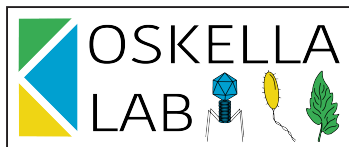


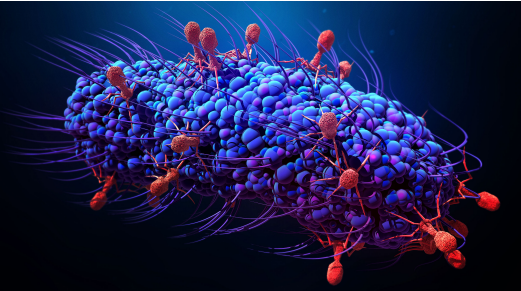
Viruses never do as they're told, and
there's a good reason for it:
bacteria-phage **coevolution** as a
driver of diversity

Britt Koskella

@bkoskella 

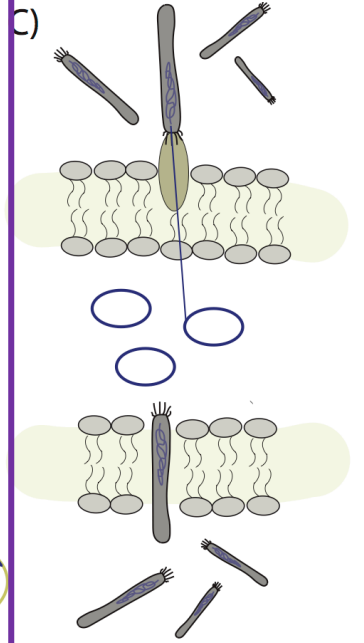
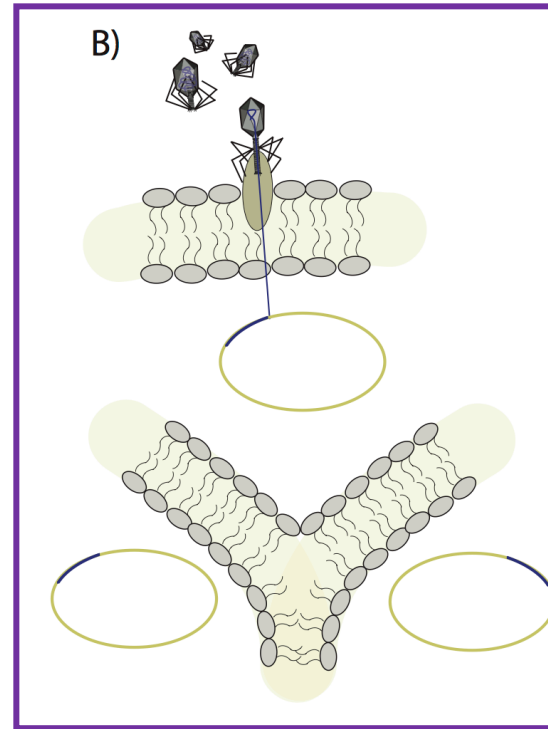
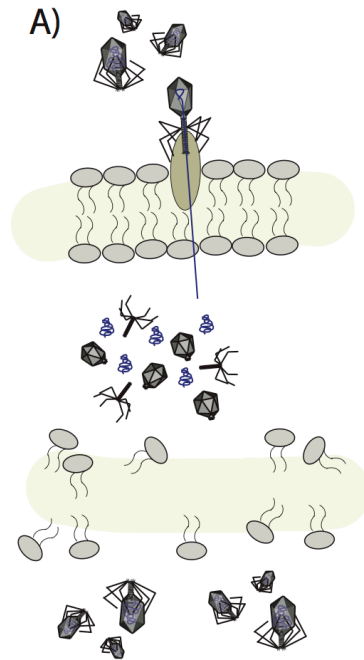
Assistant Professor, Integrative Biology
UC Berkeley





Bacteria- phage coevolution

Photo credit: Design_Cells

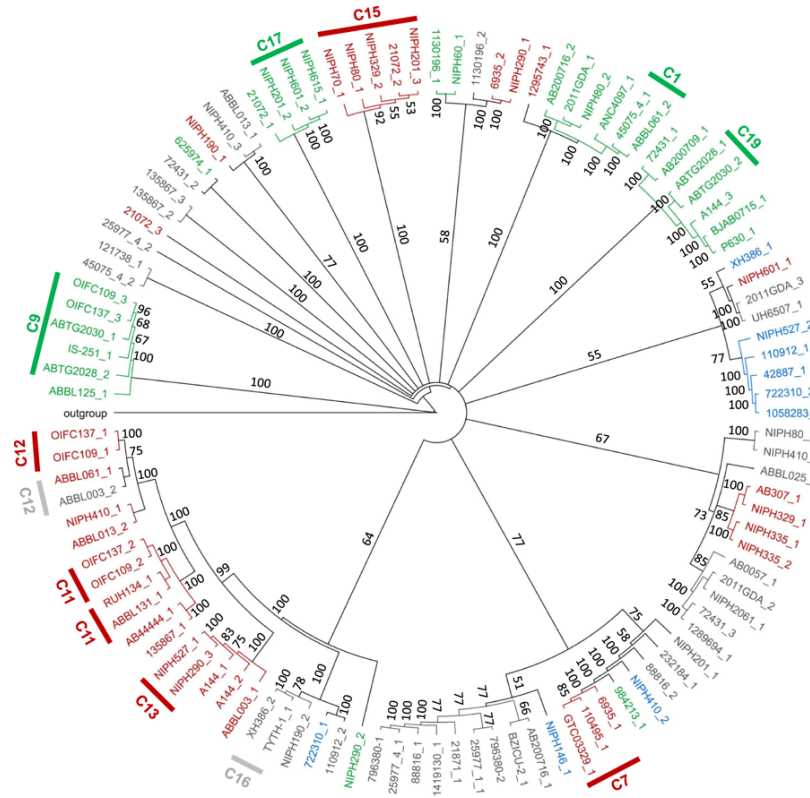


Temperate phage

- Koskella & Brockhurst *FEMS Microbiol Rev* 2014

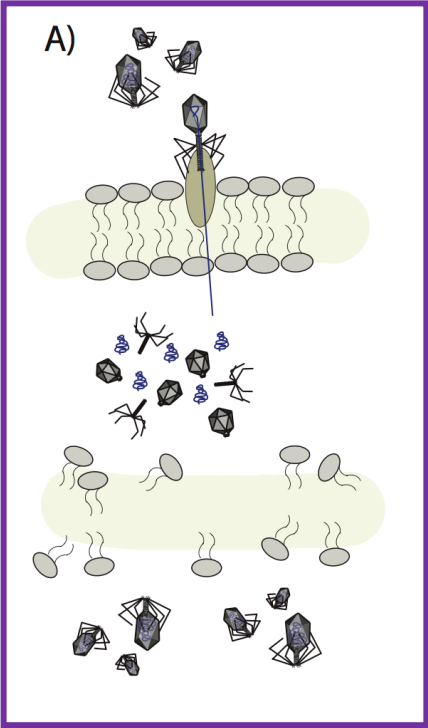


795 genomes of *Acinetobacter baumannii* → 4,122 prophages

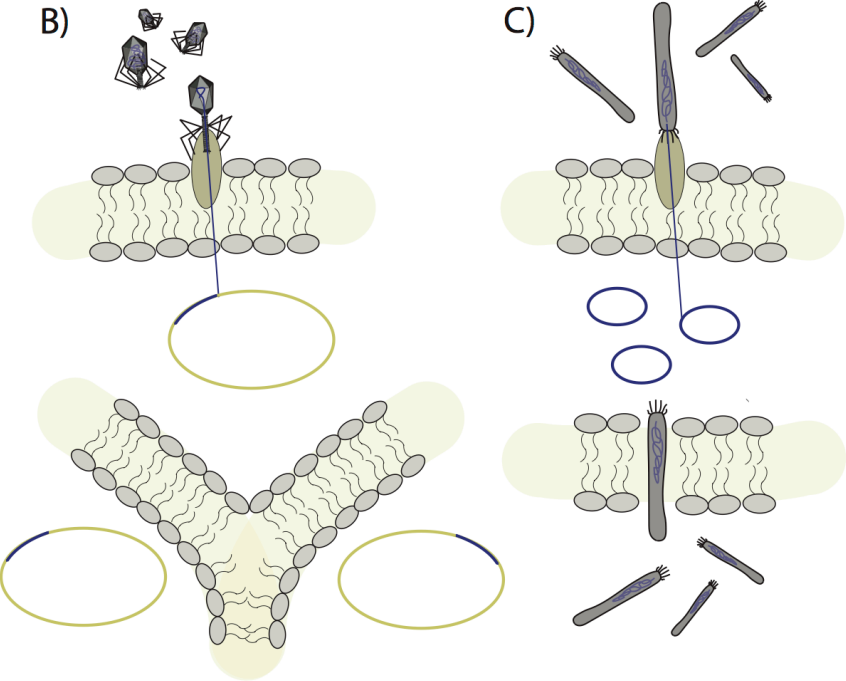


78% of the *A. baumannii* “intact prophages” encode putative virulence genes, with an average of 1.75 virulence factors in their genomes

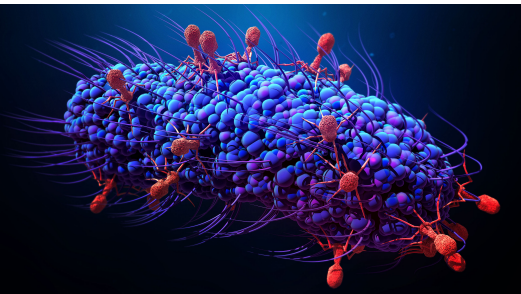
- Costa, A. R., Monteiro, R., & Azeredo, J. 2018. *Scientific reports*, 8.



Lytic phage



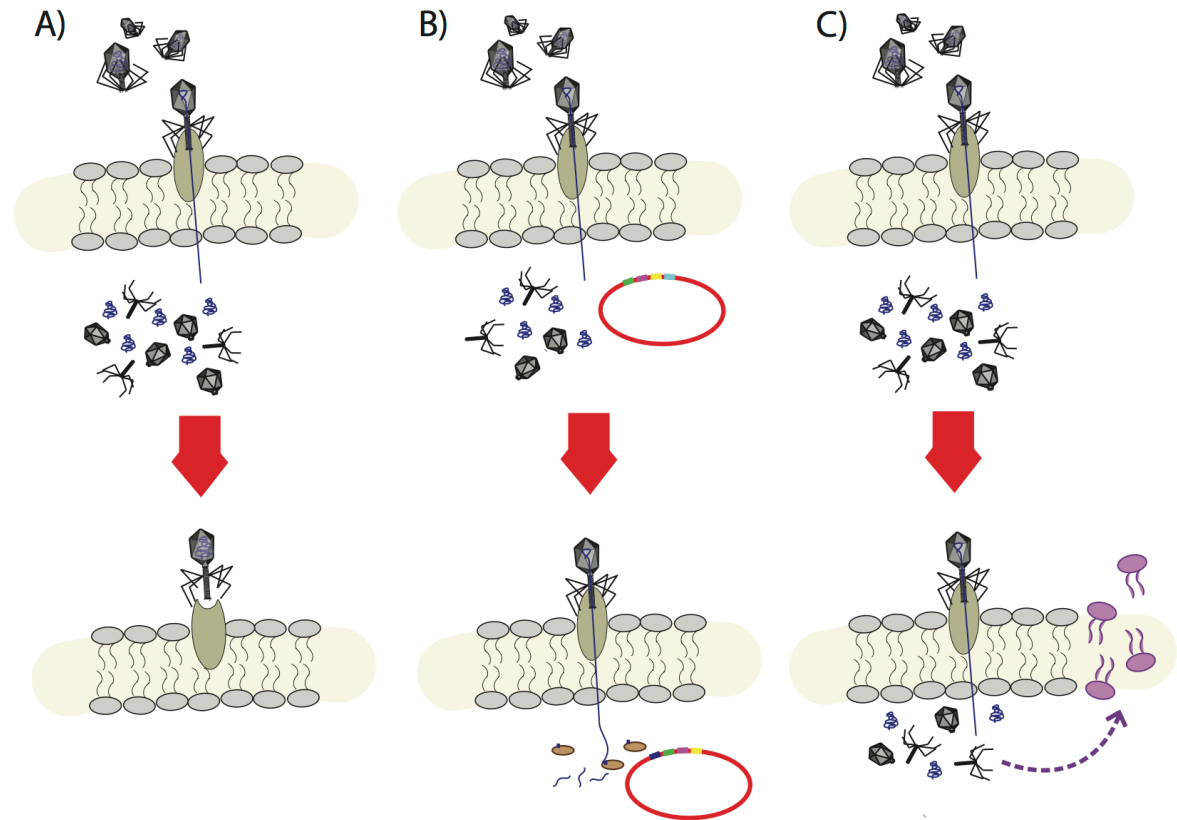
- Koskella & Brockhurst *FEMS Microbiol Rev* 2014



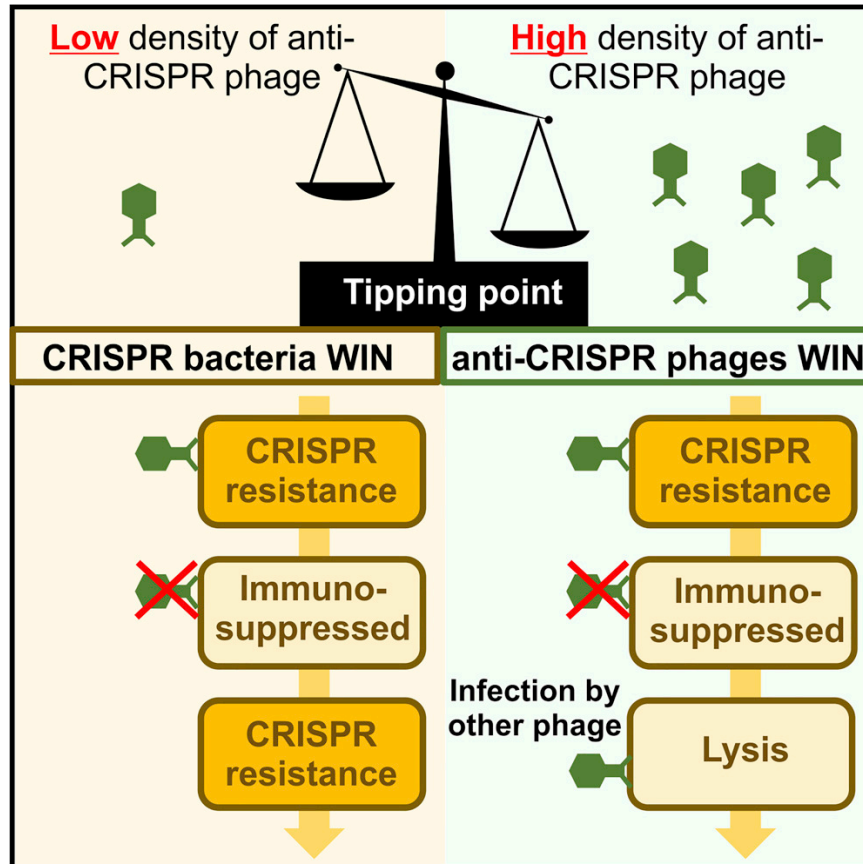
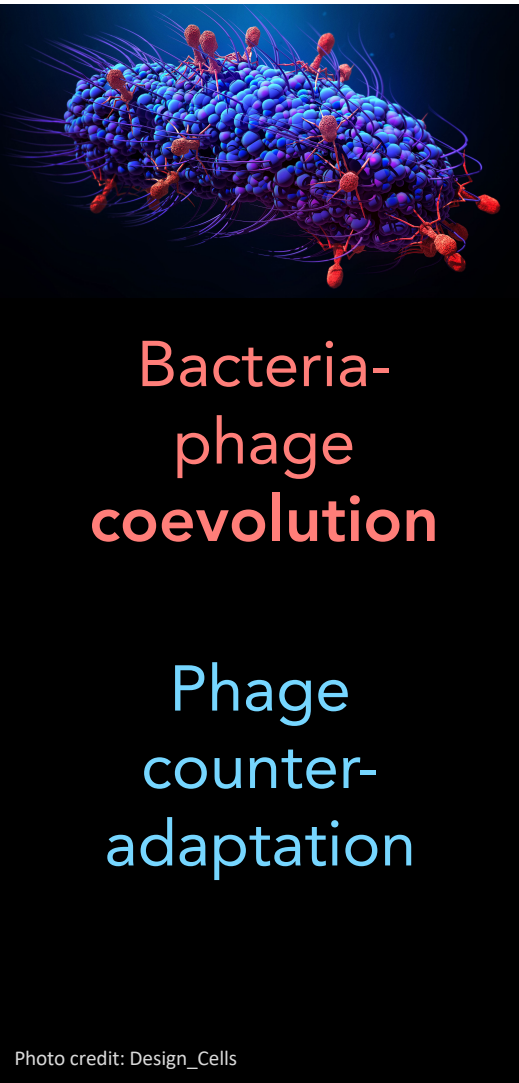
Bacteria- phage coevolution

Bacterial resistance

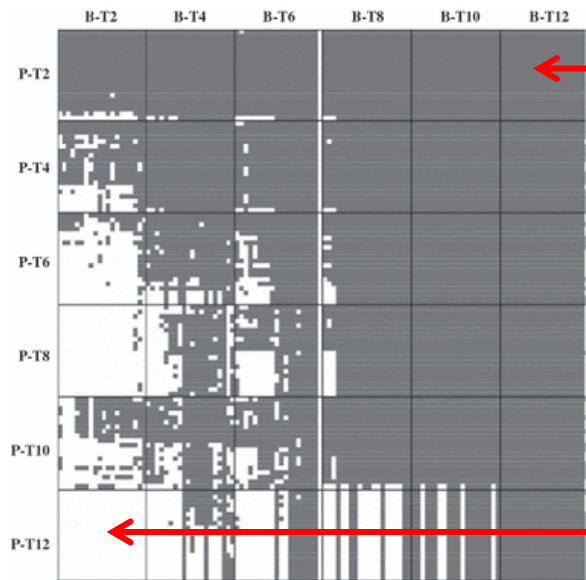
Photo credit: Design_Cells



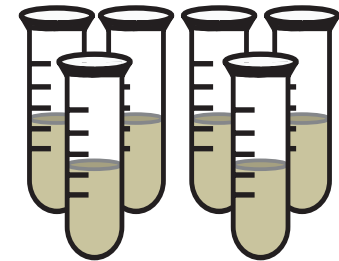
- Koskella & Brockhurst *FEMS Microbiol Rev* 2014



- Landsberger, M. et al. 2018. *Cell*, 174(4), 908-916.

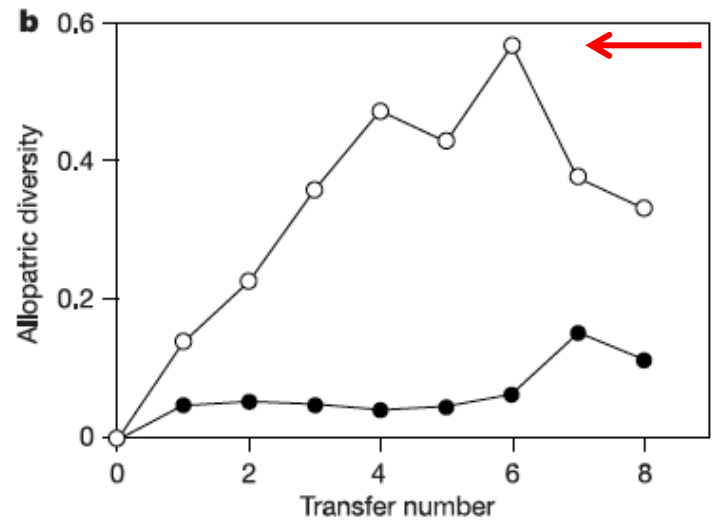


Bacteria increase resistance to phage

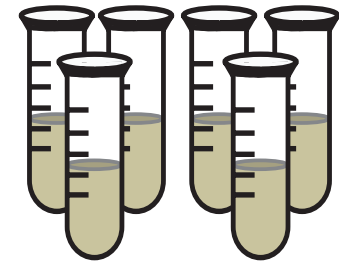


Phages increase infectivity to bacteria

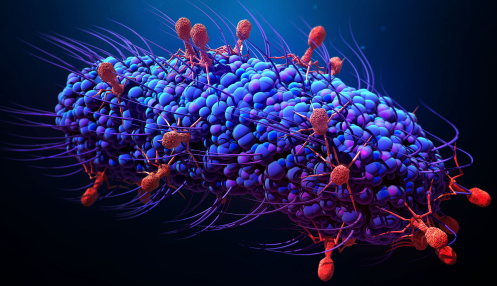
- Scanlan, Hall, Lopez-Pascua & Buckling 2010. *Mol Ecol* 20(5), 981-989.



With phages



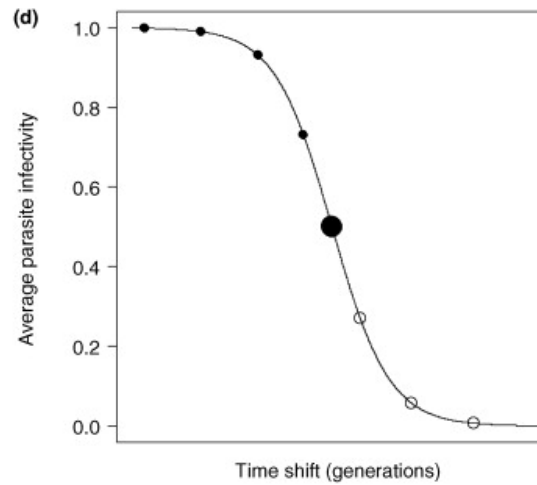
- Buckling & Rainey 2002. *Nature* 420 (6915): 496.



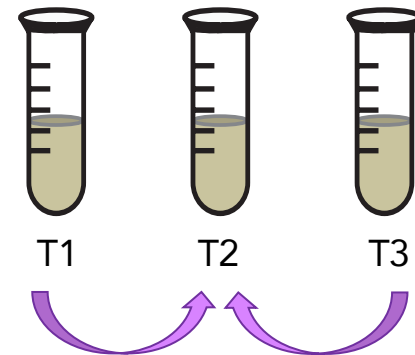
**Bacteria-
phage
coevolution**

**Time
shift
experiment**

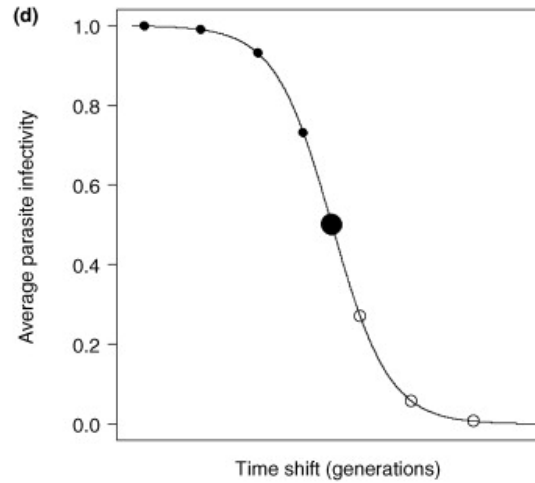
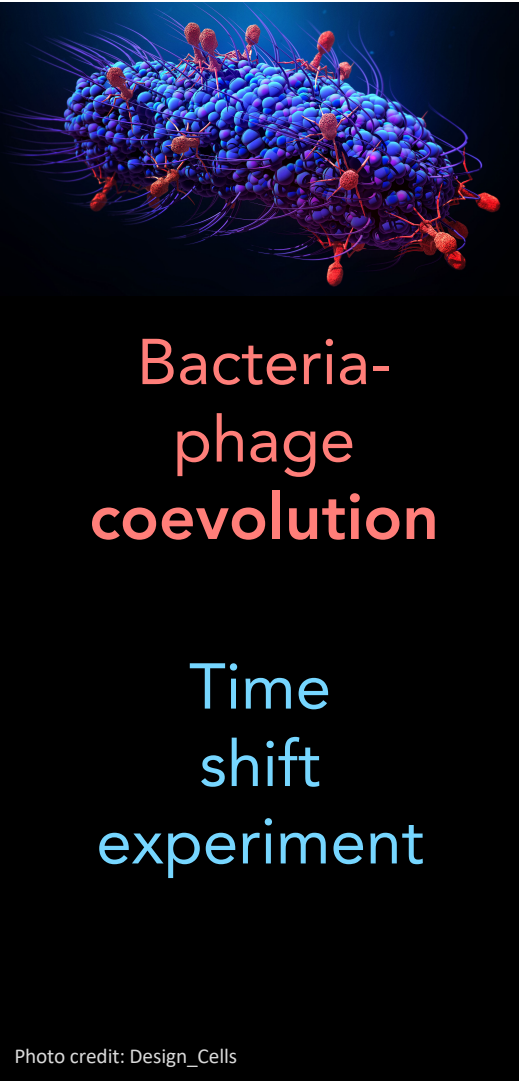
Photo credit: Design_Cells



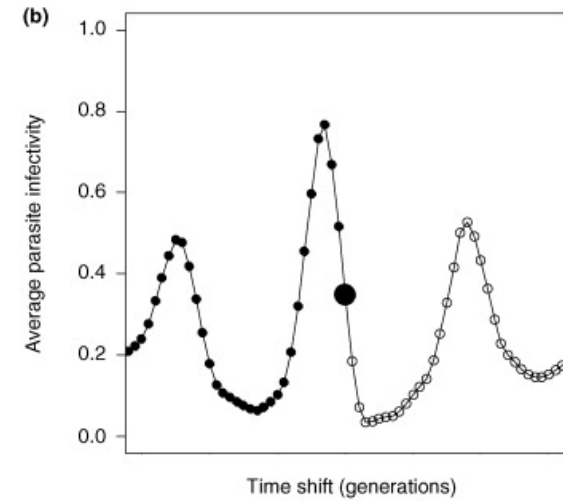
Measuring
coevolution
using time shift
experiments



- Gaba & Ebert 2009 *TREE* 24(4), 226-232.



Arms race dynamics



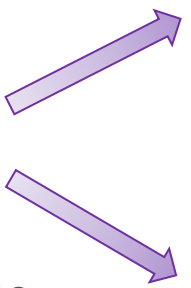
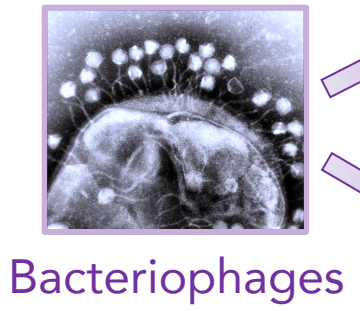
Fluctuating selection dynamics

- Gaba & Ebert 2009 *TREE* 24(4), 226-232.



**Bacteria-
phage
coevolution**

Photo credit: Design_Cells



Plant pathogen



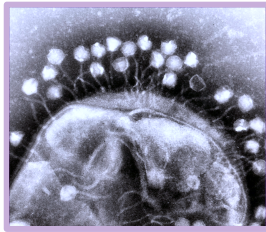
Host-associated microbiome



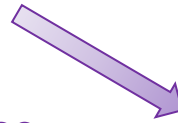


**Bacteria-
phage
coevolution**

Photo credit: Design_Cells

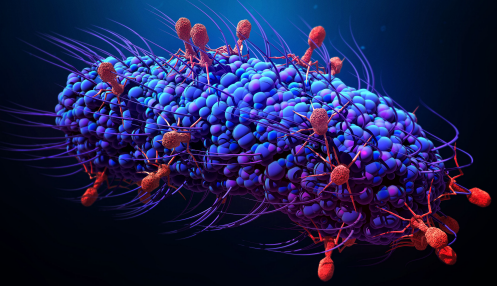


Bacteriophages



Host-associated microbiome

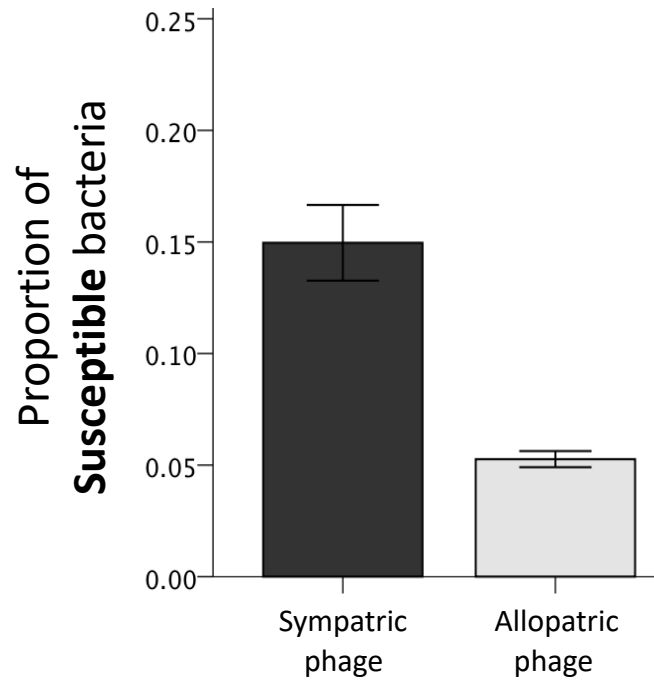




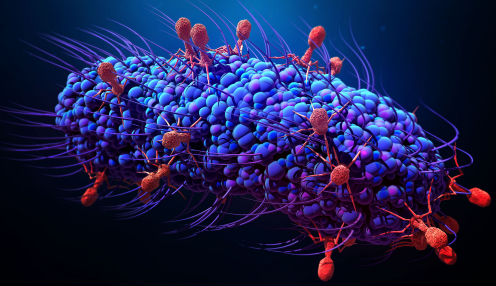
**Bacteria-
phage
coevolution**

Phages are
locally
adapted

Photo credit: Design_Cells



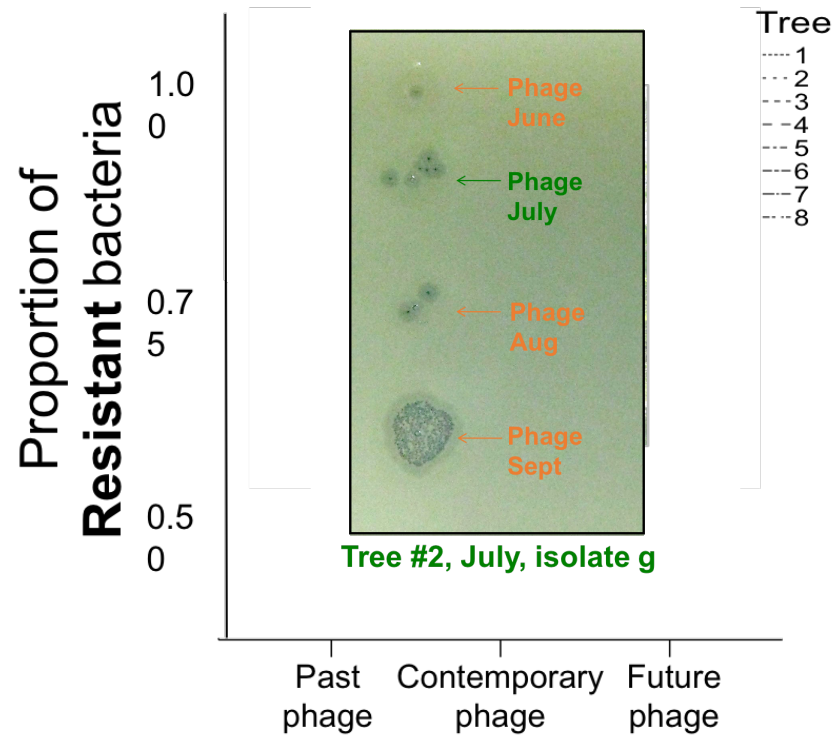
- Koskella et al., American Naturalist 2011. 177(4), 440-451.



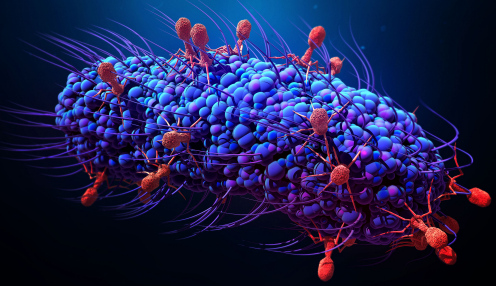
**Bacteria-
phage
coevolution**

**Time
shift
experiment**

Photo credit: Design_Cells



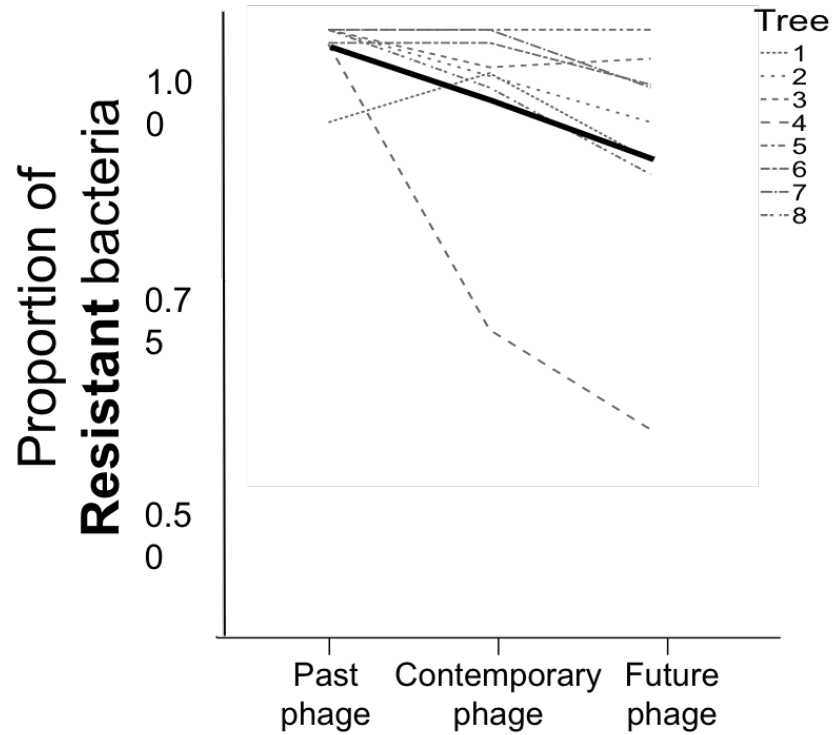
- Koskella, *Current Biology* 2013. 23(13), 1256-1260.



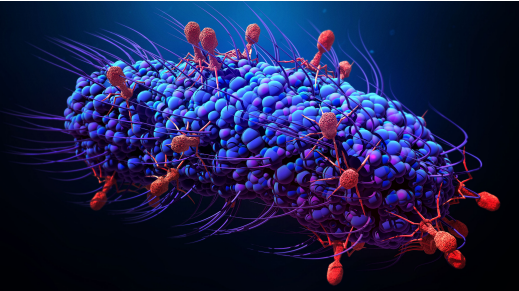
**Bacteria-
phage
coevolution**

Show bacterial
resistance,
phage
counter-
adaptation

Photo credit: Design_Cells



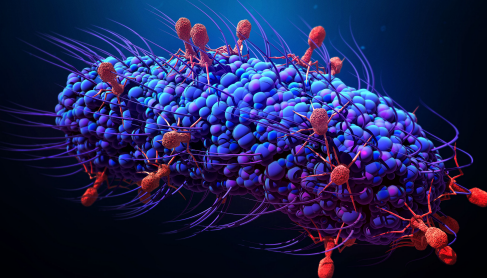
- Koskella, *Current Biology* 2013. 23(13), 1256-1260.



Bacteria- phage coevolution

Impacts on
microbiome
diversity

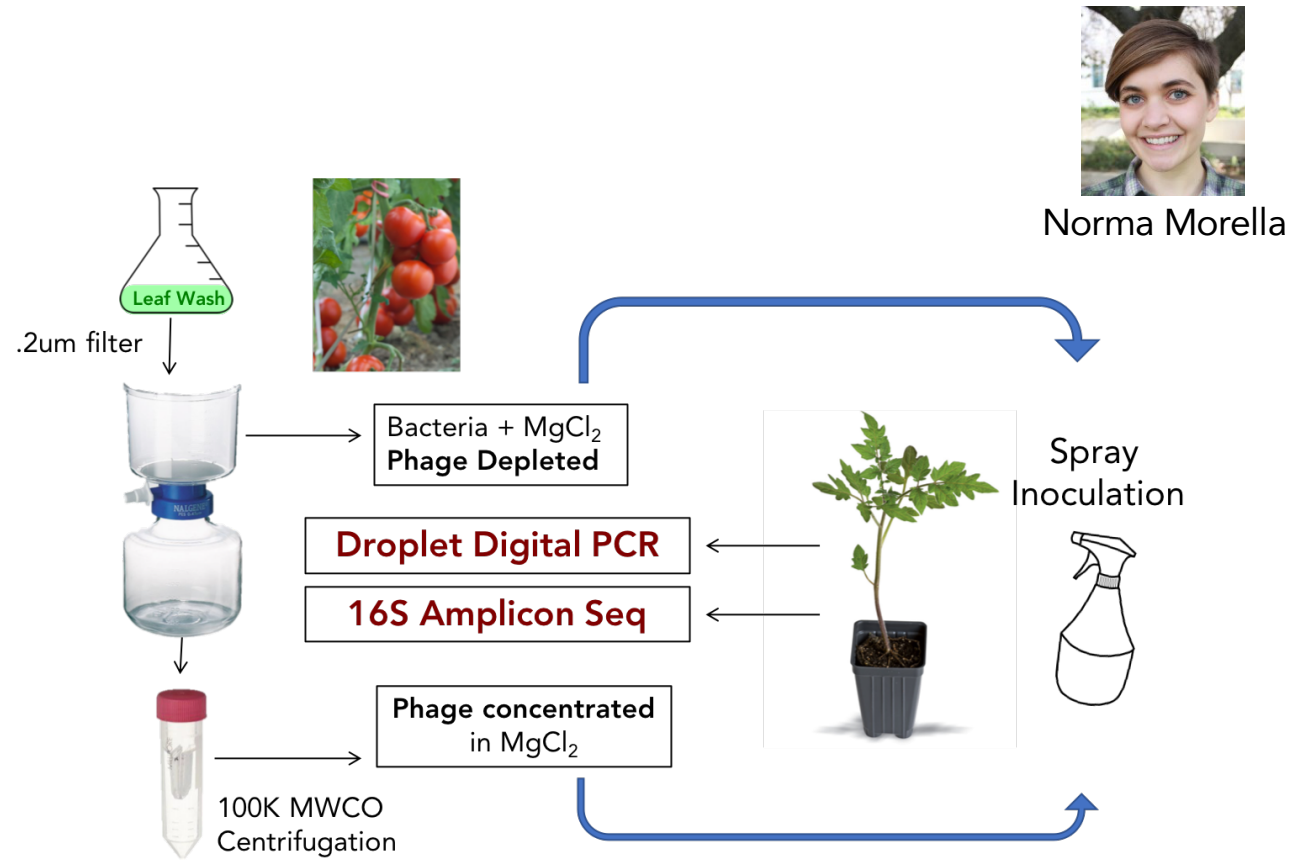
Photo credit: Design_Cells



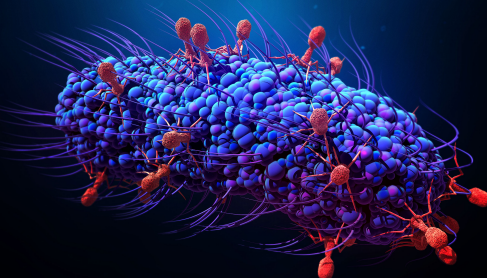
**Bacteria-
phage
coevolution**

**Impacts on
microbiome
diversity**

Photo credit: Design_Cells



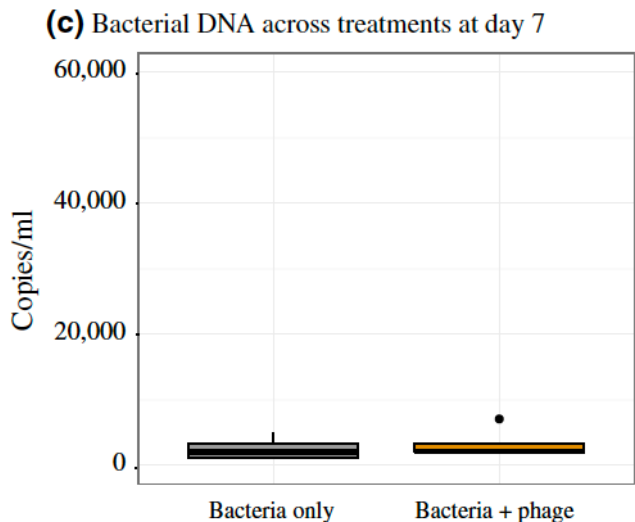
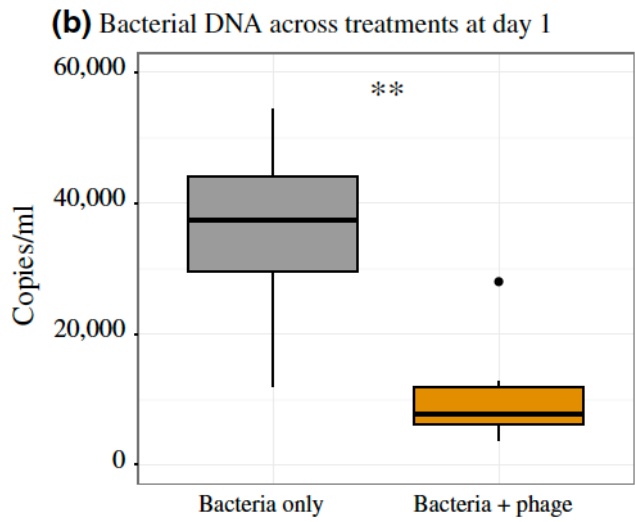
- Morella *et al.*, Molecular Ecology 2018. 27(8), 2025-2038.



Bacteria-phage coevolution

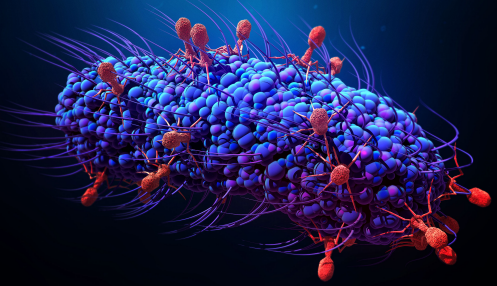
Impacts on microbiome diversity

Photo credit: Design_Cells



X 6 per treatment

- Morella *et al.*, Molecular Ecology 2018. 27(8), 2025-2038.

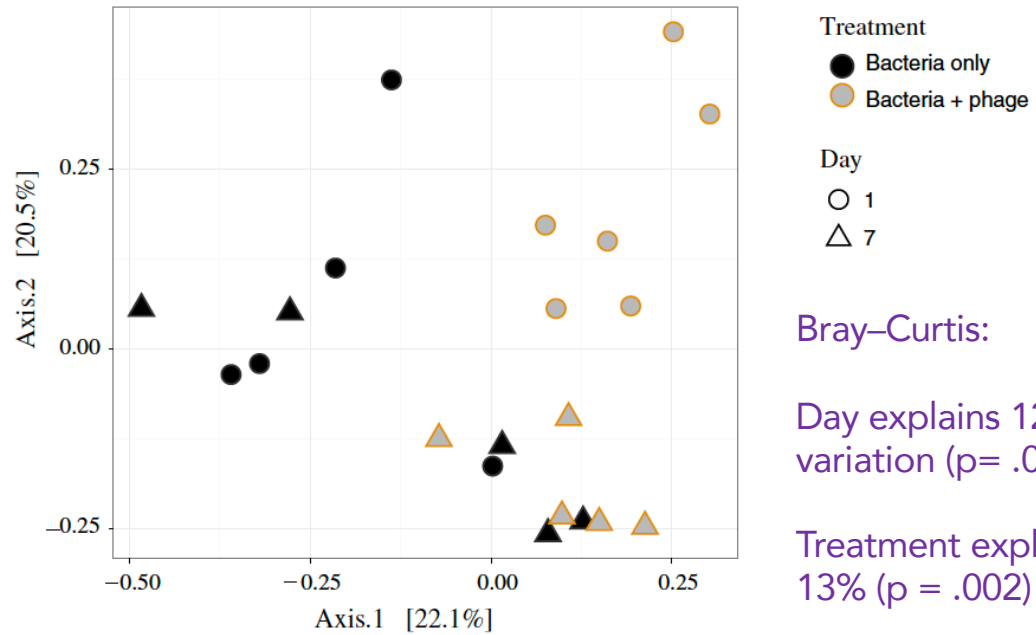


Bacteria-phage coevolution

Impacts on microbiome diversity

Photo credit: Design_Cells

(a) Phyllosphere compositional dissimilarity across treatments and time



Bray-Curtis:

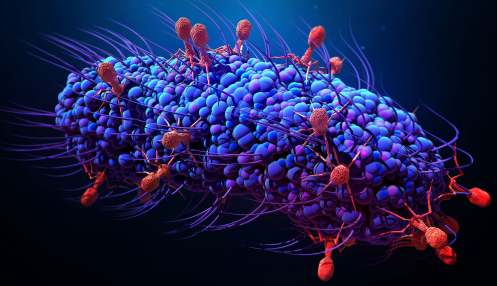
Day explains 12% of variation ($p = .006$)

Treatment explains 13% ($p = .002$)



X 6 per treatment

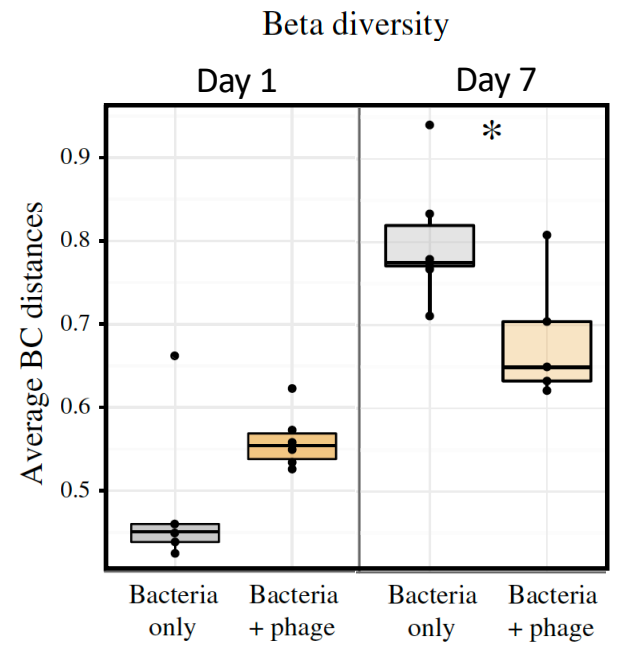
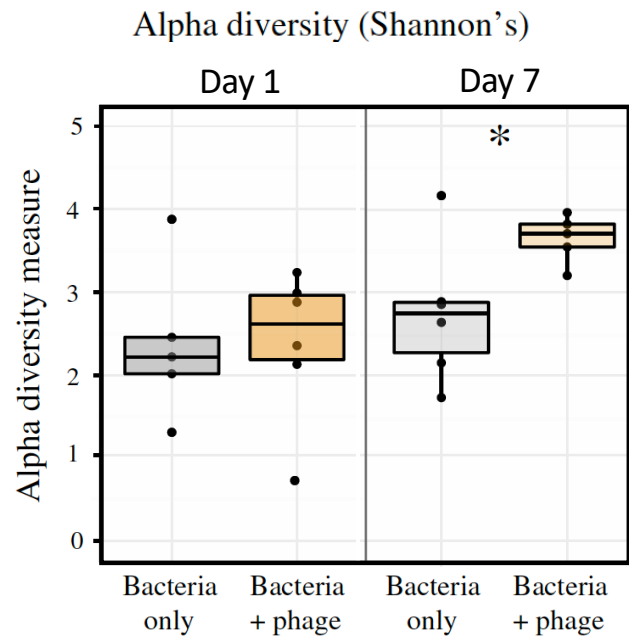
- Morella *et al.*, Molecular Ecology 2018. 27(8), 2025-2038.



Bacteria-phage coevolution

Impacts on microbiome diversity

Photo credit: Design_Cells



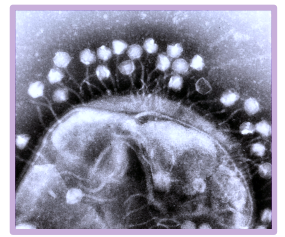
X 6 per treatment

- Morella *et al.*, Molecular Ecology 2018. 27(8), 2025-2038.

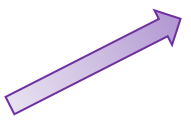


**Bacteria-
phage
coevolution**

Photo credit: Design_Cells

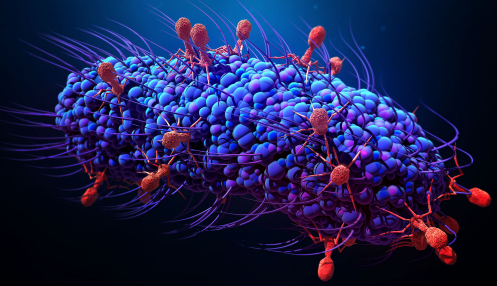


Bacteriophages



Plant pathogen



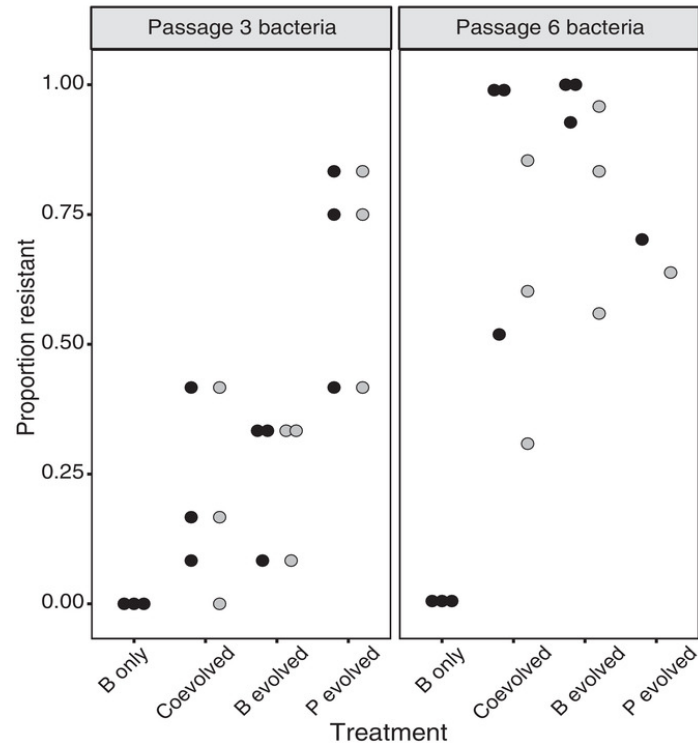


Bacteria-phage coevolution

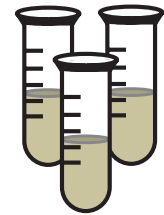
...Varies depending on environment

Photo credit: Design_Cells

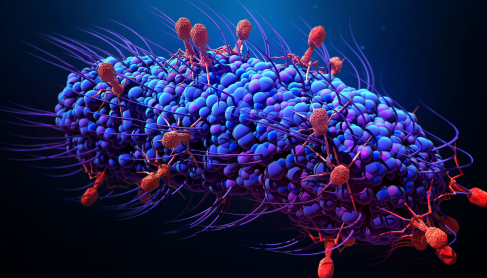
A *In vitro* lines



Cathy Hernandez



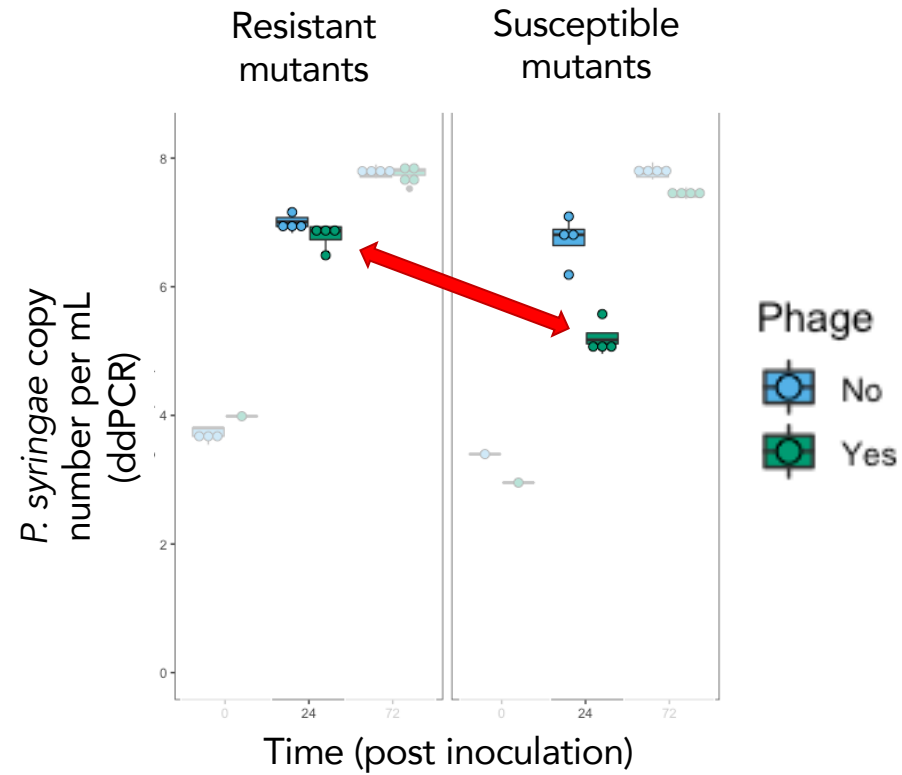
- Hernandez, C.A. & B. Koskella 2019. *Evolution* (online early).



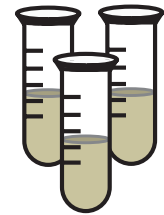
Bacteria-phage coevolution

...Varies depending on environment

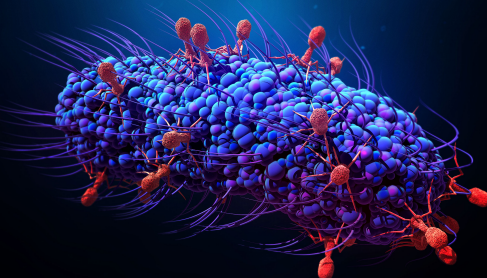
Photo credit: Design_Cells



Cathy Hernandez



- Hernandez, C.A. & B. Koskella 2019. *Evolution* (online early).

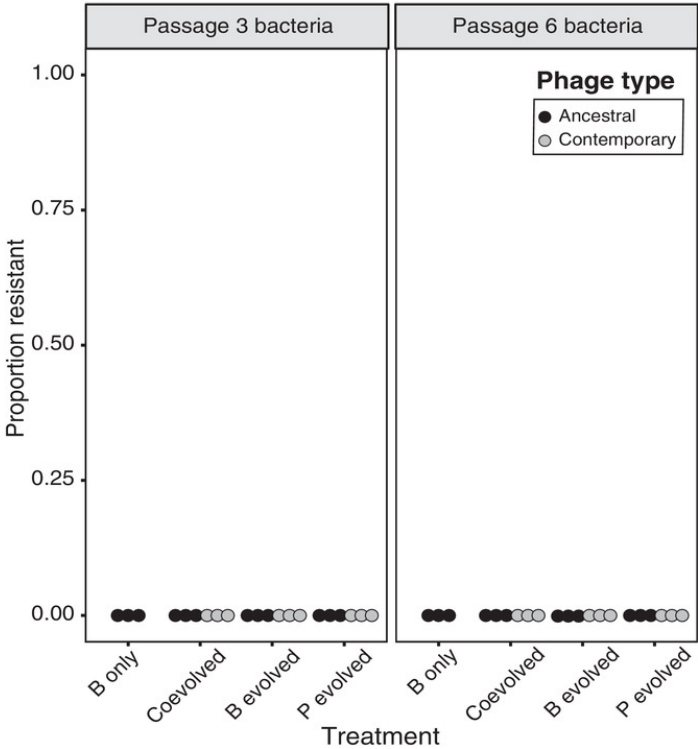


Bacteria-phage coevolution

...Varies depending on environment

Photo credit: Design_Cells

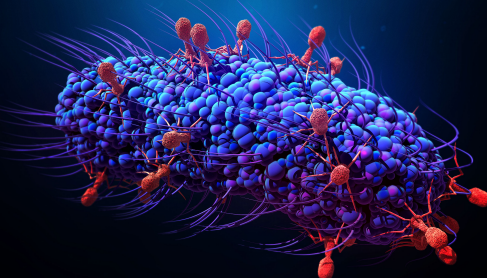
B *In planta* lines



Cathy Hernandez



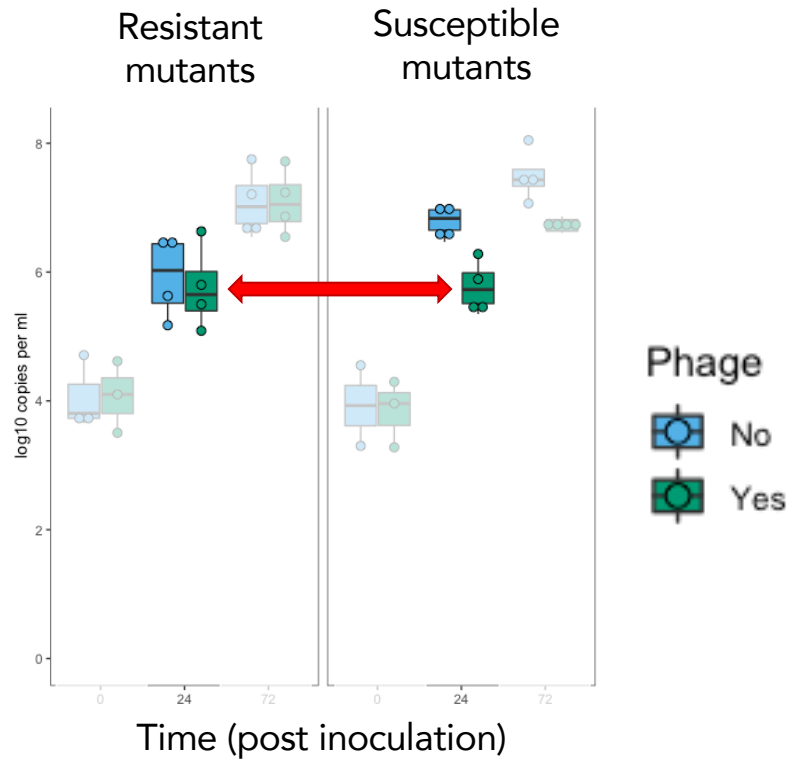
- Hernandez, C.A. & B. Koskella 2019. *Evolution* (online early).



Bacteria-phage coevolution

...Varies depending on environment

Photo credit: Design_Cells



Cathy Hernandez



- Hernandez, C.A. & B. Koskella 2019. *Evolution* (online early).



Microbial communities are:

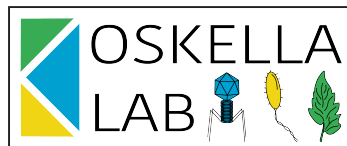
- Complex
- Variable (across space)
- Dynamic (across time)
- Important in shaping host phenotype



Microbial communities are:

Phages are known to....

- Complex
 - Shape composition of bacterial communities
- Variable (across space)
 - Show specific adaptations to 'local' bacteria
- Dynamic (across time)
 - Drive changes in composition over time
- Important in shaping host phenotype
 - Be important in shaping host phenotype

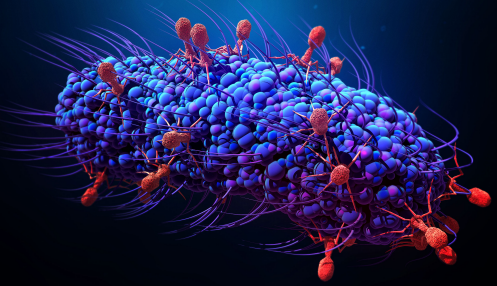


Britt Koskella

@bkoskella 

Assistant Professor, Integrative Biology
UC Berkeley

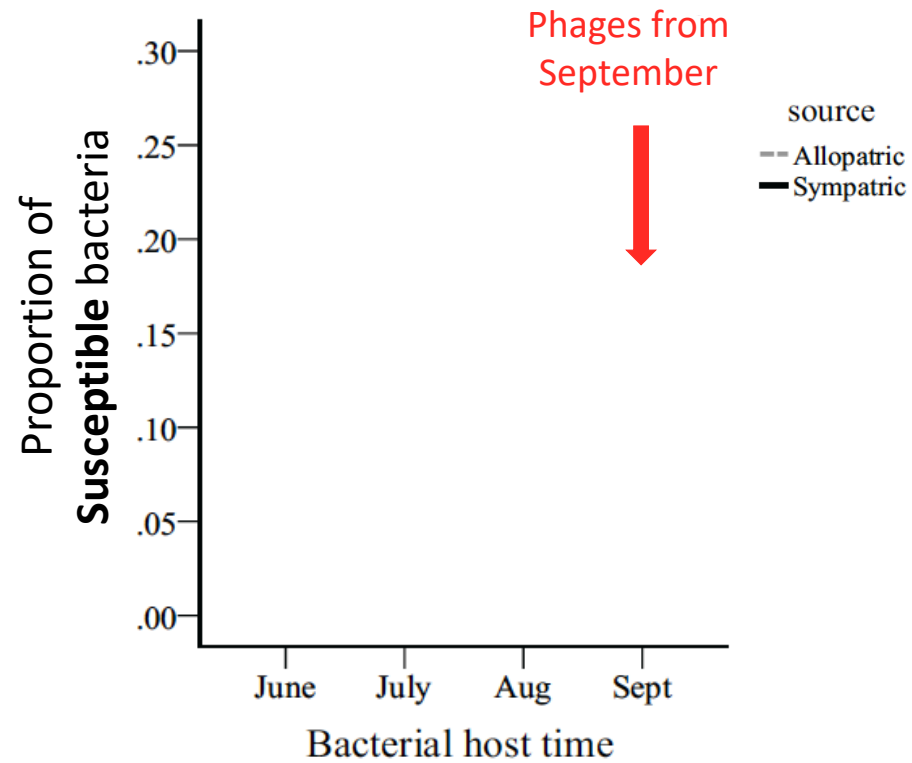




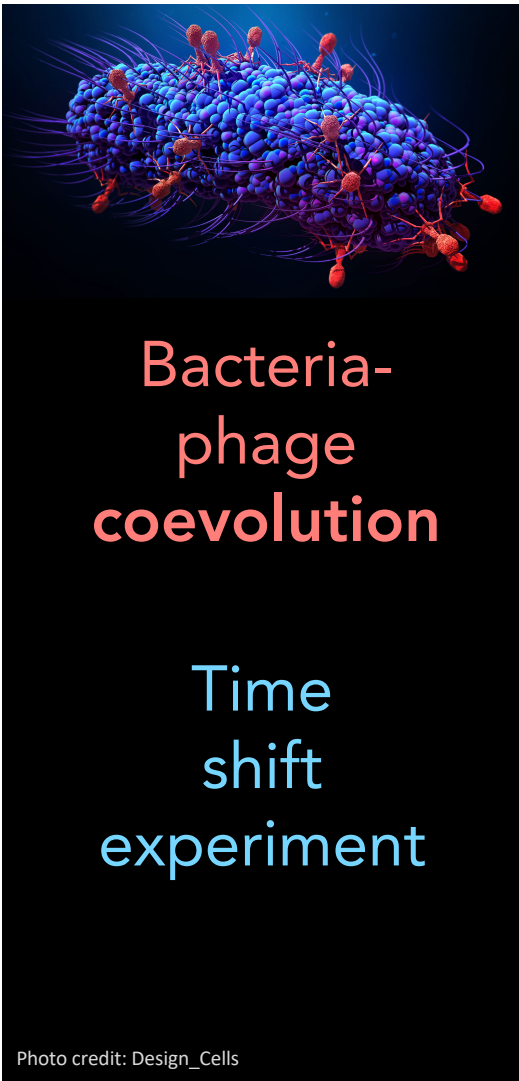
**Bacteria-
phage
coevolution**

**Time
shift
experiment**

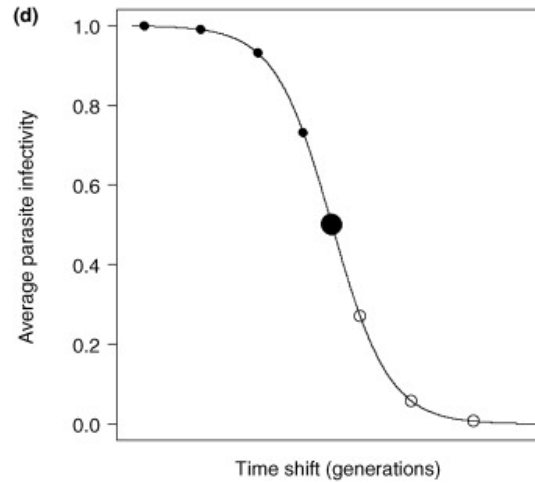
Photo credit: Design_Cells



- Koskella, *American Naturalist* 2014. 184(S1), S9-S21.

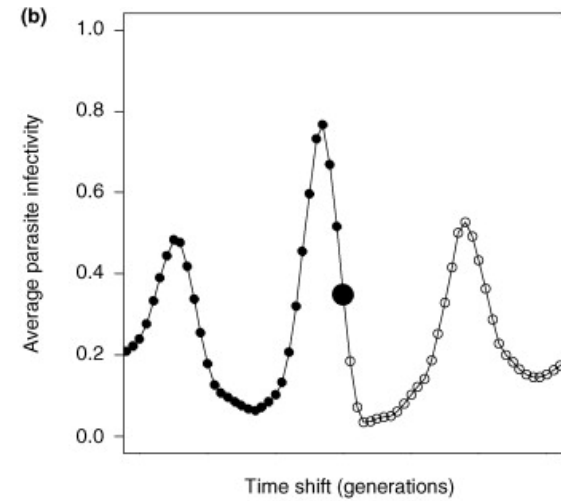


Bacteria



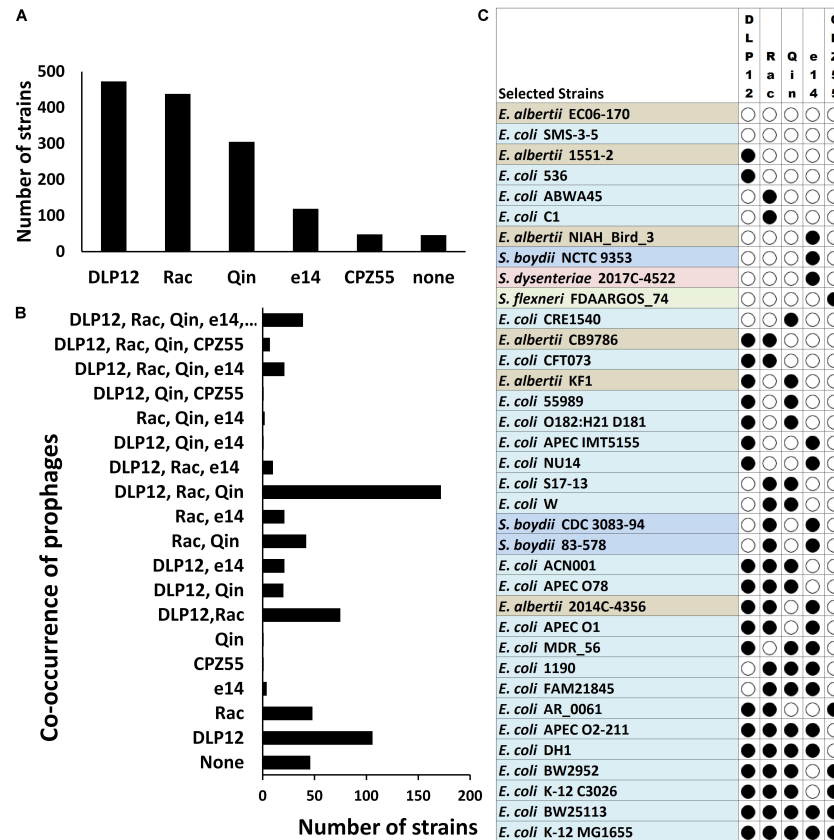
Arms race dynamics

Phages



Fluctuating selection dynamics

- Gaba & Ebert 2009 *TREE* 24(4), 226-232.



Prophages in *E. coli* carry genes encoding: transportation, metabolism, recombination, virulence, transcriptional regulation, and resistance (e.g., Tellurite/Colicin resistance)

- Ramisetty, B. C. M., & Sudhakari, P. A. 2019. *Frontiers in genetics*, 10, 65.