A meta-analysis on the benefits and costs of hosting secondary endosymbionts in sap-sucking insects

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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

CeMEB seminars - September 2020

Not only in insects: the human microbiome

> Human body has 10 (1?) times more microbial cells than *Homo sapiens* ones

> Microbiome and obesity

> Fecal transplants to cure chronic bacterial diseases resistant to antibiotics, e.g. *Clostridium difficile*

> Skin microbes and mosquitoes

> Sexual communication in hyenas . . .

van Nood et al (2013) *New Eng J Med*
Ridaura et al (2013) *Science*
Theis et al (2014) *PNAS*

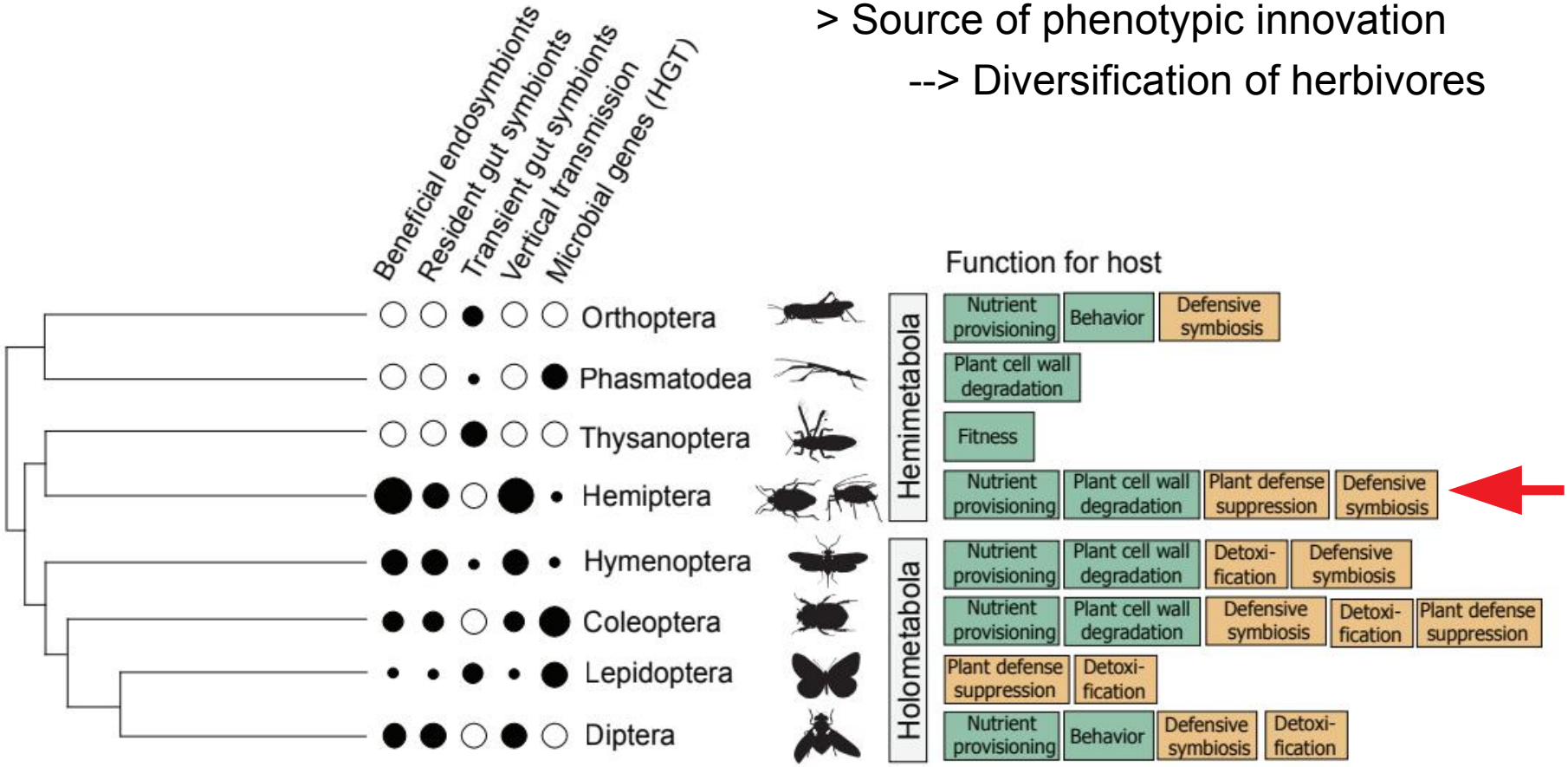
Insect symbionts

> Bacteria, fungi and protozoans

> Evolved independently in many taxa

> Source of phenotypic innovation

--> Diversification of herbivores



Frago, Fatouros & Zytynska (2020)
Advances Insect Physiology

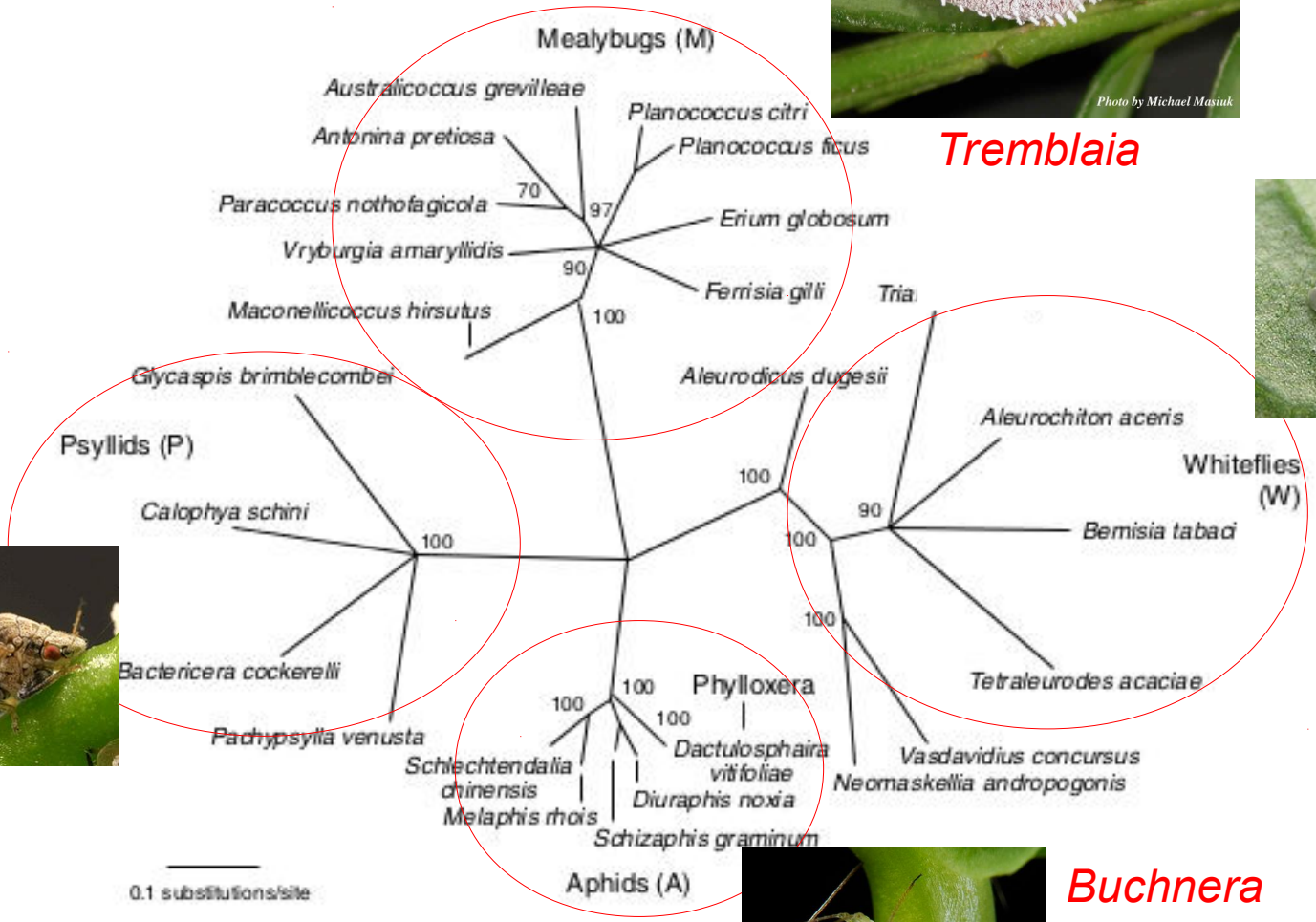
Insect symbionts in phloem feeding insects: aphids, whiteflies, psyllids and mealybugs

Tremblaia

Portiera

Carsonella

Buchnera



Insect symbionts in phloem feeding insects: aphids, whiteflies, psyllids and mealybugs

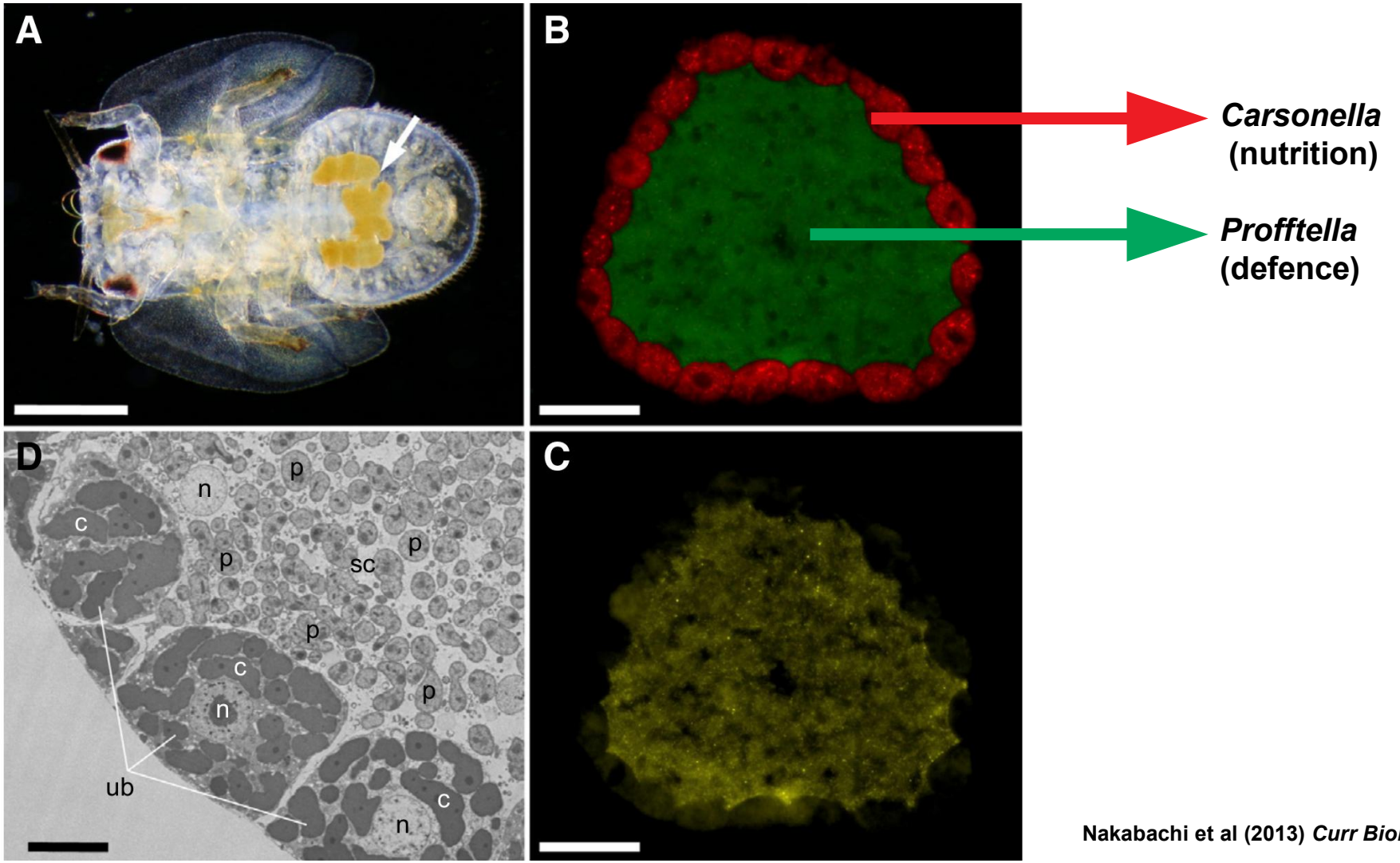
Obligatory endosymbionts:

- In bacteriome
- Provide essential nutrients

Facultative endosymbionts:

- In bacteriome (or not)
- Provide conditional benefits
- Not always present

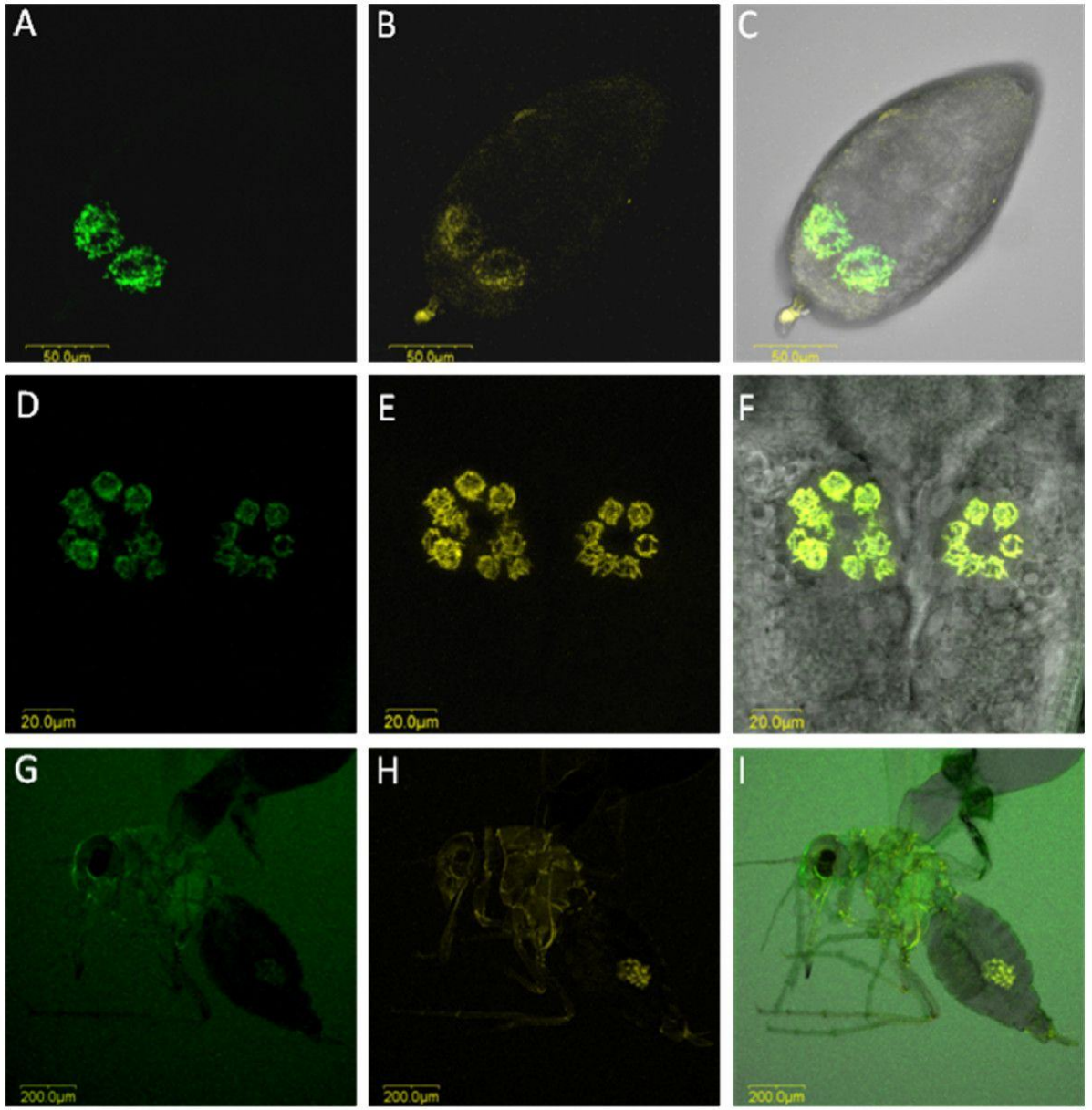
Insect symbionts: Asian citrus psyllid



Nakabachi et al (2013) *Curr Biol*

Insect symbionts: whitefly *Bemisia tabaci*

Facultative:
Hamiltonella (green)
Arsenophonus (yellow)



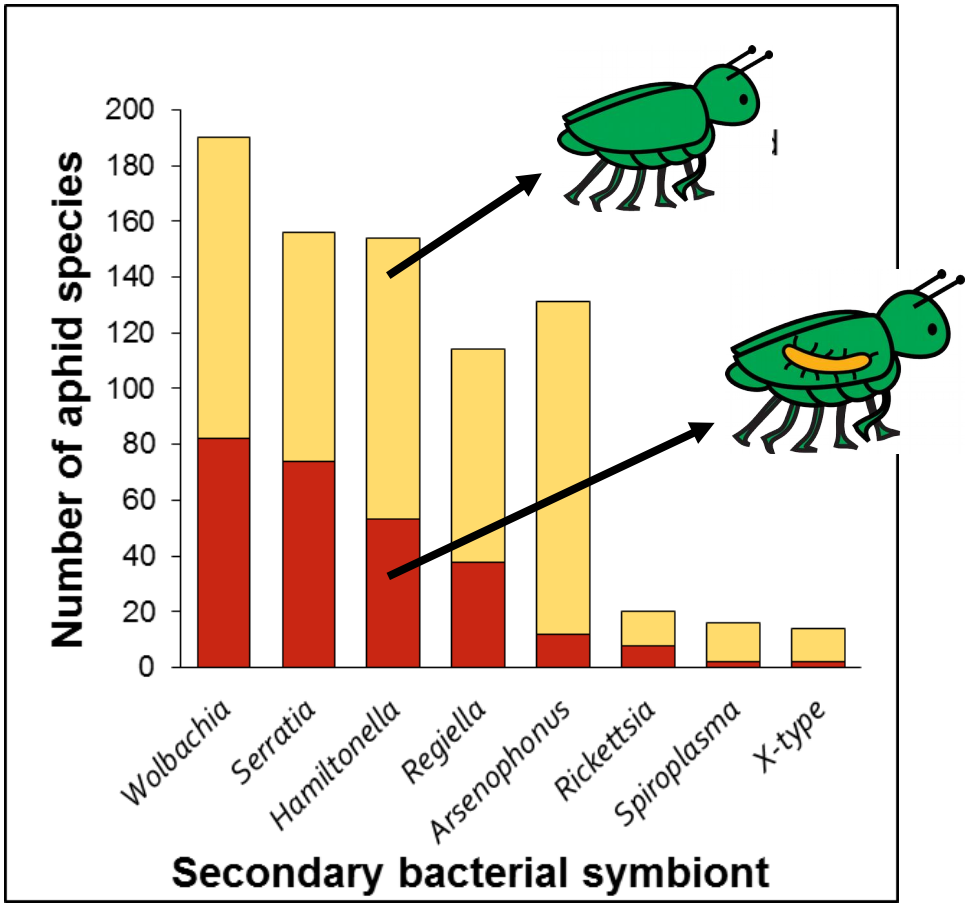
Skaljac et al (2010) *BMC Microbiol*

Symbionts in aphids

Primary symbiont: *Buchnera aphidicola*

>300 aphid species have been tested for at least one of the common nine secondary symbionts:

- *Hamiltonella defensa*
- *Serratia symbiotica*
- *Regiella insecticola*
- *Rickettsia*
- Rickettsiella
- *Spiroplasma*
- X-type (PAXS)
- *Arsenophonus*
- *Wolbachia*



Zytynska and Weisser (2016) Ecol Ent 41:13-26

Symbionts in aphids

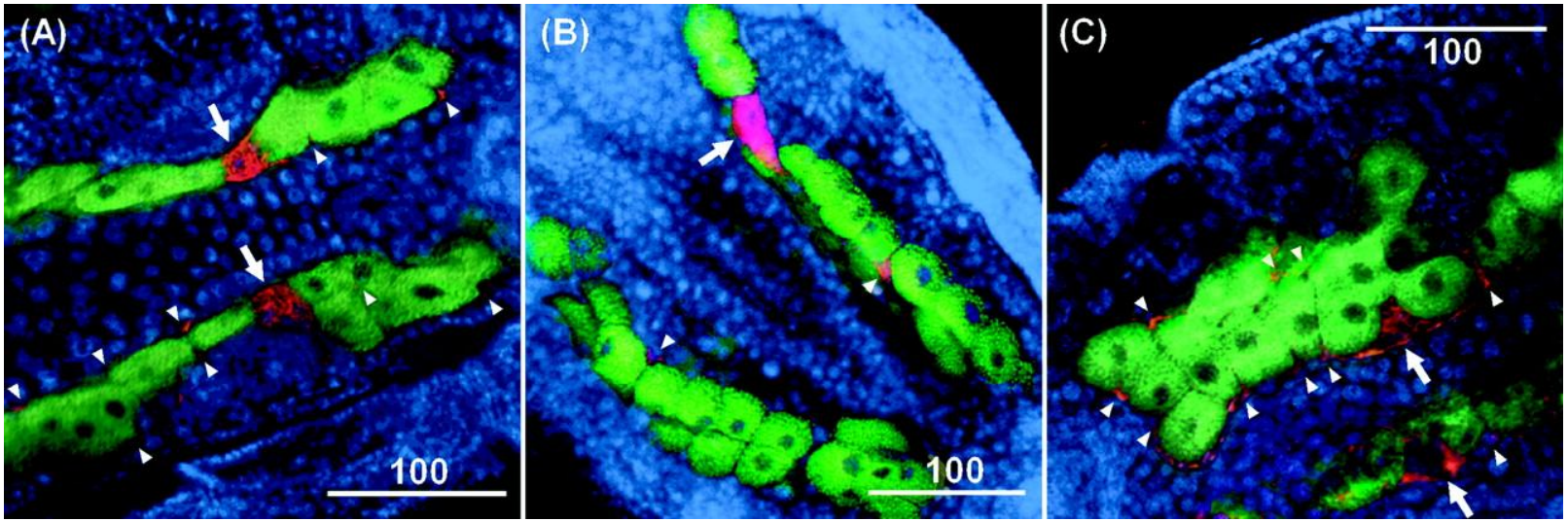
> Obligate symbiont *Buchnera aphidicola*

> Seven facultative symbionts:

Protection from pathogens: *Regiella insecticola*

Protection from heat shocks: *Serratia symbiotica*

Protection from parasitoids: *Hamiltonella defensa*

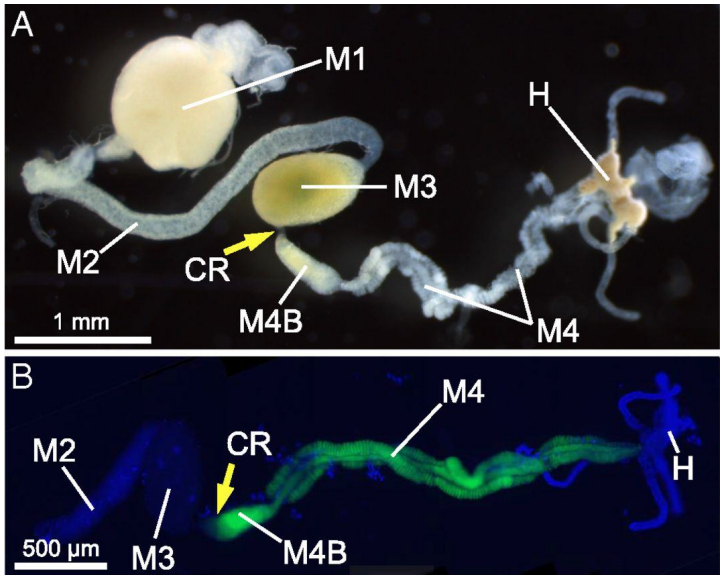


Insect symbionts in phloem feeding insects: Heteropterans - stink bugs, shield bugs and true bugs

Megacopta punctatissima

Megacopta cribraria

Riptortus pedestris

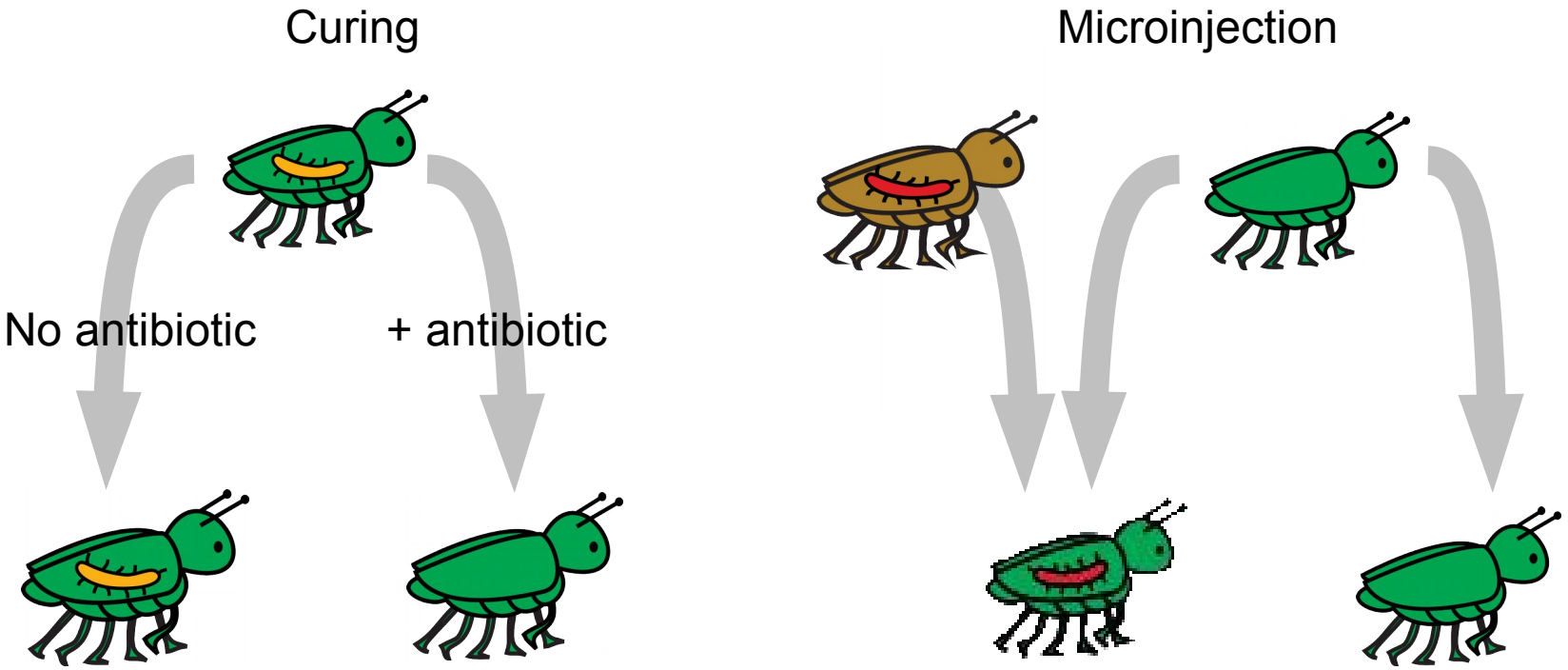


Hosokawa et al. (2007) *Proc. B*

Ohbayashi et al (2015) PNAS

Manipulating symbionts

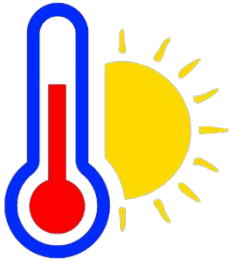
> Lines in the lab (asexual reproduction in aphids)
> "Cured" from facultative symbionts with antibiotics
> In aphids "infected" with new symbionts through microinjection
> In whiteflies "introgression" via crossing



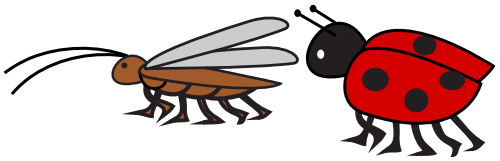
Oliver et al. (2010) *Ann. Rev. Ent*

Diverse beneficial effects of aphid secondary symbionts

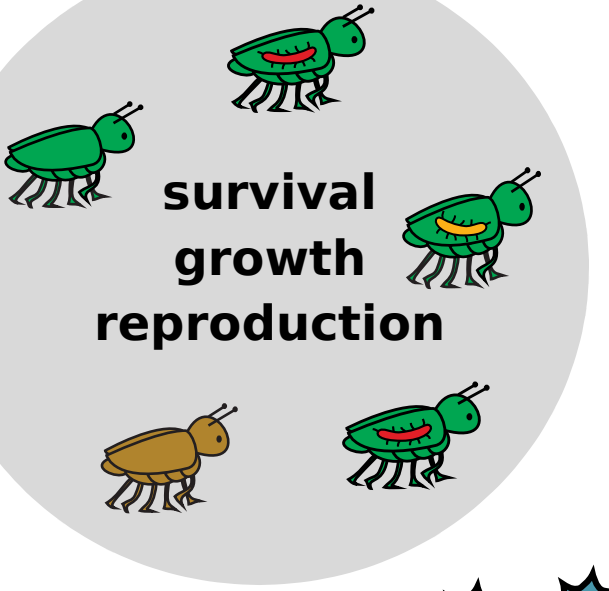
BENEFITS **COSTS**



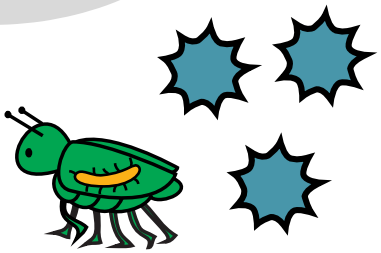
Heat shock



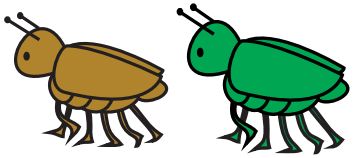
Natural enemies



Resource use



Pathogens



Aphid colour

Meta-analysis questions

1. Which groups have been sufficiently experimentally examined for the effects of symbionts on the host?

2. Is there a tradde-off between costs and benefits?

3. Are symbiont effects species-dependent?

Meta-analysis methods

"A meta-analysis is a statistical analysis that combines the results of multiple scientific studies"

1. Keywords Web of Science

2. Establish selection criteria
   e.g. we need mean, SE and n

3. Data mining: extract values from figures,
   tough work!
   (WebPlotDigitaliser)

4. Standardise measures: "effect size"
   Hedges'd value

5. Analise and validate models
   (similar to GLMM)

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(whitefl* OR bemisia* OR siphoninus* OR Trialeurodes OR Aleurodicus OR Aleuronudus OR Dialeurodicus OR Metaleurodicus OR Palaealeurodicus OR Paraleyrodes) AND symbio*

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Experimental test for symbiont effects using:
- Antibiotics
- Introgression
- Microinjections

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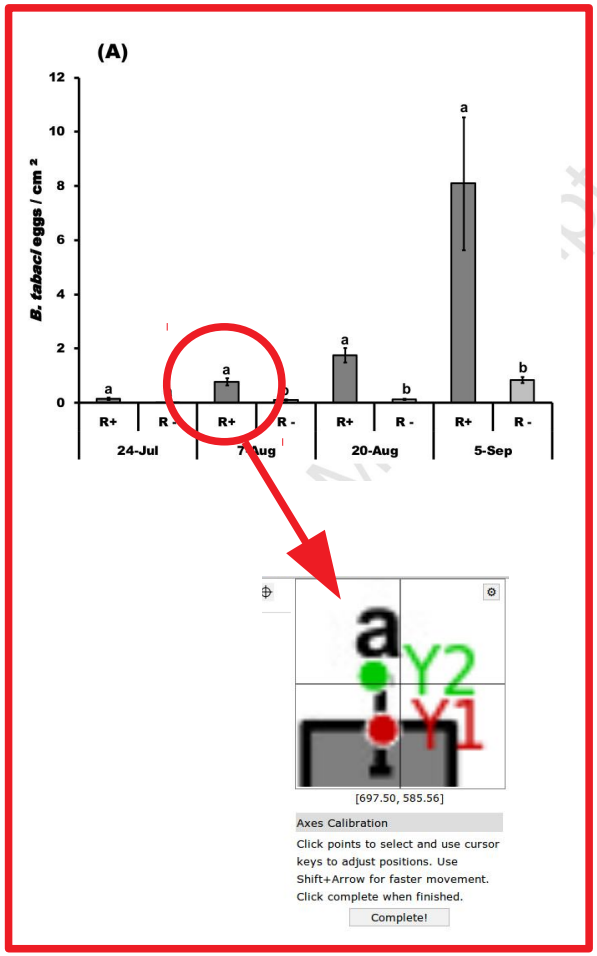

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Life-history traits

- Body size
- Development time
- Lifespan
- Fecundity
- Survival / parasitism

Validation

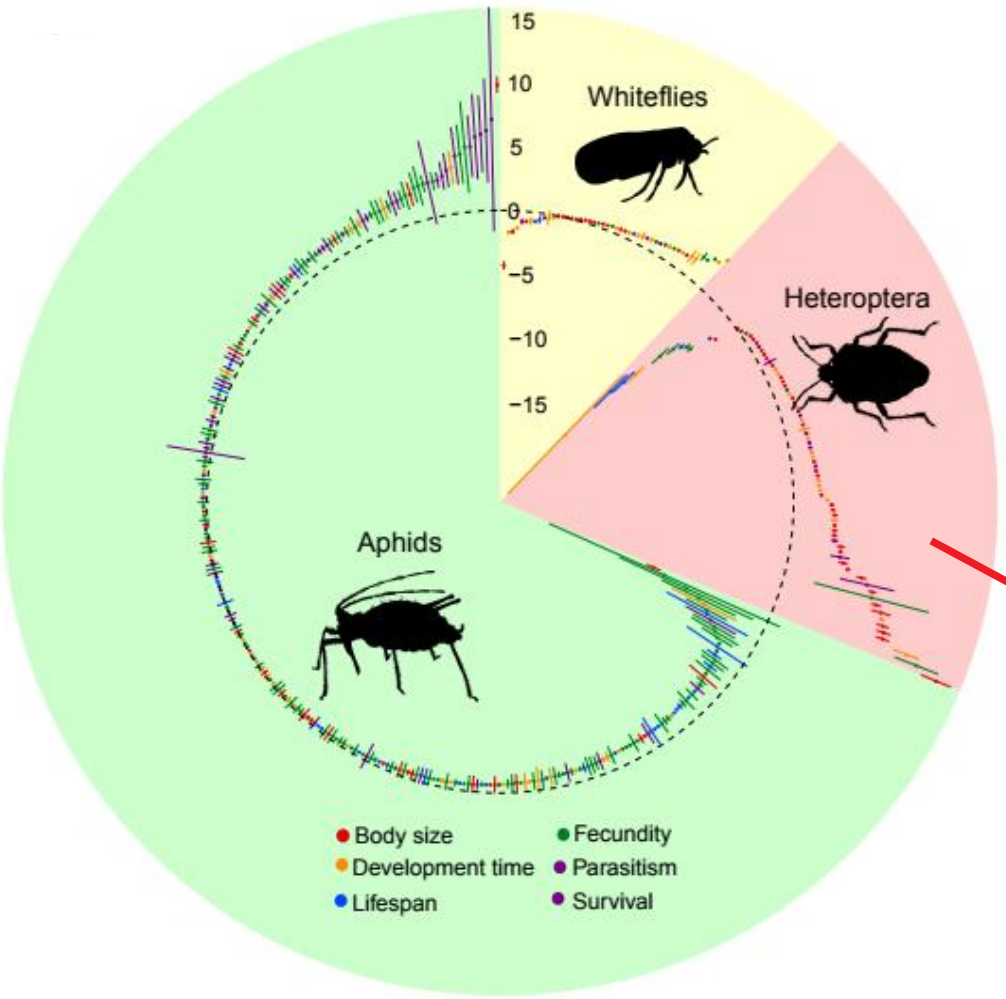
- p-hacking
- Publication bias

1. *Which groups have been sufficiently experimentally examined for the effects of symbionts on the host?*

- Not enough data for psyllids and mealybugs
- Large diversity of heteropteran species
- Only one whitefly species: *Bemisia tabaci*
- Most aphid data comes from pea and black bean aphids

Group	WebSci #papers	Criteria OK #papers	Criteria OK #datapoints	#species
Heteroptera	530	13	79	14
Whitefly	260	8	49	1
Aphid	512	68	281	13

1. *Which groups have been sufficiently experimentally examined for the effects of symbionts on the host?*



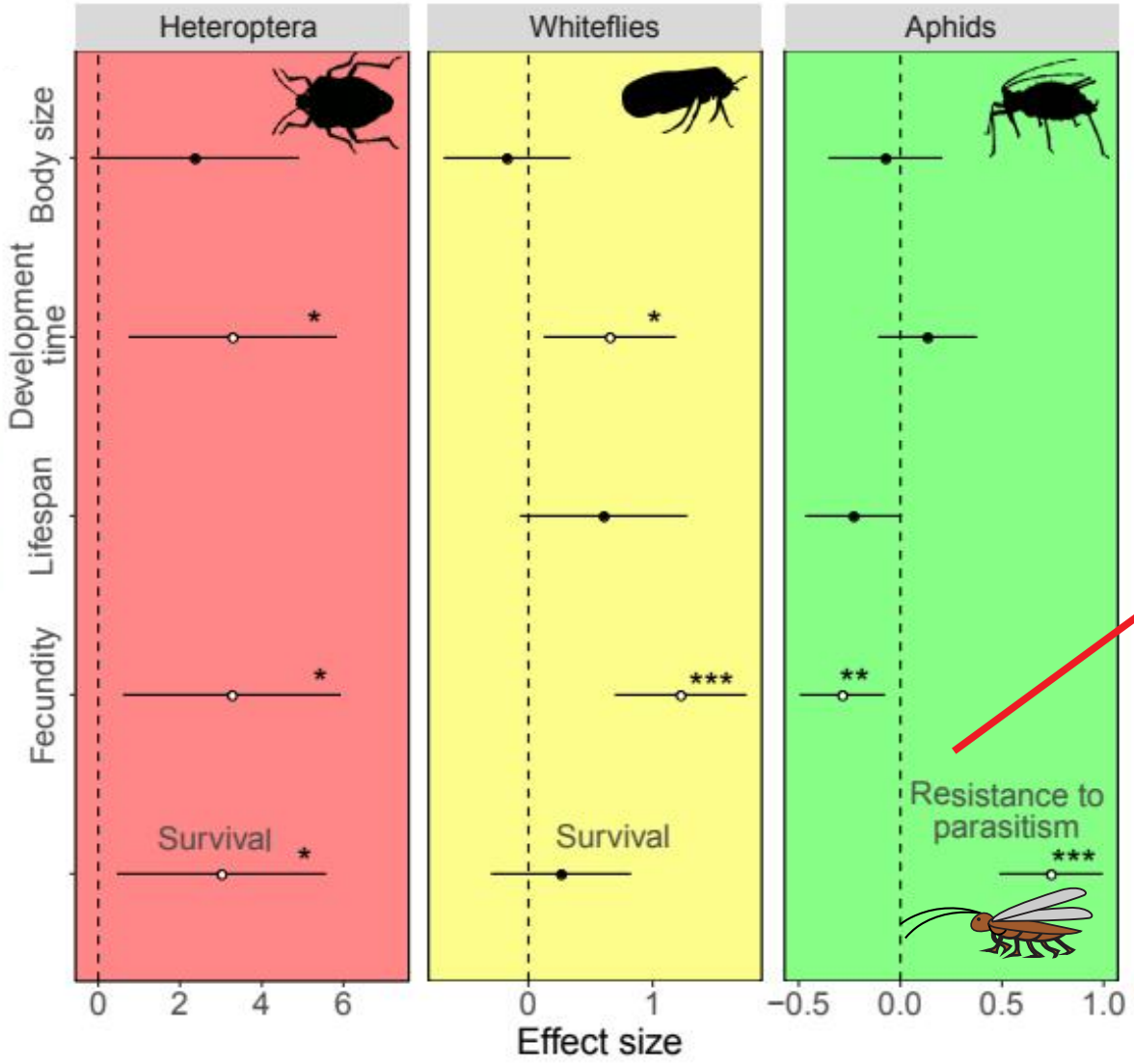
Life-history traits

- **Body size**
- **Development time**
- **Fecundity**
- **Lifespan**
- **Survival / parasitism**

Heteropterans

- Large and + effects sizes
- Are symbionts obligatory?

2. *Is there a tradde-off between costs and benefits?*



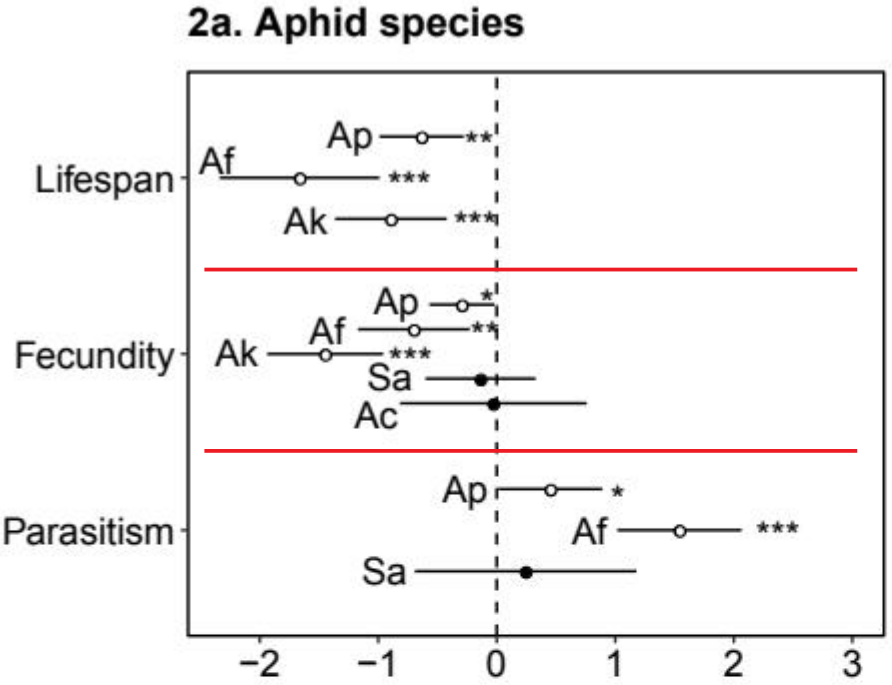
Heteropterans:
are symbionts obligatory?

Whiteflies:
data from a single species *B. tabaci*

Aphids:
Tradde-off between fecundity and resistance to parasitic wasps

3. *Are symbiont effects species-dependent?*

Only possible to test in aphids



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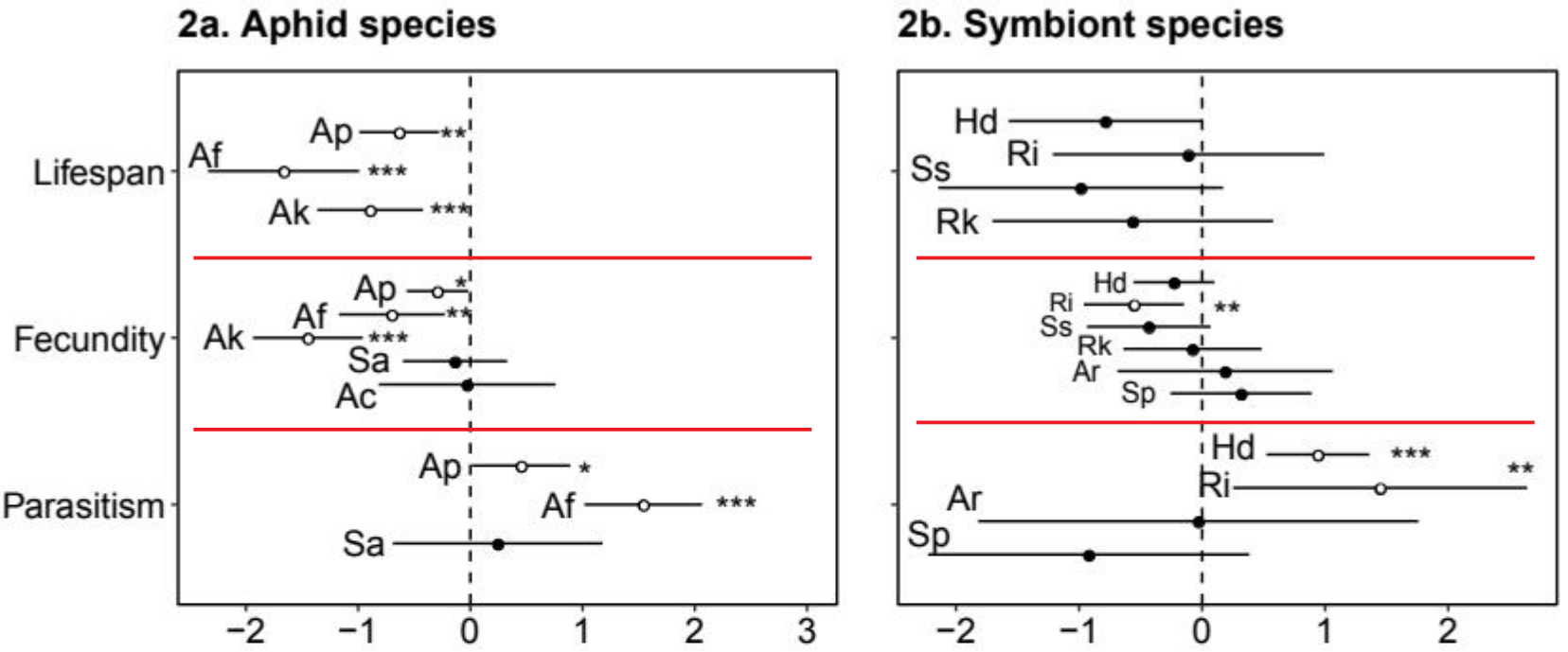
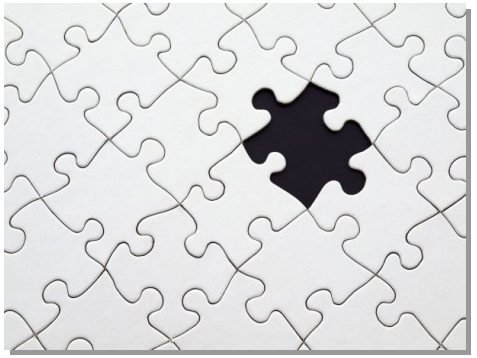


Summary



1. Which groups have been sufficiently experimentally examined for the effects of symbionts on the host?

- Enough data for aphids and heteropterans.
- Only one species of whitefly.
- No data for psyllids and mealybugs.

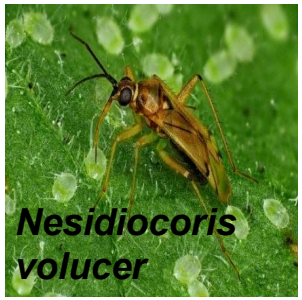
2. Is there a tradde-off between costs and benefits?

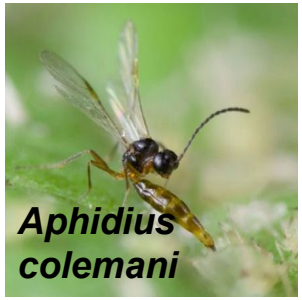
- YES in aphids. Driven by *Hamiltonella* in pea and black bean aphids.
- NO in whiteflies and heteropterans: beneficial effects only.

3. Are symbiont effects species-dependent?

- Data only for aphids.
- Protective but costly symbionts in pea and black bean aphids.
- *Hamiltonella* and *Rickettsia* as defensive symbionts.
- Lack of data on multiple infections.

Current research on experimental community ecology





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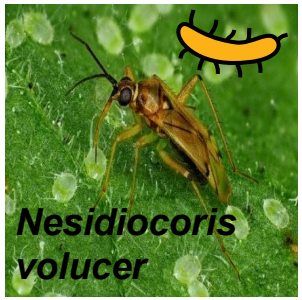

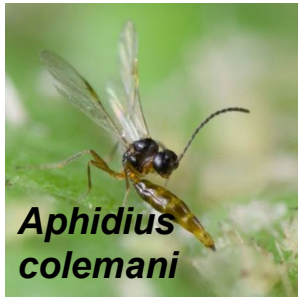

Thanks for your attention!!

People involved:

Sharon Zytynska (University of Liverpool)

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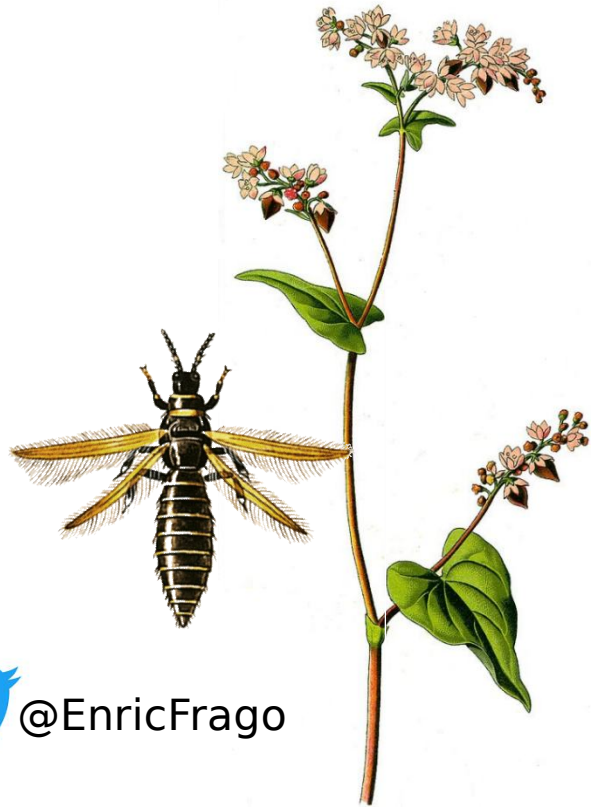

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