

Consequences of host life cycles for symbiont genome evolution

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Background

+Aphids:

- + They are commonly known as pest species
- + They feed on plant sap (nutritionally poor)



Image Source: Illinois Natural History Survey- Prairie Research Institute



Keatley Garvey

Image Source: UCANR Bug Squad

Background

+Aphids can be broadly categorized by the type of plant(s) they live on and how long they feed on these plants



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Background

+Plant sap being nutritionally poor creates an issue- where do aphids get essential amino acids and vitamins?



Image Source: Illinois Natural History Survey- Prairie Research Institute

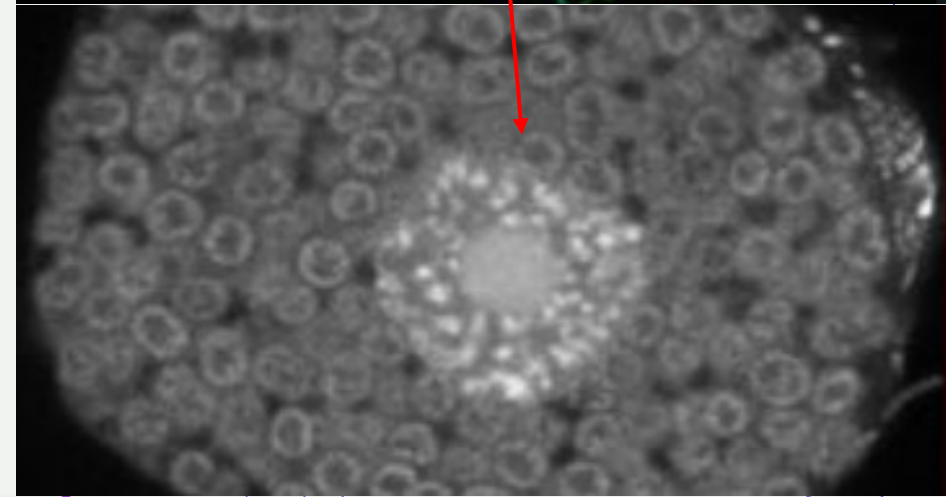
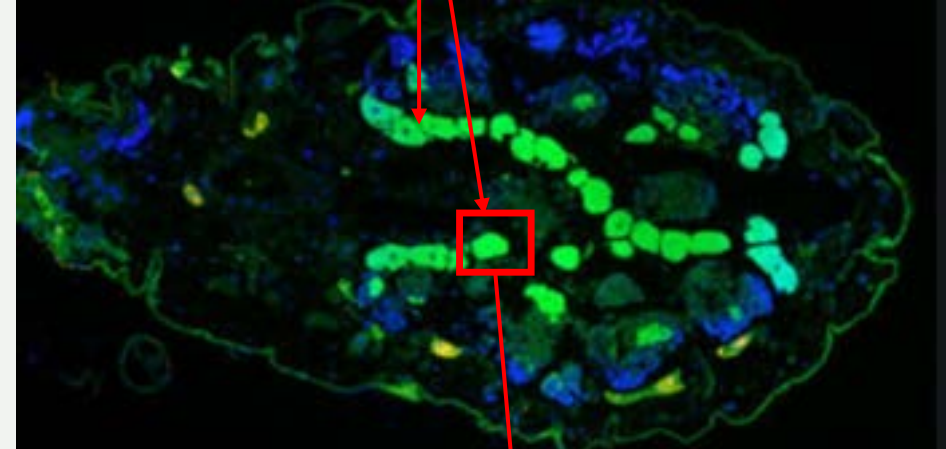
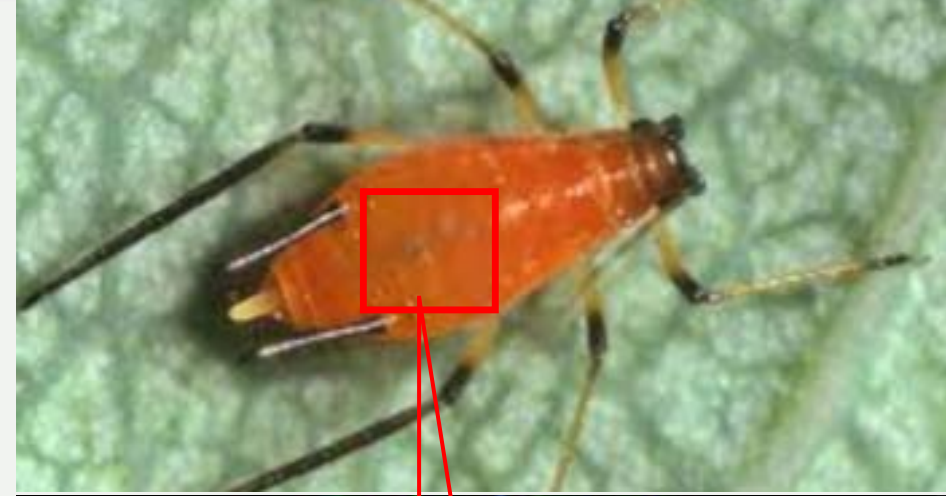


Keatley Garvey

Image Source: UCANR Bug Squad

Background

- + Now introducing *Buchnera aphidicola*!
- + They are bacterial nutritional endosymbiont- what does this mean?
- + *Buchnera* + aphids = relationship for ~160MYA¹ ❤️



Background

- + But wait! There's a problem: *Buchnera* genome degrading away?
- + Some quick stats on *Buchnera* genome size and GC content

	<i>E. coli</i>	<i>Buchnera aphidicola</i>	<i>Nasuia deltocephalinicola</i>
Genome Size	4.6 – 5.3 Mb ²	0.419 – 0.657 Mb	0.112 – 0.144 Mb ⁴
GC Content	50.4% – 50.8% ³	18.8% – 28.3%	17.1% ⁴

2. Bergthorsson & Ochman. Heterogeneity of genome sizes among natural isolates of *Escherichia coli*. *Journal of Bacteriology*, 177(20):5784-5789. 1995.

3. Mann & Chen. Bacterial genomic G+C composition-eliciting environment adaptation. *Genomics*. 95(2010):7-15. 2009. doi:10.1016/j.ygeno.2009.09.002

4. Bennett & Moran. Small, smaller, smallest: the origins and evolution of ancient dual symbioses in a Phloem-feeding insect. *Genome Biol Evol.* 5(9):1675-88. 2013 doi: 10.1093/gbe/evl118.

Background

How does this happen?

- Introduction of large numbers of mutations + deletions

Why is this important?

- ‘Rabbit-hole’ effect
- No examination of symbiont genomes in this framework

2. Bergthorsson & Ochman. Heterogeneity of genome sizes among natural isolates of *Escherichia coli*. *Journal of Bacteriology*, 177(20):5784-5789. 1995.

3. Mann & Chen. Bacterial genomic G+C composition-eliciting environment adaptation. *Genomics*. 95(2010):7-15. 2009. doi:10.1016/j.ygeno.2009.09.002

4. Bennett & Moran. Small, smaller, smallest: the origins and evolution of ancient dual symbioses in a Phloem-feeding insect. *Genome Biol Evol.* 5(9):1675-88. 2013 doi: 10.1093/gbe/evl118.

5. Bennet & Moran. Heritable symbiosis: The advantages and perils of an evolutionary rabbit hole. *PNAS*:112(33):10169-10176. doi.org/10.1073/pnas.1421388112

Aphid Ecology and Life Cycle

- + Variation in *Buchnera* genome size
- + Aphid ecology differs
- + **Ecology**: life cycle and type of plant(s) that aphids feed on



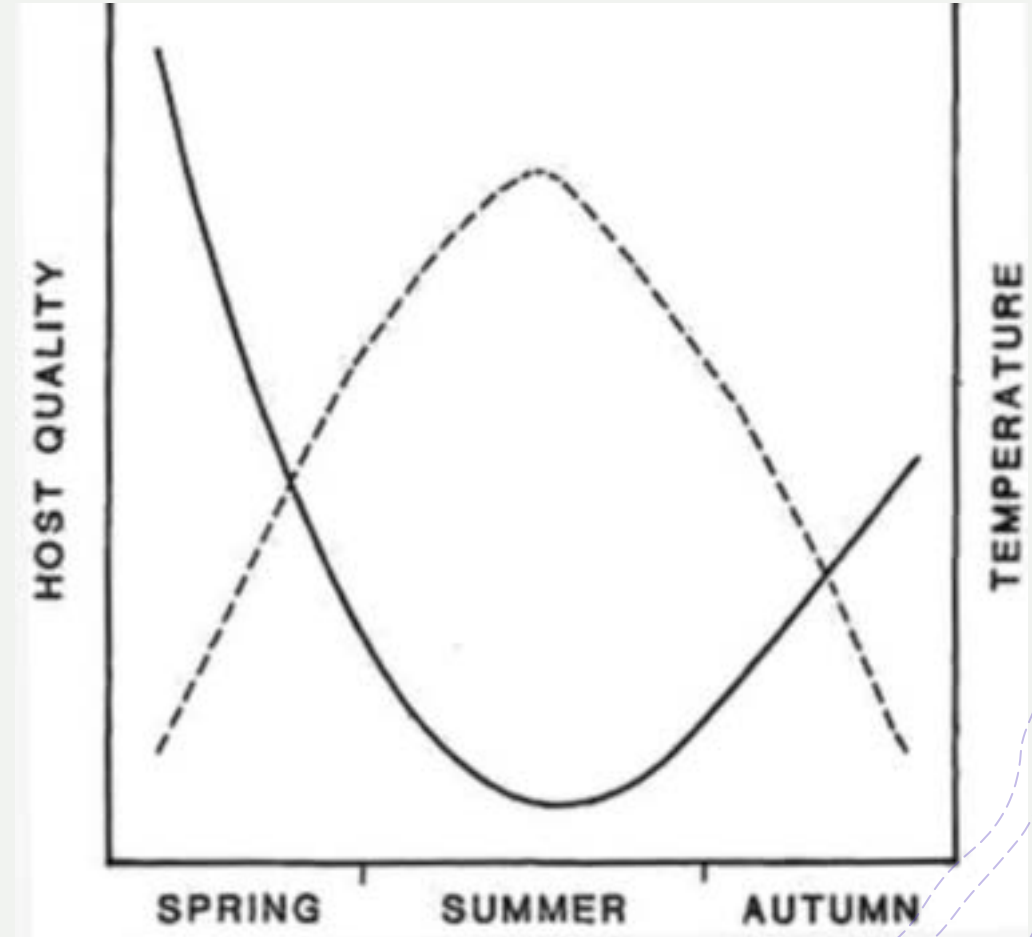
Research Question

+ Does the ecology of aphids affect the course of genome evolution in *Buchnera*?



Hypothesis and Predictions

- + **Hypothesis: The ecology of aphids affects patterns of genome decay in symbionts**
- + Predictions:
 - + *Buchnera* genomes of host-alternating and galling aphids will show relaxed selection on nutritional functions
 - + *Buchnera* genomes of tree-feeding aphids will be smaller due to selection for increased host control



Solid line: Seasonal changes in tree nutrition
Dashed line: Temperature experienced by aphids living on trees

Goals of the Research

1

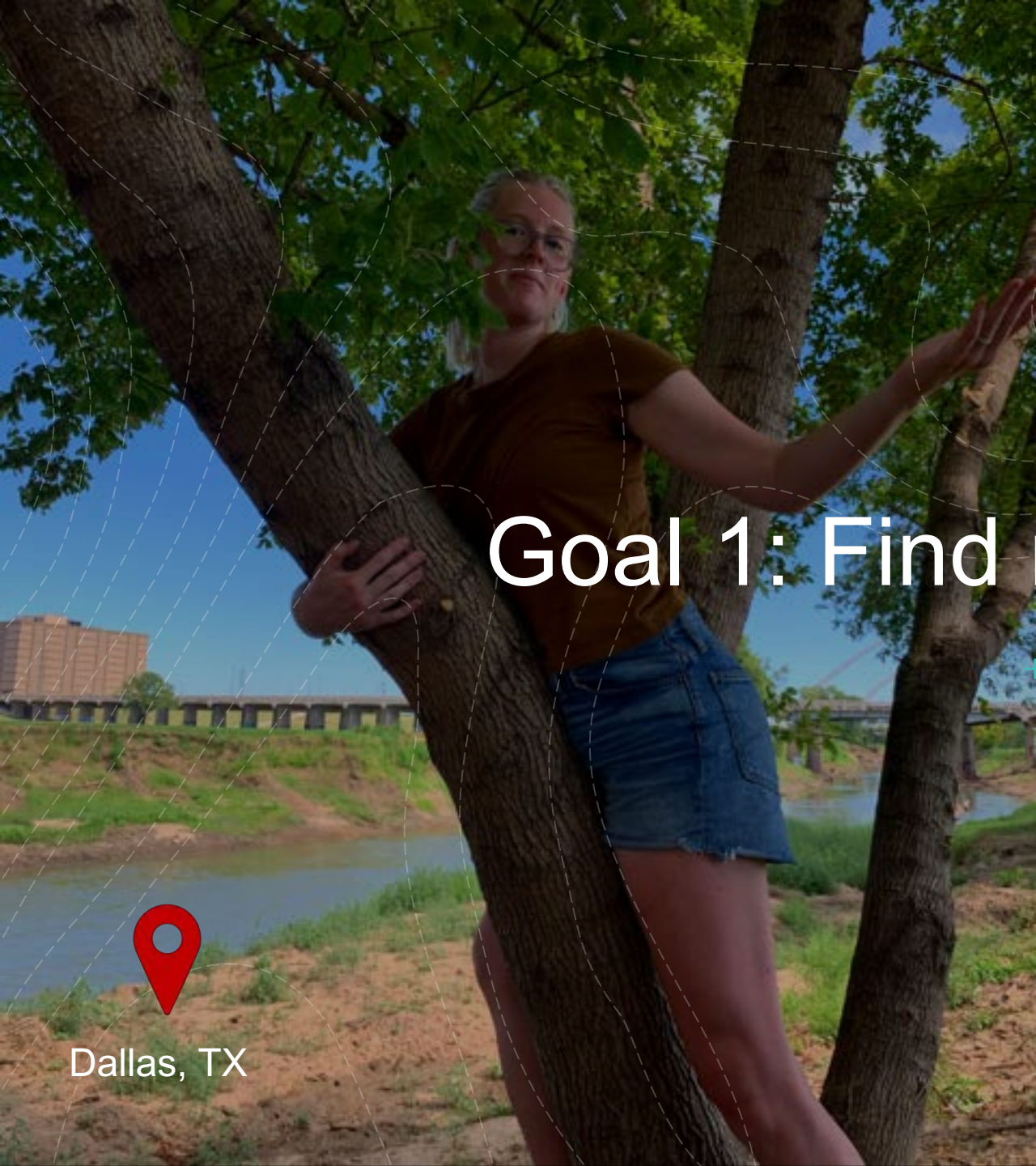
1. Assemble *Buchnera* genomes from a more diverse array of aphid species

2

2. Test for patterns of genomic degradation across aphid ecologies

3

3. Compare categories of gene losses across aphid ecologies



Dallas, TX



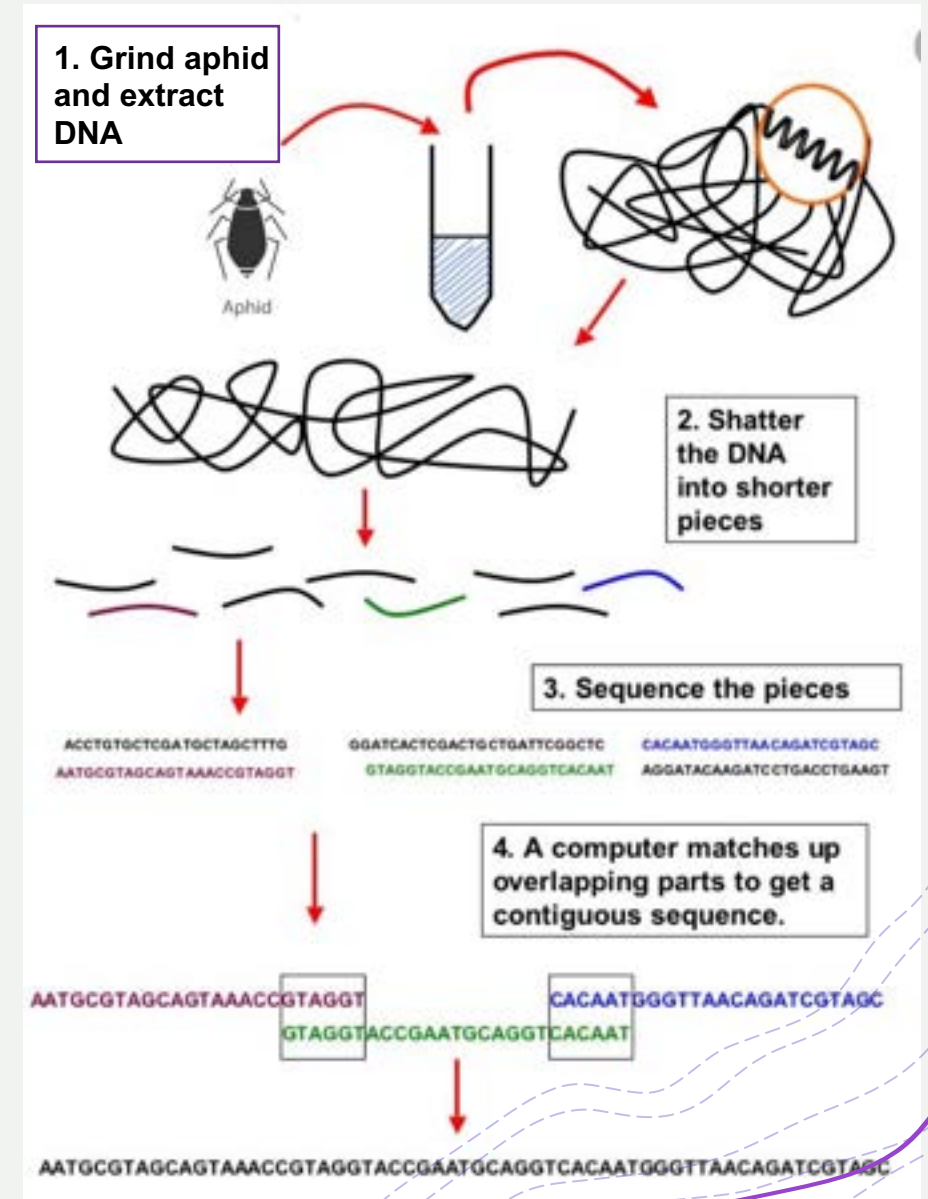
Sioux Falls, SD

Goal 1: Find more aphids...



Goal 1: ... and assemble *Buchnera* genomes

Extract	Sequence	Assemble
DNA from aphids	DNA using Illumina NovaSeq 150x150	<i>Buchnera</i> genomes



Goal 2: Test for patterns of genomic degradation across aphid ecologies



Calculate genome size for 65 *Buchnera* genomes obtained from NCBI along with my new assemblies



Test for significant differences across aphid ecologies with ANOVA

Goal 3: Compare categories of gene losses across aphid ecologies

- + Use R scripts created by me to compare groups for:
 - + Genes in essential amino acid and vitamin pathways
 - + Core genes



Results

Goal 1: Assemble *Buchnera* genomes
from a more diverse array of aphid
species



Goal 2: Test for patterns of genomic degradation across aphid ecologies

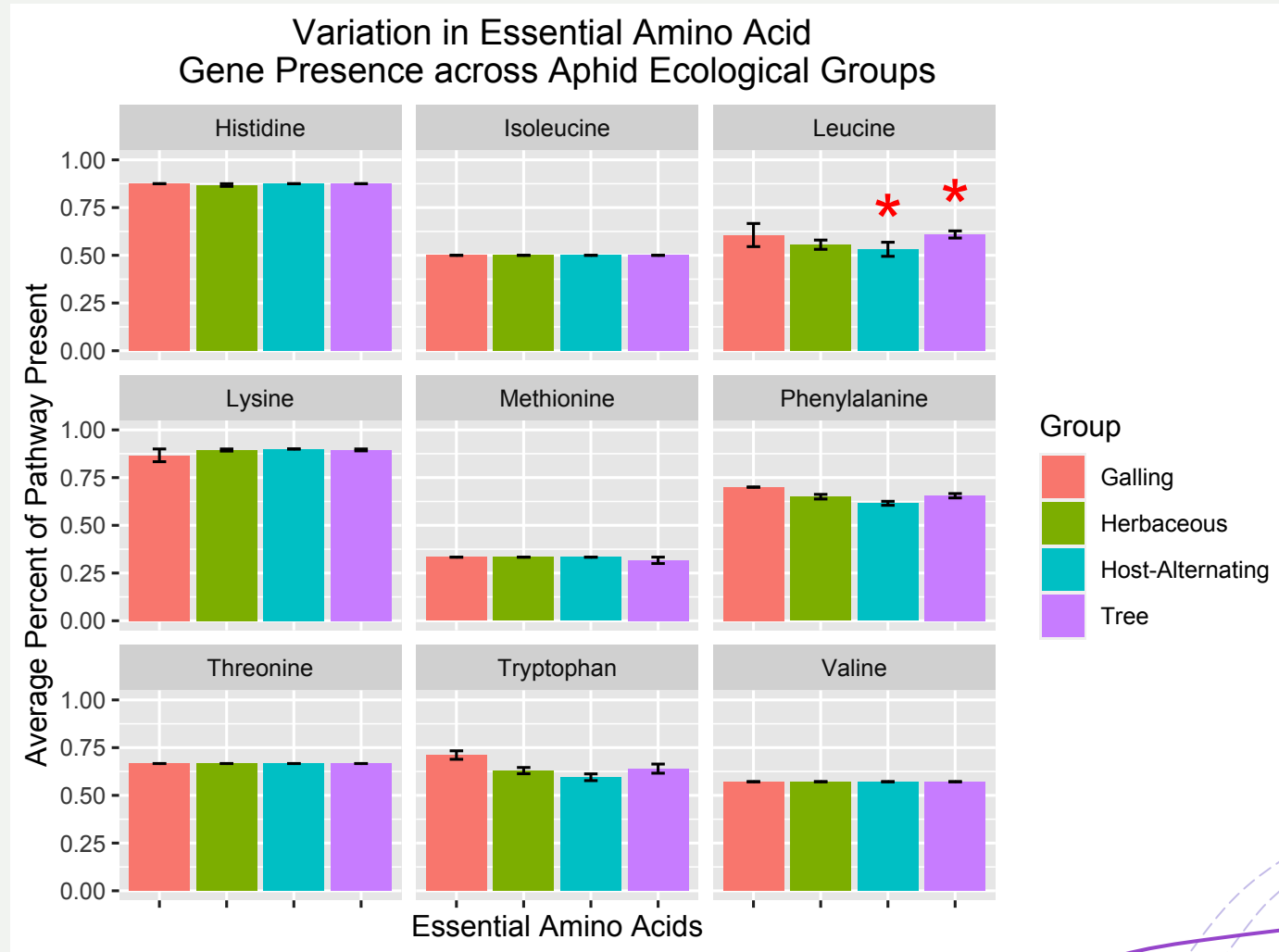
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Analysis of Variance Table

Response: GenomeSize
      Df Sum Sq Mean Sq F value    Pr(>F)
Group   3  0.43204  0.144013   324.74 < 2.2e-16 ***
Residuals 46  0.02040  0.000443
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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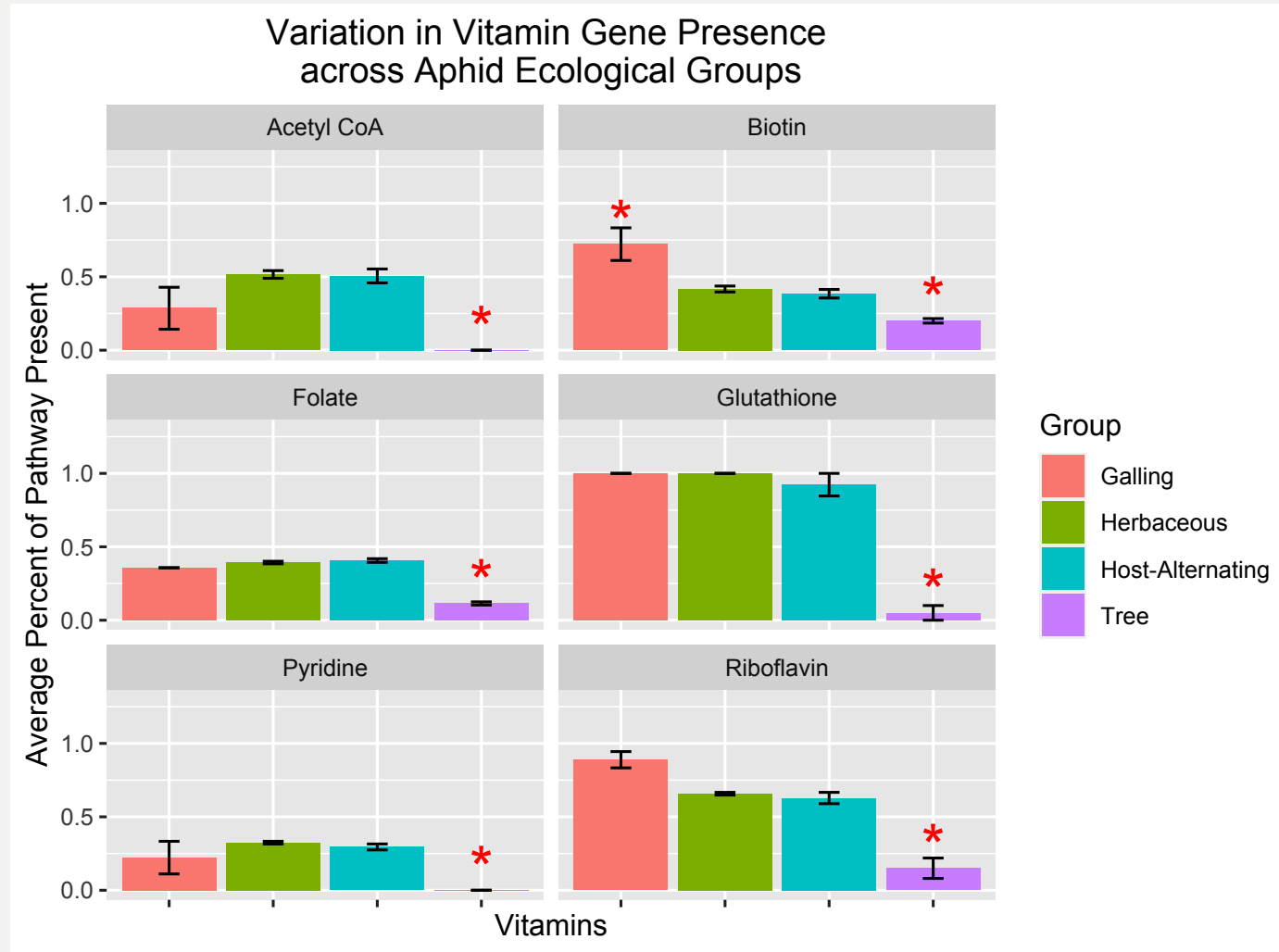
Goal 2: Test for patterns of genomic degradation across aphid ecologies



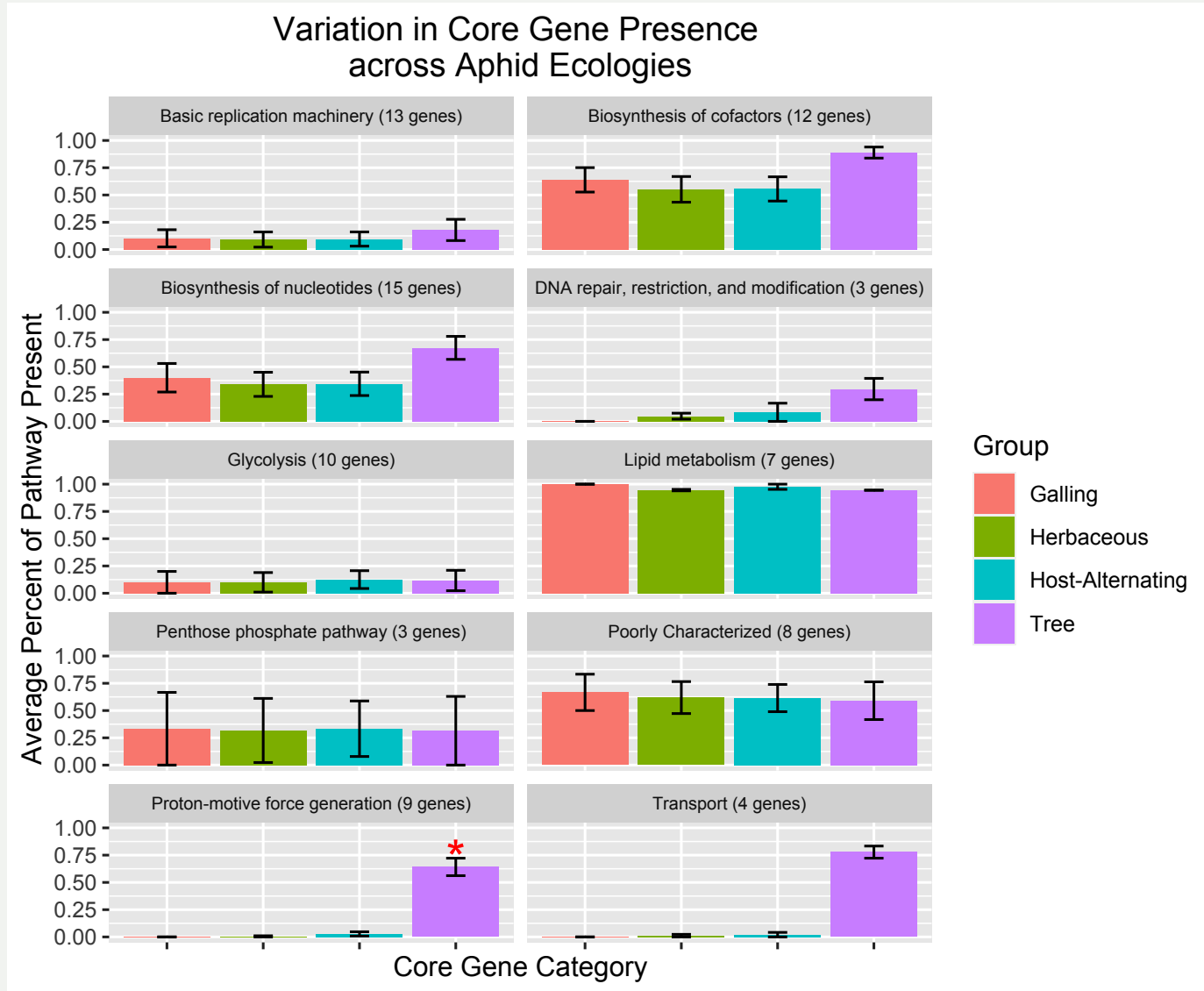
Goal 3: Compare categories of gene losses across aphid ecologies



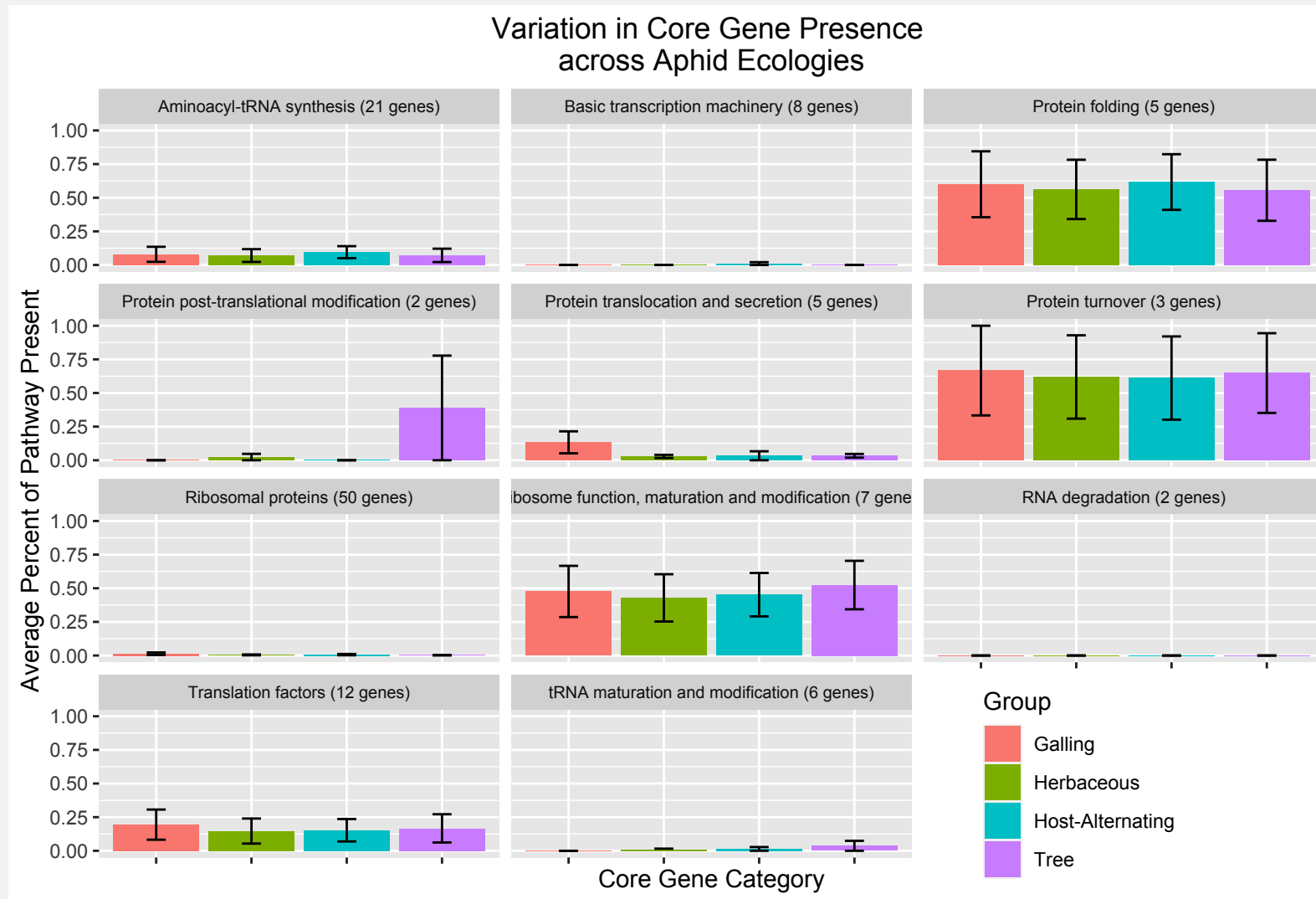
Goal 3: Compare categories of gene losses across aphid ecologies



Goal 3: Compare categories of gene losses across aphid ecologies



Goal 3: Compare categories of gene losses across aphid ecologies



Discussion

Hypothesis-
Is there
support?

YES: The ecology of aphids affects patterns of genome decay in symbionts



Predictions
– Are these
correct?

NO: *Buchnera* genomes of host-alternating and galling aphids will show relaxed selection on nutritional functions

YES AND NO: *Buchnera* genomes of tree-feeding aphids will be smaller due to selection for increased host control

Future Directions



Test for relaxed selection on *Buchnera* genomes of host-alternating and galling aphids



Investigate host control and function of core genes through transcriptomics experiments during different seasons

Acknowledgements

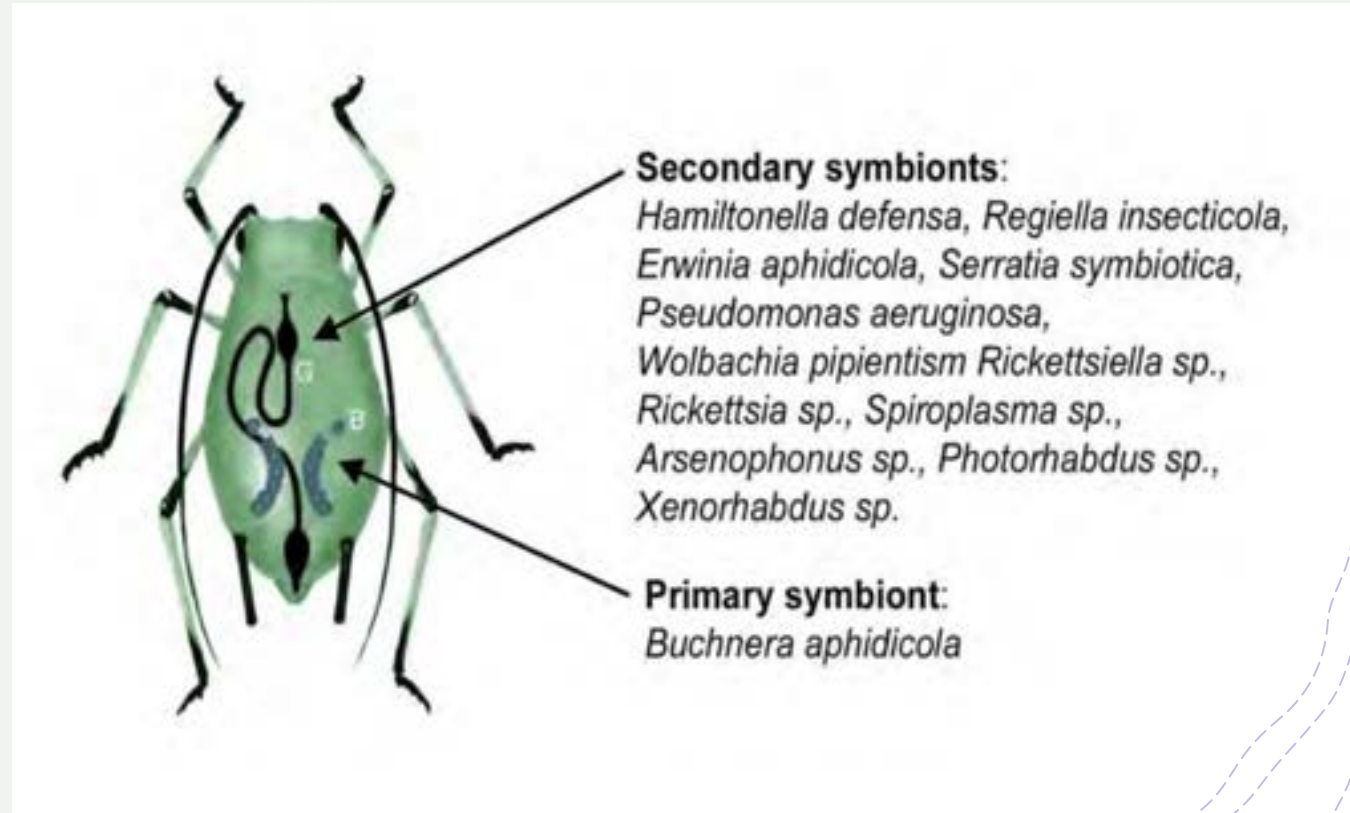
- + von Dohlen Lab
- + Jonathan Bravo, Dustin T. Dial
- + CHPC at University of Utah
- + Funding
 - + USU Biology Department: Matt del Grosso Award, Joseph E. Greaves Scholarship
 - + Ecology Center Graduate Research Award
 - + Lewis and Clark Fund for Exploration and Field Research, American Philosophical Society
 - + National Science Foundation (von Dohlen)



Questions?

Things to Keep in Mind

- + Phenology/seasonal nutritional profile of host plant
- + What species have obligate secondary symbionts?



Aphid Ecology and Life Cycle

- + One major factor varying between *Buchnera* is their aphid ecology
- + **Ecology**: life cycle and type of plant(s) that aphids feed on
- + Idea about galling aphids
- + This has **not** been tested

