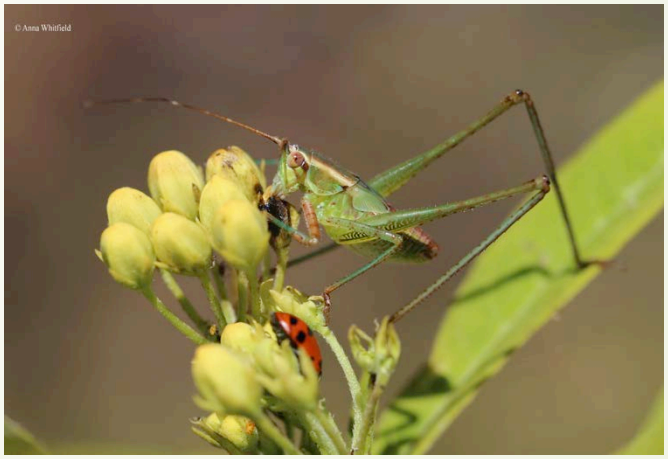
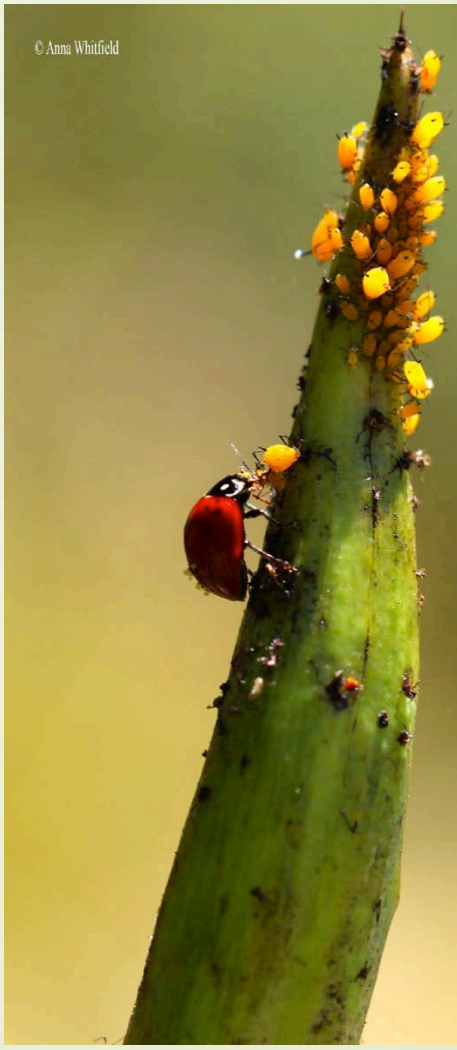
Diversification of Feeding in Insects

Carly Coleman and Anna Whitfield

What kinds of foods do insects consume?





What is the difference between endosymbionts and symbionts?

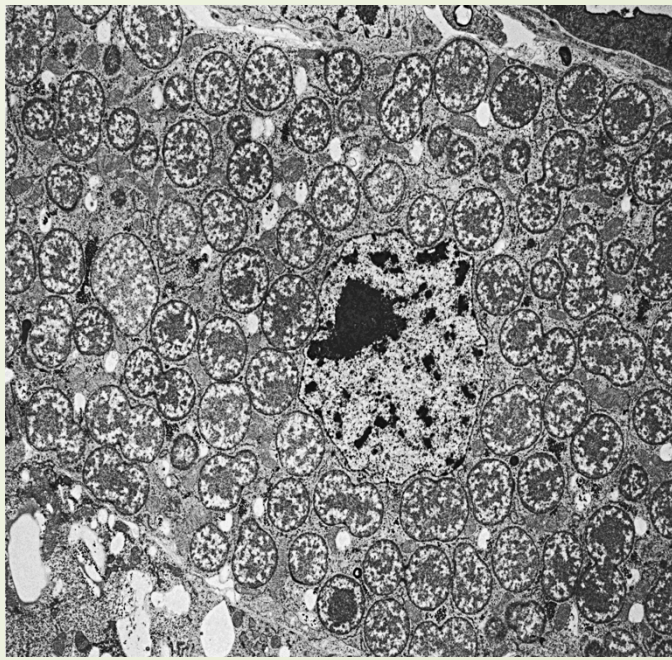
Different relationships

Symbiosis: relationship between 2 or more organisms that live closely together

- Ex: Mutualism, Parasitism, Commensalism

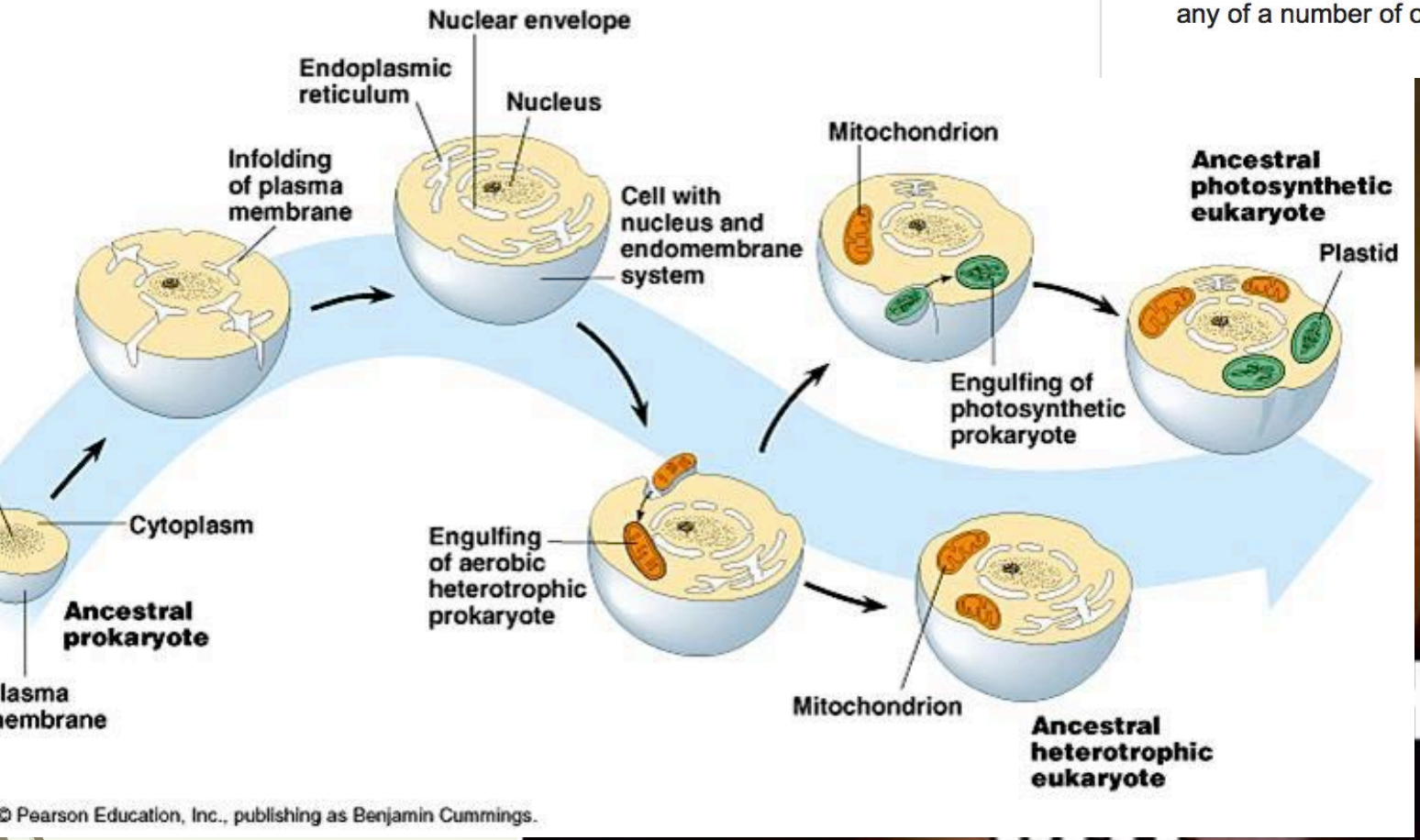
Endosymbiosis: interaction between two species where one lives inside the cells of the other

- Endosymbionts are found in bacteriocytes
  - Bacteriocytes are found within an abdominal organ called the bacteriome



Above is a *Buchnera* symbiont within a bacteriocyte of a pea aphid

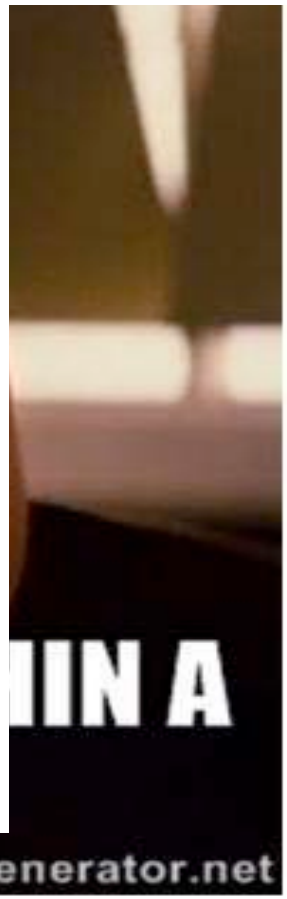
Origin of Organelles through Endosymbiosis



or·gan·elle
/ˌôrgəˈnel/

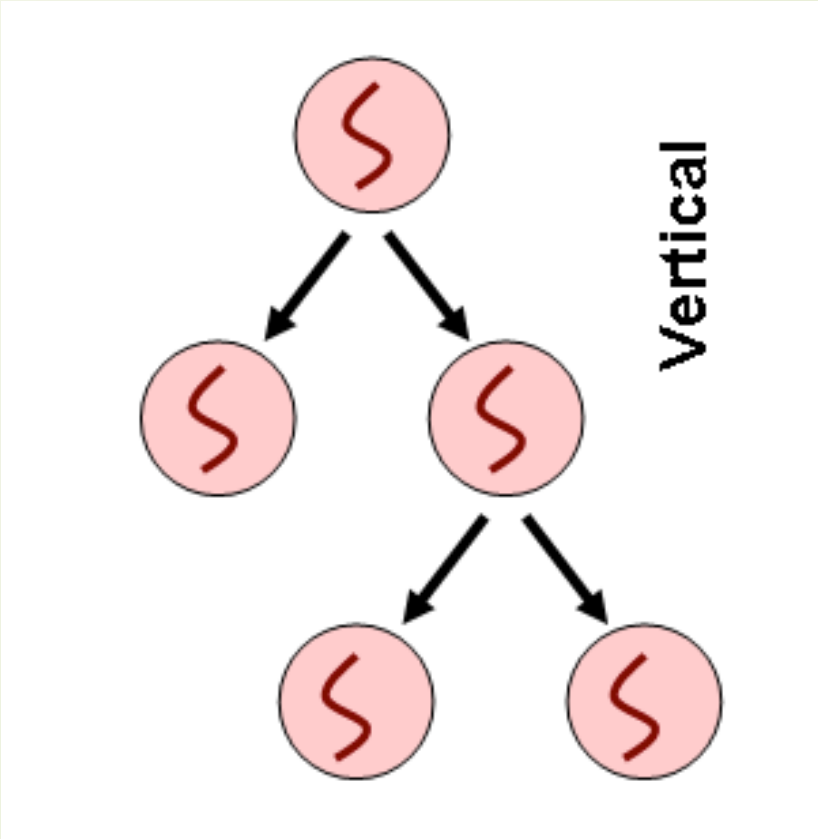
noun BIOLOGY

any of a number of organized or specialized structures within a



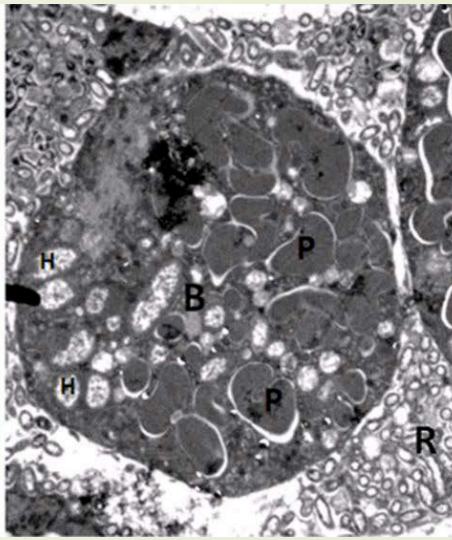
What is the importance of endosymbionts?

- 15% of all insects
- Buchner: function of endosymbionts is synthesizing missing nutrients
- Important for diverse host functions
- Transmission
  - **What are some of the advantages and disadvantages of using vertical transmission instead of horizontal transmission?**
    - Advantages: Promotes coevolution and optimization of interaction, make more resources available for the host
    - Disadvantages: reduced environmental interactions for symbiont, restrict gene flow



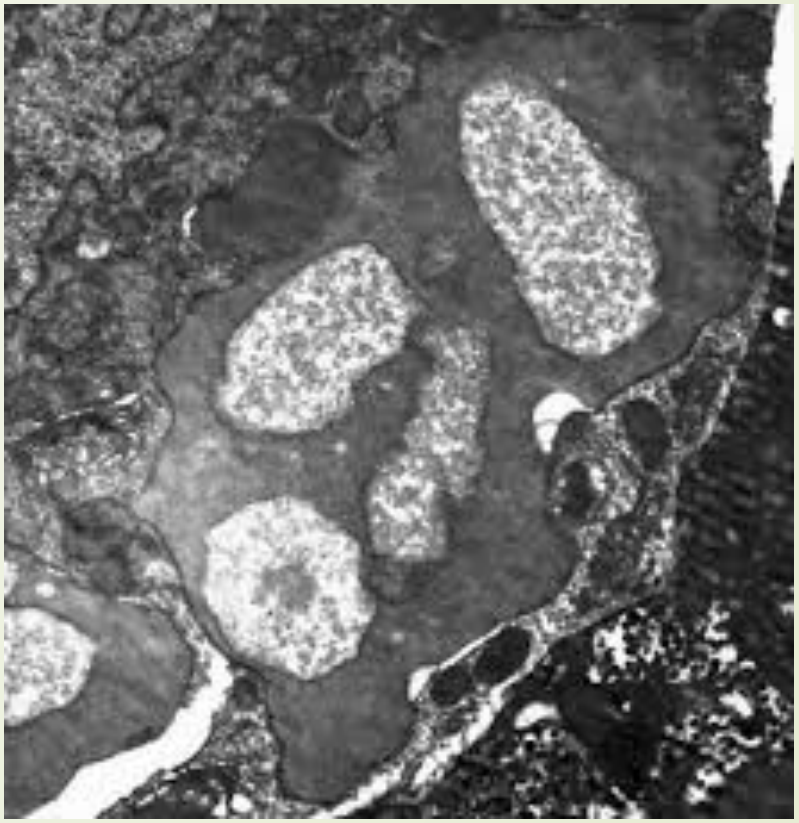
What are P Endosymbionts?

- In most taxa
- Single infection of an insect
- Essential
- Mutualistic



Question: What are characteristics of S-Endosymbionts?

- Morphologically diverse
- Facultative
  - Parasitic
  - Mutualistic
- Nonessential



Discussion Question:

If endosymbionts never started this mutualistic relationship with insects, how would evolution have differed for those insects and what do you predict their feeding and microhabitats be today?

P-Endosymbiont Co-speciation

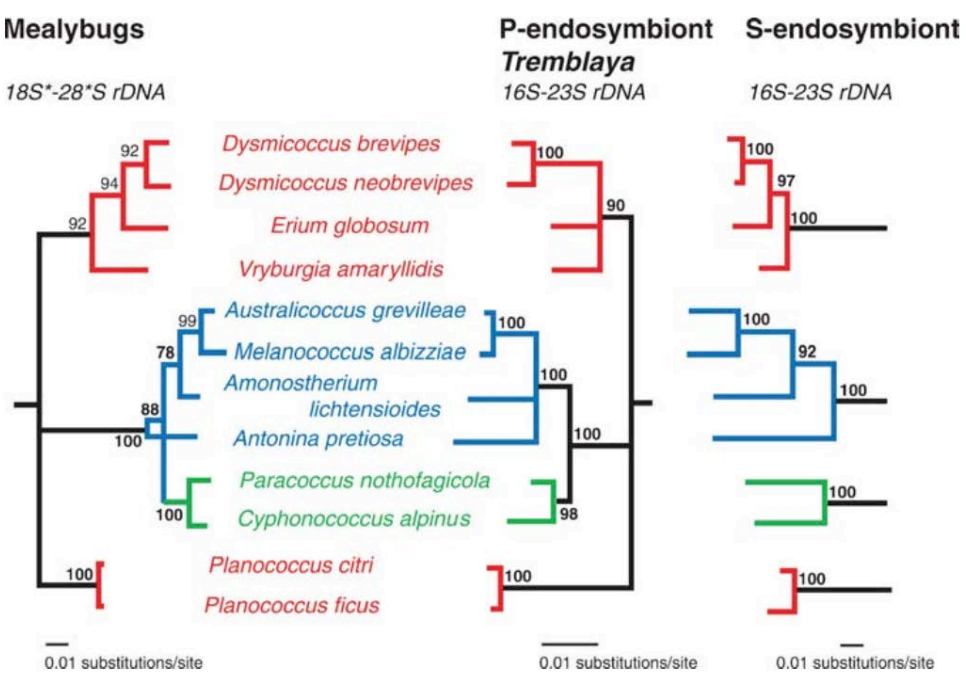


Figure 1

Comparisons of the phylogeny of mealybugs with *Tremblaya* (P-endosymbionts) and the *Tremblaya*-contained S-endosymbionts. *Tremblaya* is monophyletic, suggesting a single infection of a mealybug ancestor followed by cospeciation with the insect host. The S-endosymbionts are polyphyletic, the different clusters are more closely related to a variety of sternorrhynchal insect S-endosymbionts than to each other. Maximum likelihood analysis, numbers at nodes represent % bootstrap values after 500 replicates; only nodes supported by 70% or greater are shown. Host sequences are from Reference 40; *Tremblaya* and S-endosymbiont sequences are from Reference 134.

- 'Red Queen' hypothesis: evolution driven by need to catch up with a changing environment, particularly with evolving microbes
- Single infection for each endosymbiont
- Domestication

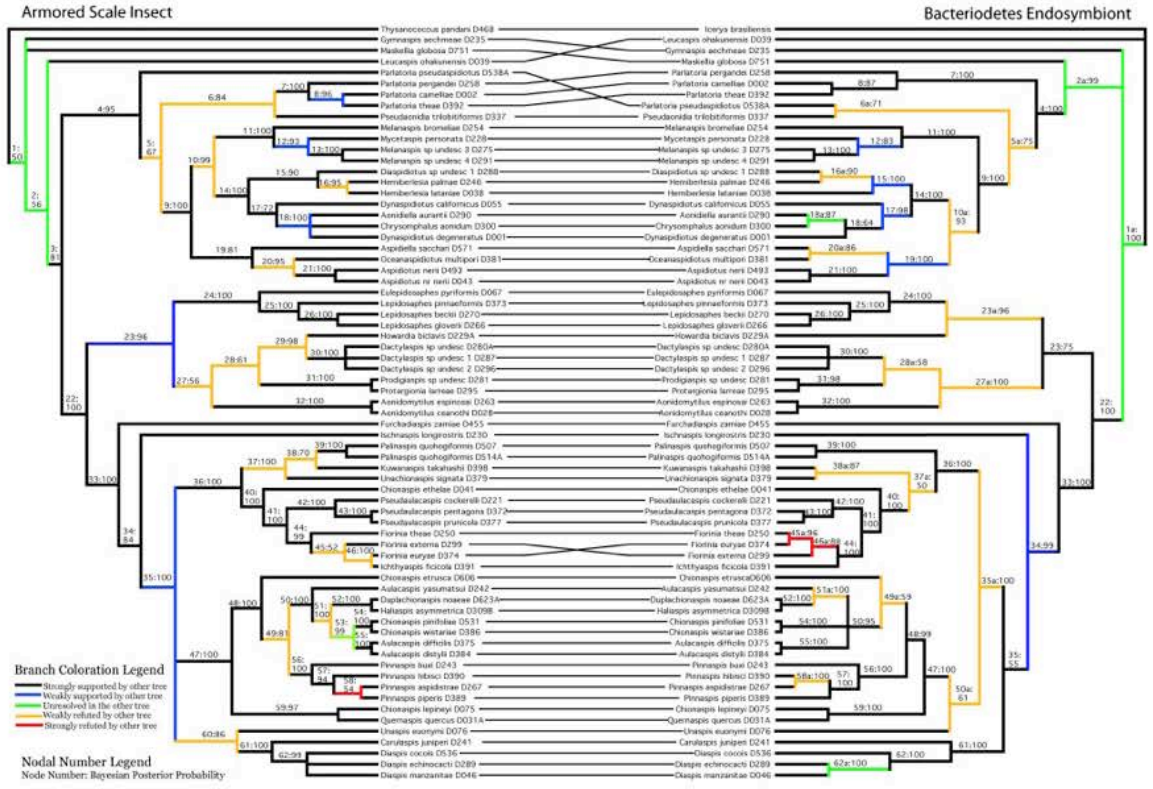


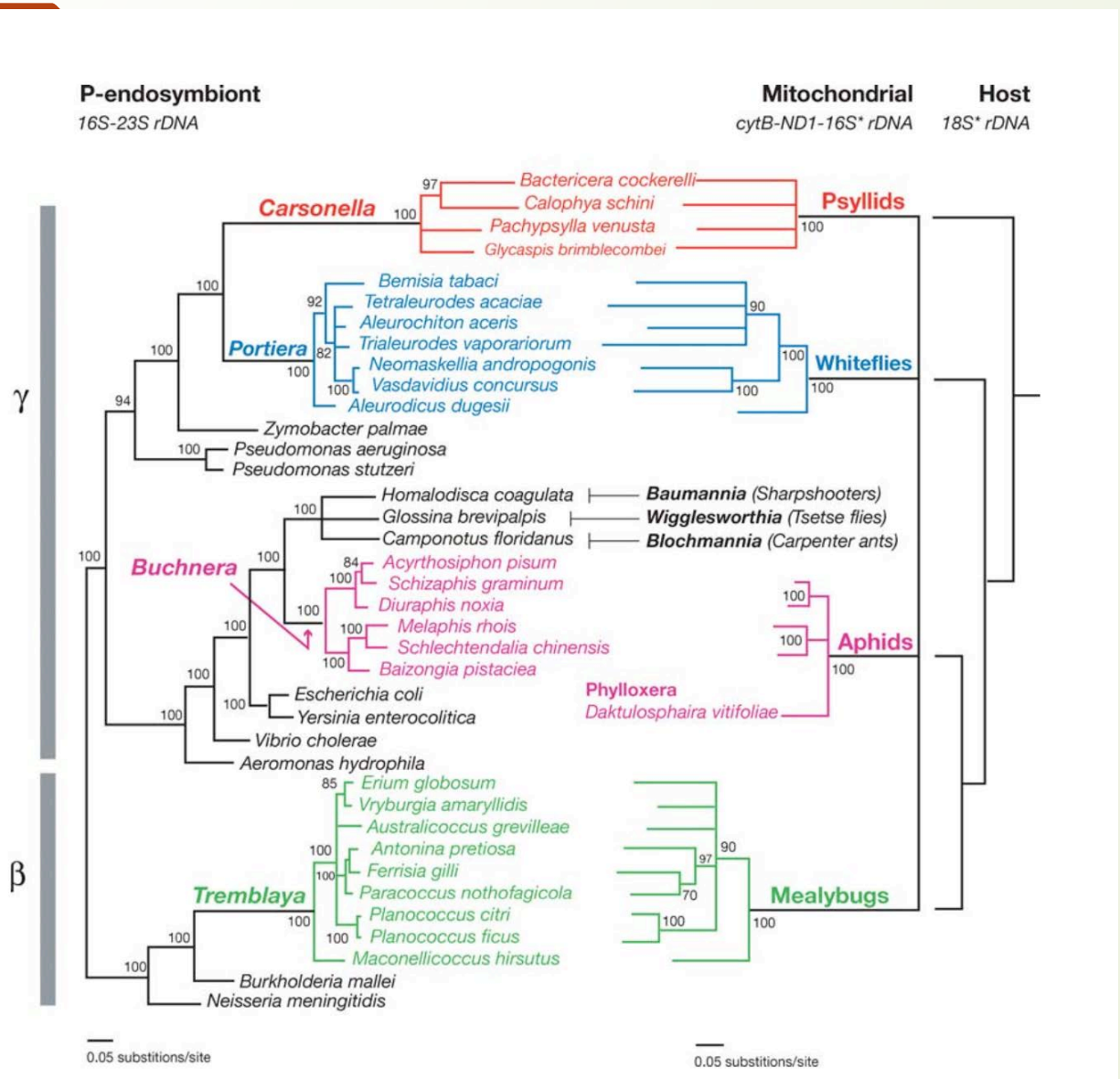
Fig. 1. Tanglegram comparing Bayesian topologies of the hosts (left) and bacteria (right). The colors of the internal branches reflect the degree of congruence with opposite tree. Strongly supported, same clade appears on opposite tree with strong support (Bay...

Matthew E. Gruwell, Geoffrey E. Morse, Benjamin B. Normark

Phylogenetic congruence of armored scale insects (Hemiptera: Diaspididae) and their primary endosymbionts from the phylum Bacteroidetes

Molecular Phylogenetics and Evolution, Volume 44, Issue 1, 2007, 267–280

http://dx.doi.org/10.1016/j.ympev.2007.01.014



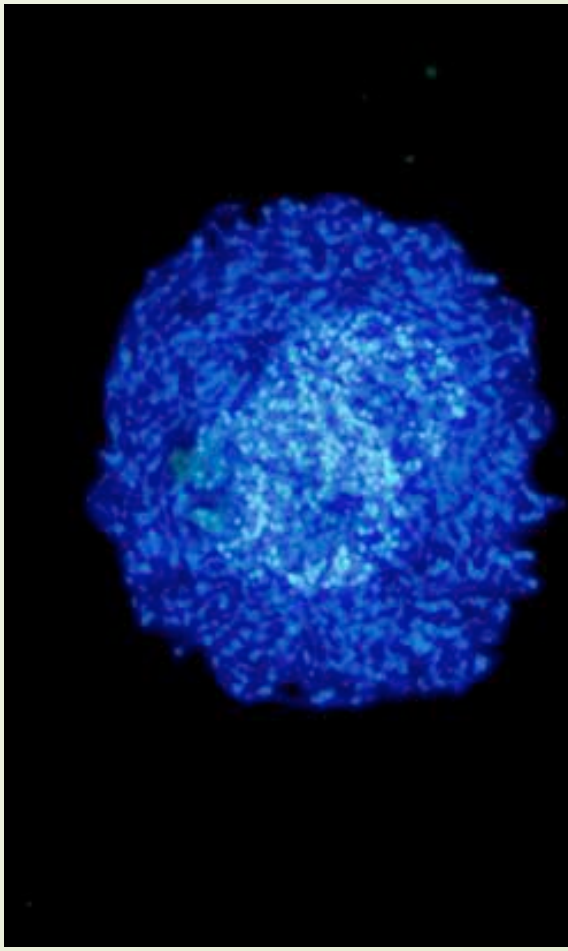
- Four different P-endosymbionts
- Same purpose

Examples:

- Whiteflies
  - *Portiera aleyrodidarum*
- Aphids
  - *Buchnera*
- Mealybugs
  - *Tremblaya*

Psyllids and *Carsonella*

- Some of the most reduced bacterial genomes
- Lost genes essential for basic cell processes



Sloan Paper

- Has *Carsonella* followed a similar trajectory as the evolution of mitochondria?
  - No evidence that HGT involve direct transfer of functional genes from obligate endosymbionts
  - Psyllids have acquired at least one gene from *Carsonella*
- Analyze genome-wide patterns of host expression
  - Dissected bacteriomes and extracted RNA
  - Identified psyllid genes of bacterial origin
  - Then ran PCRs

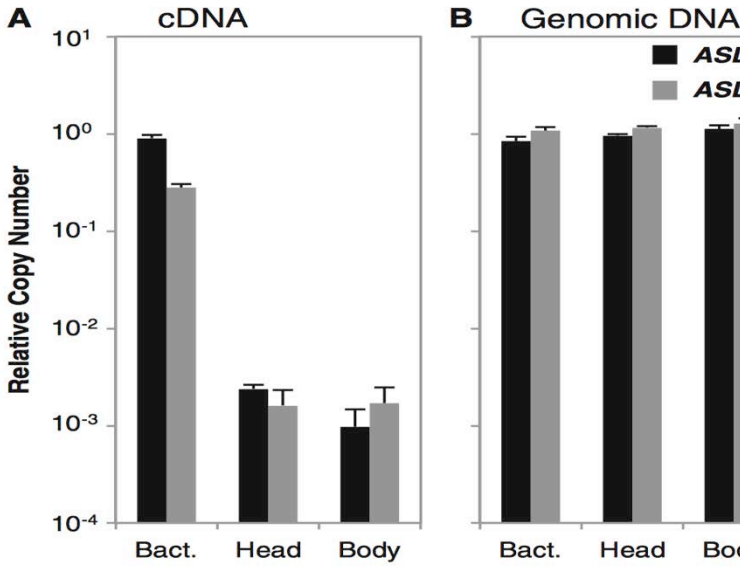
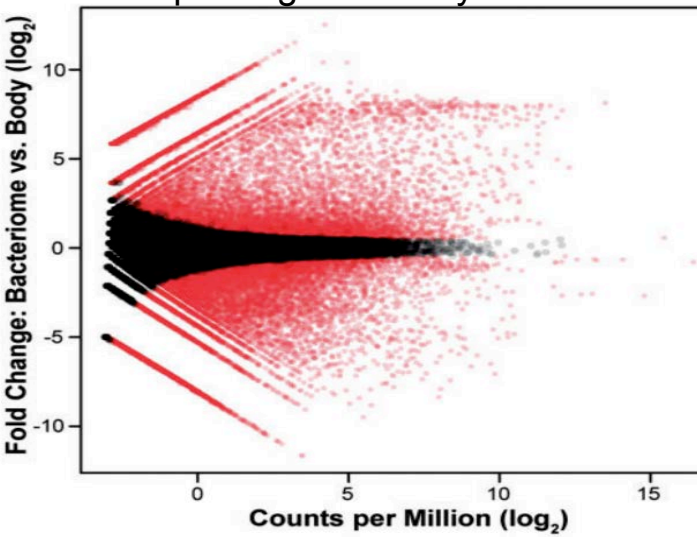


FIG. 3. Quantitative PCR analysis of ASL gene expression (cDNA) genomic copy number (genomic DNA) in bacteriome, head, and tissues from *Pachypsylla venusta*. Abundance values were normalize the psyllid nuclear gene encoding the ribosomal protein (Rp)L18e. bars represent one standard error.

Argininosuccinate lyase – responsible for terminal step in arginine biosynthesiss



Discussion Question: Why has Carsonella's genome become so small?

Three Mechanisms

- 1) Modification of highly conserved cell processes or selection for multifunctional protein could have allowed disposal of "essential" genes
- 2) Additional endosymbionts
  - Ex: Loss of specific Carsonella gene in eucalyptus-feeding psyllid
- 3) Replacement
  - Host-encoded proteins functionally replace Carsonella genes

How does DNA transfer occur between bacteria and eukaryotes?

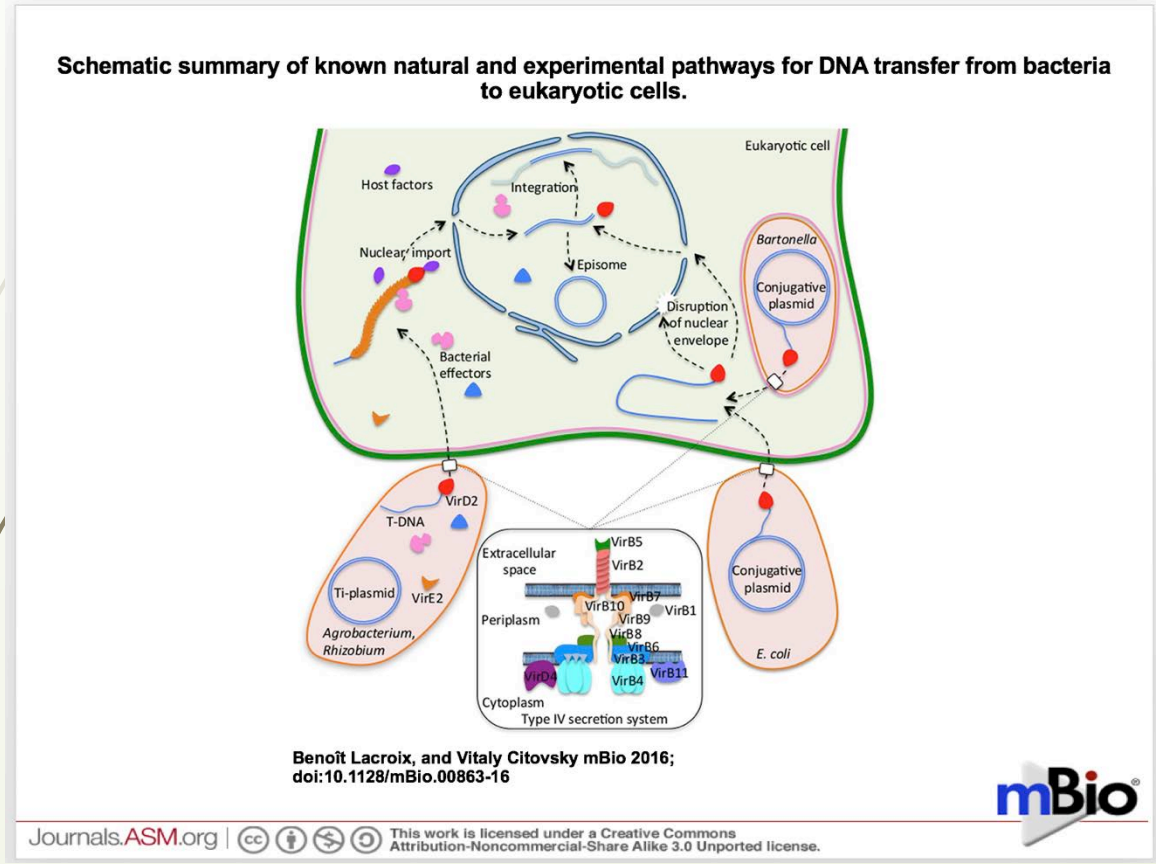


FIG 1

Schematic summary of known natural and experimental pathways for transfer from bacteria to eukaryotic cells. *Agrobacterium* and related bac *E. coli*, and *Bartonella henselae* can transfer DNA to different typ eukaryotic cells via the activity of their type IV secretion systems comp of VirD4/VirB proteins. Inside the host eukaryotic cell, the bac transferred DNA, usually a single-stranded molecule packaged i nucleoprotein complex, is imported into the host nucleus. Nuclear impor further DNA processing, i.e., conversion to a double-stranded integration into the recipient cell genome, or formation of an epis depend on interactions of the transferred DNA and its associated pro with numerous host cell factors that represent different types of ce machineries, such as nuclear import machinery, the ubiquitin/protea system, and DNA repair machinery. For further details, see the text.

"This DNA transfer relies on type IV secretion systems (T4SSs), the molecular machines that transport macromolecules during conjugative plasmid transfer and also during transport of proteins and/or DNA to the eukaryotic recipient cell" (Lacroix 2016).

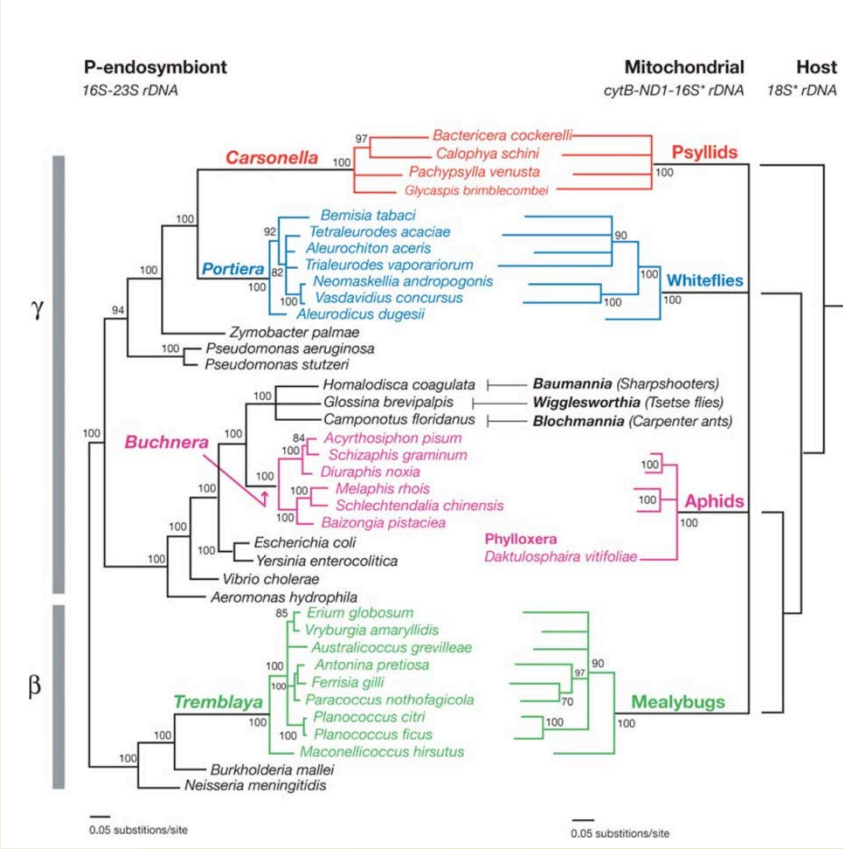
Discussion Question:

What might we observe if we implanted Buchnera's closest relative into an aphid bacteriome? Conversely, might insects closely related to aphids – or even certain kinds of aphids – be unresponsive to Buchnera?

- Conjugation
  - Transfer of genetic information between bacterial cells of the same or closely related species
  - Is the direct transfer of DNA from one bacterial cell to another bacterial cell.

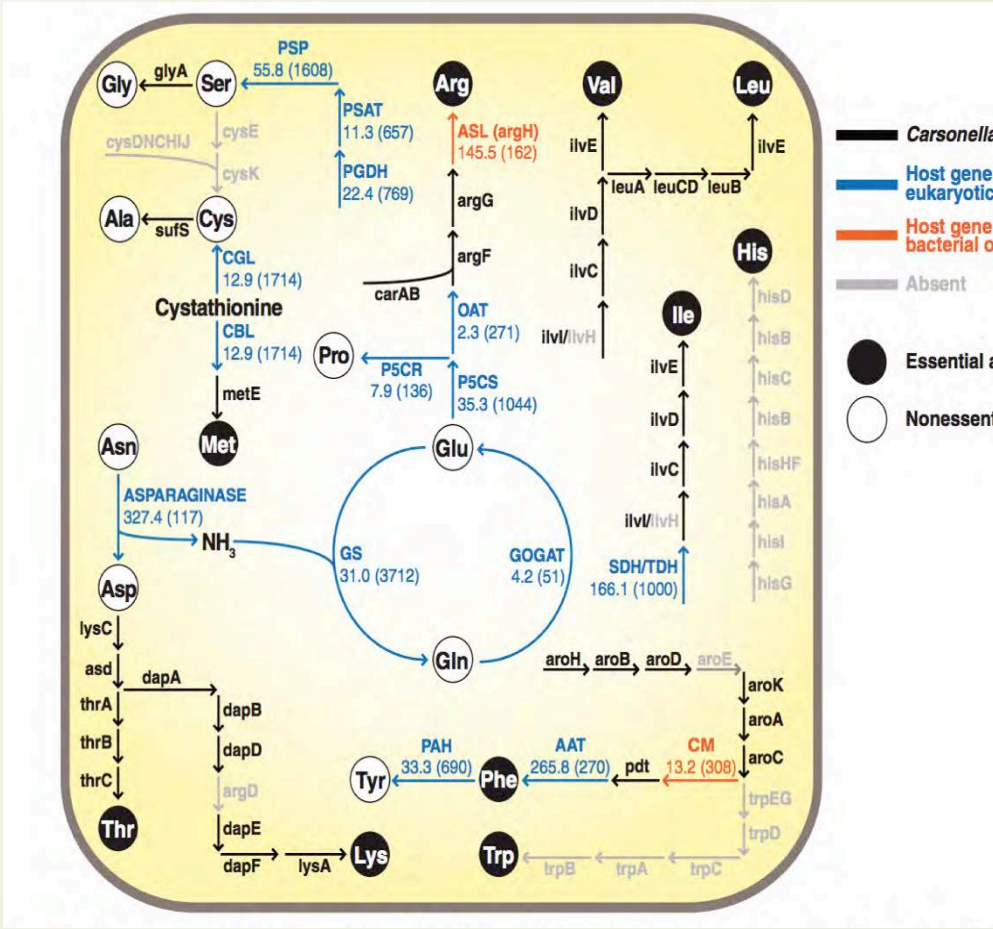
- Would most likely function in the same way
  - Similar genomes → similar reductions

- On the other hand, insects closely related to aphids would most likely reject Buchnera because of cospeciation

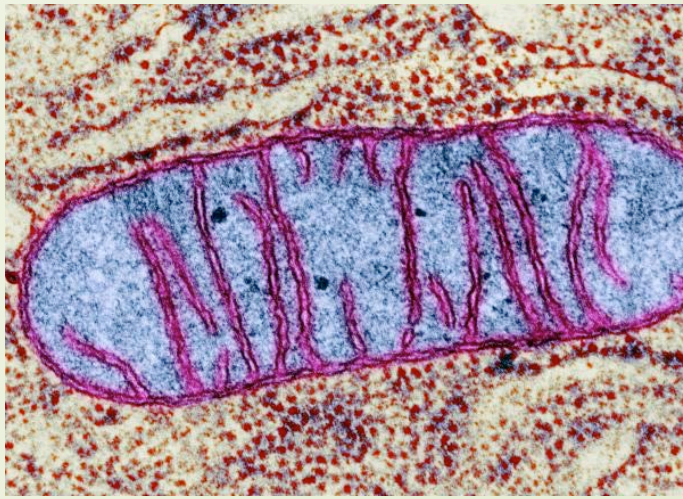


Host gene effect on Carsonella

- Carsonella genome is enriched for genes in amino acid biosynthesis
- Many pathways are absent or incomplete
  - Host genes in the bacteriome were upregulated
  - These complement missing pathways
- Confirms bacteriome is essential in the synthesis of essential and nonessential amino acid



Discuss/Debate:
Do you think endosymbiont
are organelles?
Why or why not



Conclusion

Sloan: Why are direct transfers from bacteria so rare?

- Ascertainment bias
  - Deviations from expected based on sampling technique
  - More common than known
- Barriers
  - Pre-zygotic
    - Prevent physical movement of DNA
  - Post-zygotic
    - Prevent genes from being retained and functional even after integration
- Dominant mode of organelle evolution is functional transfer to nucleus

Campbell

- *Hodgkinia*
- Physical Location
  - Cytologically distinct but not in mitochondria (fission and fusion, genome fragments → chromosomes, stay throughout)
  - When *Hodgkinia* lineage fragments, each segment stays in discrete cells and do no mix
- Secondary genome expansion
  - Through different methods: lineage splitting, reciprocal gene inactivation vs. DNA proliferation and acquisition

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