**Short-sighted evolution**

A pathogen will experience many generations within a host that makes it well-adapted to its host before it can be transmitted.

Traits for growth at the cost of transmissibility may rise to high frequency.

Example: Polio virus is not problematic when it infects gut cells, but it is catastrophic after infecting nerve cells.
Trade-off hypothesis
Pathogenicity and transmissibility shape the alleles that rise to high frequency

Diseases transmitted by physical contact have reduced virulence
-host too sick to transmit is a dead-end for pathogen

Pathogens that live in different hosts, like insect vectored diseases, can be highly virulent
Proteobacteria
-the most speciose and one of the oldest phyla
Proteobacteria
-the most speciose and one of the oldest phyla
-important plant pathogens
Proteobacteria
-the most speciose and one of the oldest phyla
-important animal pathogens
Escherichia coli Shiga
Rickettsia prowazekii
Neisseria meningitidis
Proteobacteria
-pathogens can successfully invade plant and animal cells

Tools for successful pathogen invasion are used by facultative symbionts
-nonobligate bacterial partners that may provide some host benefit
Symbiosis

> different species living together

mutualistic
Hamiltonella defensa
- use secretion systems to invade and stay in aphids
- symbionts not abundant except in parasitized populations
- fitness experiments indicate that it's costly to maintain
Hamiltonella defensa
-use secretion systems to invade and stay in aphids
-symbionts not abundant except in parasitized populations
-fitness experiments indicate that its costly to maintain
-trade-off between reproductivity and resistance to wasps
**Hamiltonella defensa**

- Host acquires adaptive benefit without having to evolve it *de novo* (‘rapid response’)

![Image of insects and pie charts](image-url)
*Hamiltonella defensa*

-use secretion systems to invade and stay in aphids
Characterizing *Hamiltonella*’s function

*Hamiltonella* could be removed from aphids by treating with antibiotics.

-Microinjection facilitates fulfilling part of ‘Koch’s postulates’
Characterizing *Hamiltonella*’s function

- *Hamiltonella* could be removed from aphids by treating with antibiotics
- Microinjection facilitates fulfilling part of ‘Koch’s postulates’
Phage toxins provide protection

A. pisum secondary endosymbiont (APSE)
- lysogenic phage present in *Hamiltonella*
  - encodes insect toxins
  - APSE can be cured from *Hamiltonella*
  - results in little parasitoid protection
  - phage toxins are likely also somewhat toxic to aphids
Gammaproteobacteria symbionts

*Buchnera* is an obligate endosymbiont-mutualist, provides nutrients to aphids

*Hamiltonella* is a facultative symbiont -protects against parasitism -reduces overall aphid fitness
Elevated mutation rates in aphid symbionts

*Hamiltonella* is vertically and horizontally transferred - multiple infections can occur - opportunities for recombination
gene flow

*more recent association*

*Buchnera* is only vertically transmitted - isolated in host tissues - limited gene flow

->100 Myo symbiosis

Habitat, host function, transmission mechanism and age of symbiosis reflected in branch lengths
Elevated mutation rates in aphid symbionts

Each generation experiences a bottleneck (‘founder’s effect’) and lack of influx of ‘new’ genes means losses tend to be permanent.
Buchnera is an obligate mutualist

Buchnera is only vertically transmitted
- isolated in host tissues
- limited gene flow

Buchnera and aphids exhibit cocladogenesis and cospeciation

Gene trees with nearly identical topologies reflect shared descent
Taxonomic diversity of insect endosymbionts
Consequences of host isolation

Genome = stuff needed to live

- smaller genome with fewer genes
Unidirectional genome reduction
“use it or lose it”
-genome reduction in obligate endosymbiotic bacteria is irreversible
-host-association leads to relaxed selection for genes nonessential for the association.

Free-living, non-host-restricted bacteria
(Escherichia coli, Bacteroides spp., Rhizobium spp. and Vibrio fischeri)

Recently host-restricted symbionts or pathogens
(Mycobacterium leprae, Serratia symbiotica and Sodalis glossinidius)

Long-term obligate symbionts or pathogens
(Buchnera aphidicola, ‘Candidatus Baumannia cicadellinicola’, Wigglesworthia spp. and Blattabacterium spp.)

Tiny-genome symbionts
(’Candidatus Sulcia muelleri’, ’Candidatus Zinderia insecticola’, ’Candidatus Carsonella ruddii’, ’Candidatus Hodgkinia cicadicola’ and ’Candidatus Tremblaya princeps’)

- Few pseudogenes
- Few mobile elements
- Ongoing gene acquisition and loss
- Interstrain recombination

- Many pseudogenes
- Many mobile elements
- Large and small deletions
- Chromosome rearrangements

- Few pseudogenes
- No mobile elements
- Stable chromosome

- Ongoing gene loss

Accelerated sequence changes, inactivation and deletion of genes, and strict asexuality
Most hosts feed on nutritionally imbalanced diets (e.g. blood or plant sap) supplemented by their endosymbionts.

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Inactivation and deletion of genes, and strict asexuality
- Few pseudogenes
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- Ongoing gene loss
Modern endosymbioses

Many insects harbor bacterial symbionts intracellularly

Highly reduced genomes
Isolated within specialized host tissues
Provide their hosts with nutrients missing from their diets
Cospeciate with their hosts
Multiple symbioses (200 Mya)
long-term acquisition (*Sulcia*) and multiple gains/losses of secondary endosymbiont
Endosymbionts occupy distinct tissues (organs or cells) that are closely associated.

- *Sulcia* + a partner
- maternally-inherited (similar to mitochondria)
Endosymbionts are functionally complementary
-cicada diets are lack protein
-Sulcia and its partner collaborate to provision amino acids
-tiny genomes
Multiple symbioses (200 Mya)
long-term acquisition (*Sulcia*) and multiple gains/losses of secondary endosymbiont
-is the 2ndary loss to acquisition of too many mutations?
Host-acquisition of bacterial genes
-Tremblaya 0.14 Mb, Moranella 0.54 Mb
-host-isolated and limited gene flow
-organelles? (>0.3 Mb)
Mealybug multiple symbiosis

*Tremblaya* harbors *Moranella* that collaborate to make Trp and Phe with help from the host.