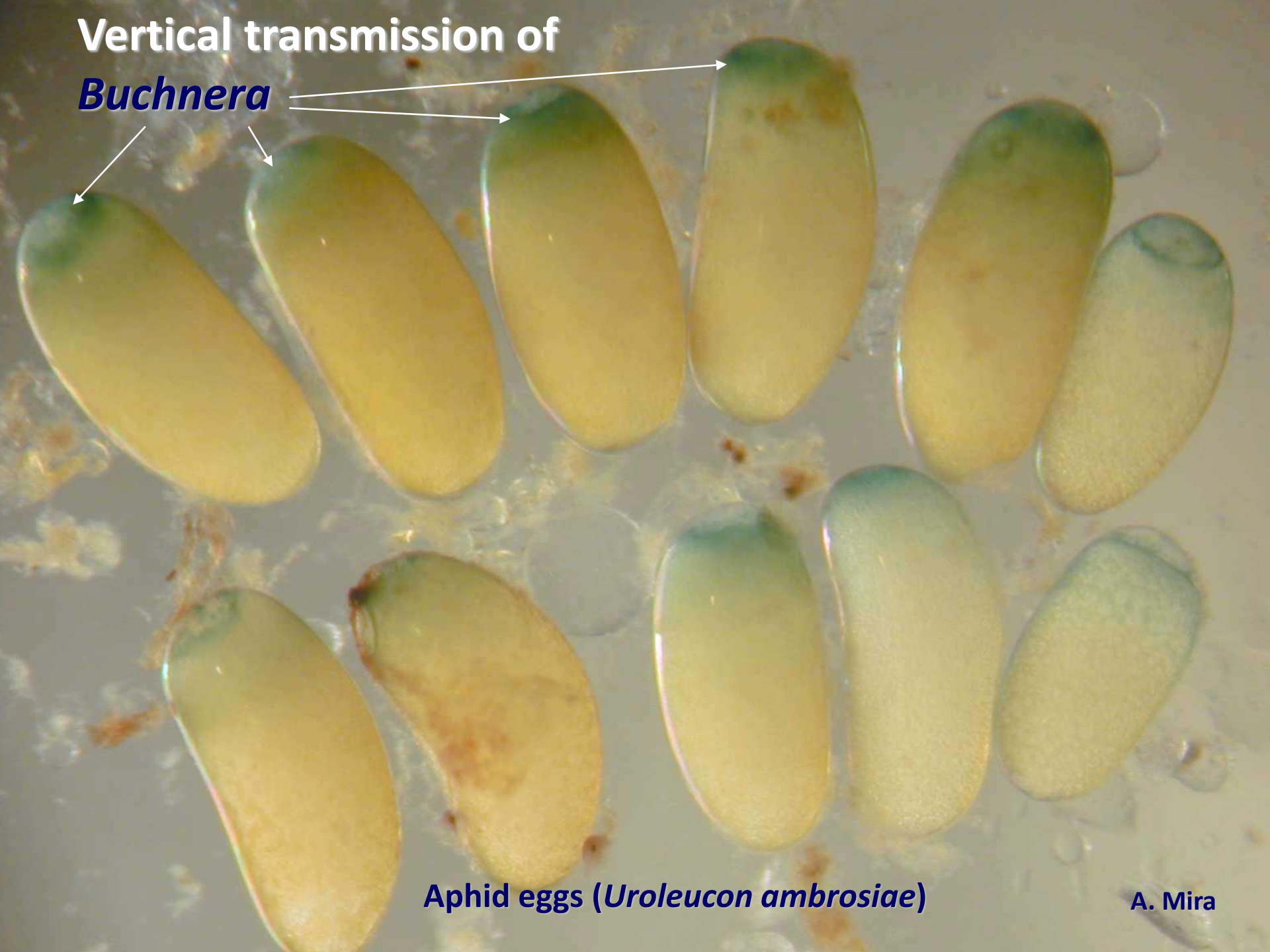
Banksia sp.

Solute (mM)	Xylem sap	Phloem sap
Sucrose	trace	493
Total amino acids	0.53	2.35
Malate	0.42	4.28
Potassium	2.39	15.2
Sodium	1.84	24.1
Magnesium	0.55	6.36
Calcium	0.48	5.96
Phosphate	0.111	0.60
Nitrate	0.01	0.38
Chloride	2.92	26.5
Sulphate	0.25	1.06

[Pate & Jeschke, 1993. Plant & Soil 155/156: 273-276]

Endosymbionts live in cells of a special organ called a mycetome, composed of 50–100 bacteriocytes





Aphid eggs (*Uroleucon ambrosiae*)

A. Mira

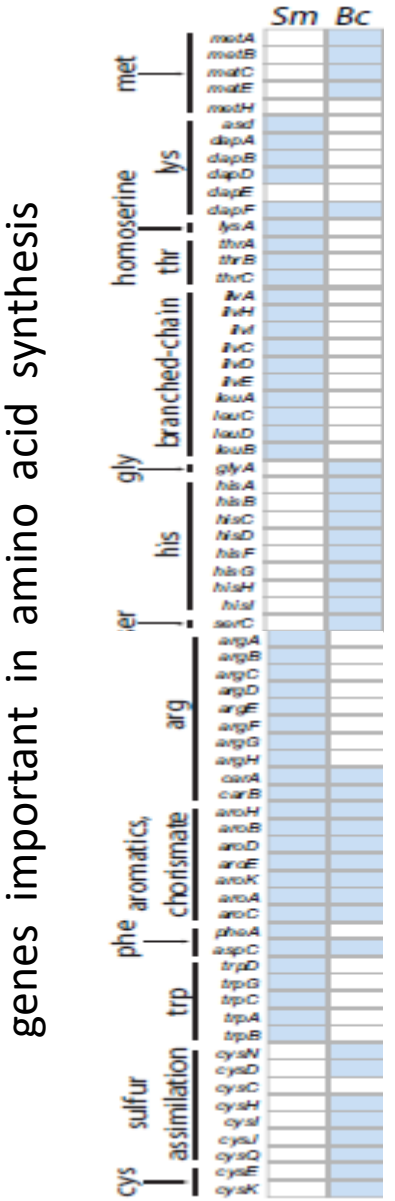
Most endosymbionts are obligate in their host with very reduced genomes of <500 genes

They provide essential compounds for the host, such as essential amino acids, but also sterols and vitamins

In many cases, the 1° and 2° symbionts make complementary essential amino acids

Glassy winged sharpshooter
Homalodisca vitripennis
[Cicadellidae]

Sulcia muelleri (1°)
Baumannia cicadellinicola (2°)



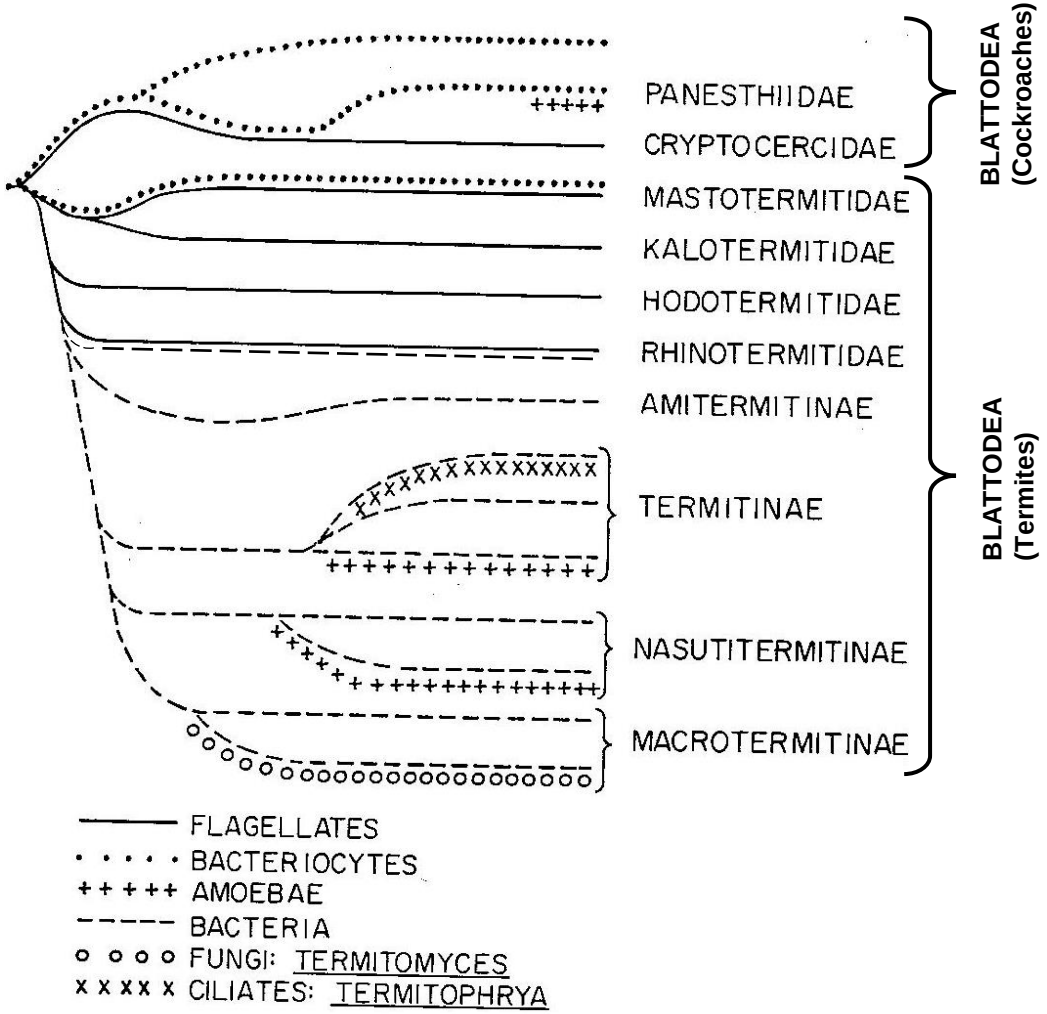
[McCutcheon et al. 2009. PNAS 106:15394]

Alimentary tract symbionts

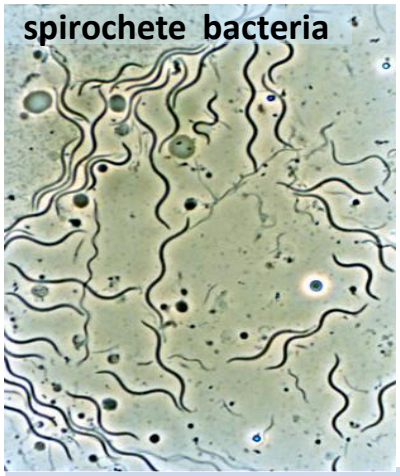
Most animals, including you and me, have these, especially those that eat plant material, incl. wood

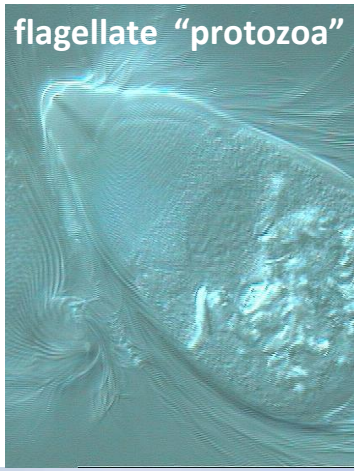
Termites have symbionts from all three domains

Advanced termites use bacteria that are often associated with eukaryotes



[modified from Wilson, 1971. Insect Societies]

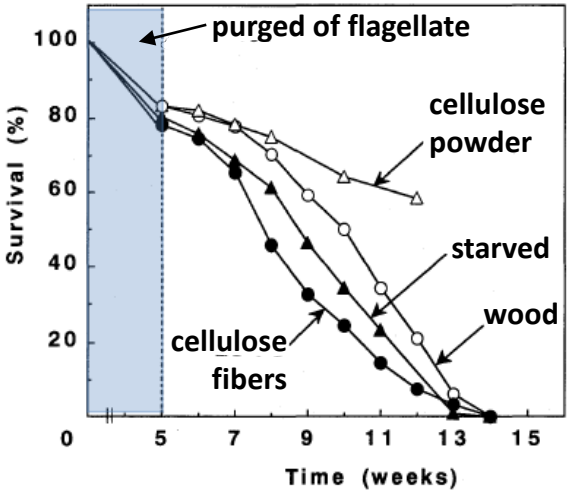




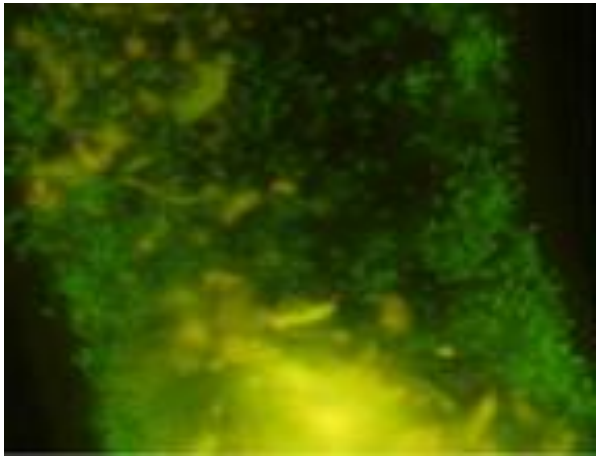
Termite Protozoa

It gets more complicated

Termites can't digest wood when the flagellate is removed

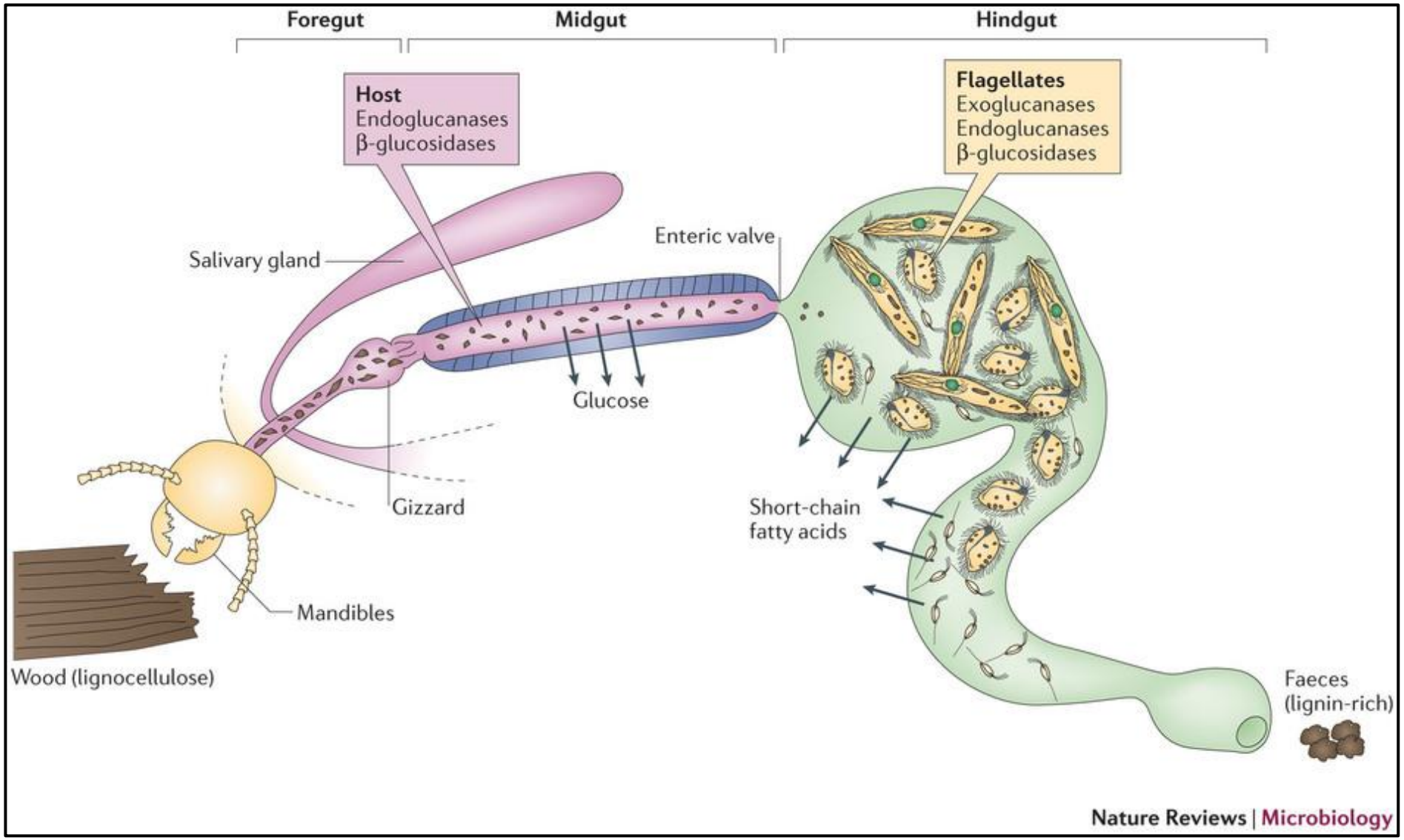


[Yoshimura, 1995. Wood Res 82:68-129]

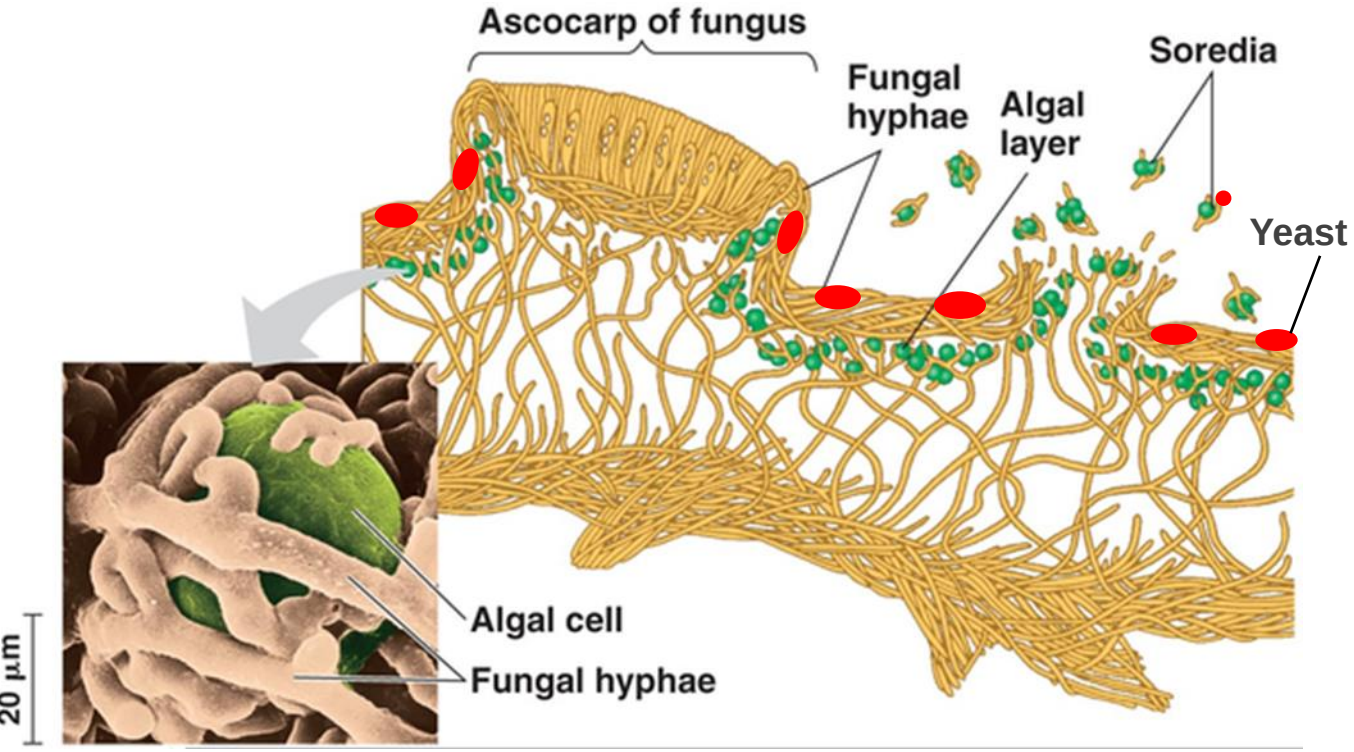


[Hongoh et al. 2008. Science 322:1108-1109]

Termite symbionts live in the hindgut,
some other plant eaters, e.g., grasshoppers, house theirs in the foregut



Lichen = symbiosis of fungi and photosynthetic partner



1. Ascomycete (most) or basidiomycete
2. Alga or cyanobacteria
3. Basidiomycete yeast

Spotted salamander, *Ambystoma maculatum*, eggs have symbiosis with alga, *Chlorococcum* (Oophila) *amblystomatis*.

Alga gets CO_2 and waste from embryo
Salamander embryo gets O_2 and sugars


Publilia sp. treehoppers on goldenrod tended by *Formica* sp. ants