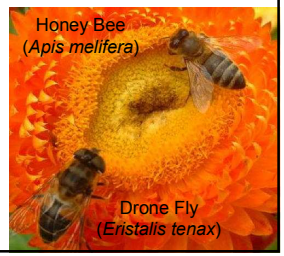
Evolution of Warning Colour and Mimicry

Common wasp
(*Paravespula vulgaris*)

Hover Fly
(Chrysotoxum cautum)

Bumblebee
(*Bombus lucorum*)

Hover Fly
(*Volucella bombylans*)



Evolution of Warning Colour and Mimicry

- **Defensive coloration**
  - **Camouflage** - also called *crypsis*, *cryptic coloration*.
  - **Flash coloration**. e.g. flying grasshoppers which have blue or red underwings or "underwing" moths.
  - **Aposematism**, or **warning colours:**
  - **Mimicry, etc.**

Aposematism

- **Aposematism**, or **warning colours:**
  - ***Unpalatability*** e.g. wasp stings, distastefulness.
  - ***Smelliness*** e.g. skunk.
  - ***Dangerousness*** e.g. coral snakes (cobra family).

Warning colours are usually ***learned***

Mimicry

MIMIC

One species evolves to look like another unpleasant species.

MODEL

Two major kinds of mimicry are:

- ***Batesian*** mimicry - (Bates 1862), cheats, parasites!

- ***Müllerian*** mimicry - (Müller 1879), mutualists.

Evidence for mimicry and warning colours

Laboratory evidence

Jane van Zandt Brower & Lincoln Brower in the 1950s performed ***laboratory experiments*** with blue jays and monarch butterflies (*Danaus plexippus*):

1) Jays fed monarchs became sick & wiped beak
   - monarchs are unpalatable.

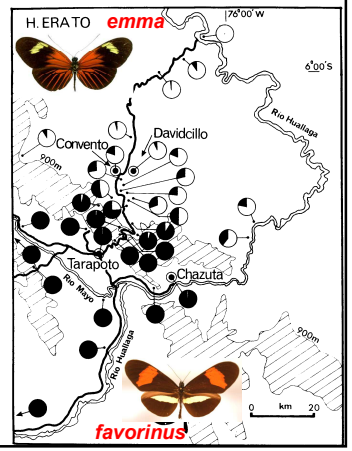
2) Jays learn to avoid monarchs
   - appropriate learning is possible

3) Having learnt, Jays avoid mimics of monarchs
   - mimicry theory correct

Evidence for mimicry and warning colours

Field evidence

Mallet & Barton (1989)



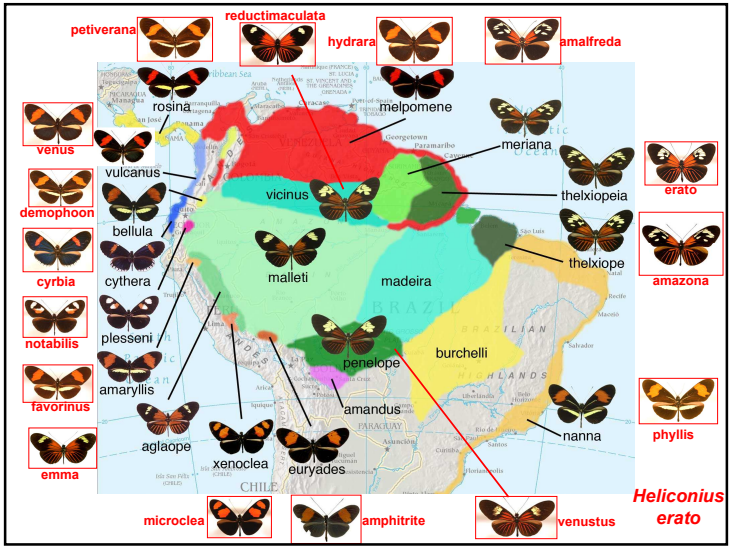
Batesian mimicry

Mimic is a cheat, taking advantage of the model.

Negative frequency-dependent selection

Papilio memnon

male is non-mimetic



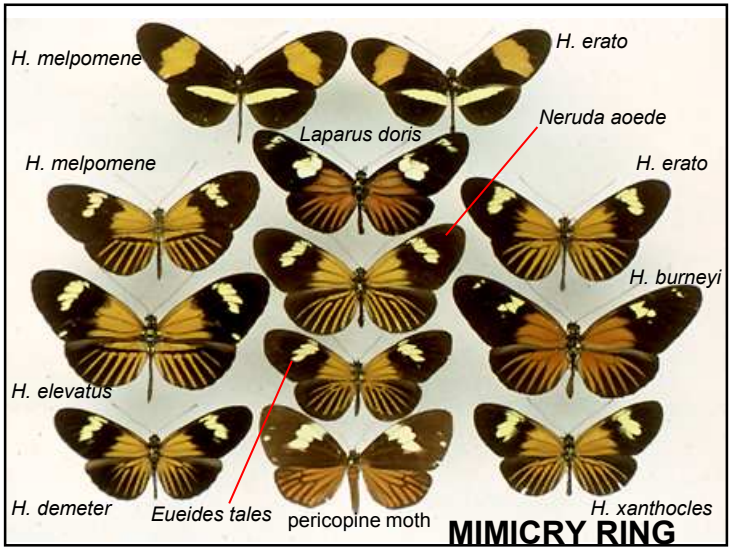
Müllarian mimicry

Positive frequency-dependent selection

Rare patterns selected against

Selection for a single colour pattern in a population

Leads to formation of mimicry rings.



Evolution of aposematism

Aposematism involves evolving two characters:
i) unpalatability
ii) warning colours

Unpalatability and warning colours could be **altruistic**

In true altruism:
cost to individual > **benefit** to individual
Character should not evolve

How can unpalatability evolve?

Costs	Benefits
Making and sequestering toxic compounds	Protection from predators
Teaching predators	

Altruistic if **cost** to individual > **benefit** to individual

But open to cheating

Maybe unpalatability evolves through **kin selection**?

Hamilton's Rule

Unpalatability: Kin Selection?

Fisher (1930): gregarious larvae, usually laid as eggs by a single female, associated with warning colour.

THE PROBLEM:
many species of unpalatable butterflies have solitary larvae
e.g. Monarch butterflies
and many *Heliconius* species

How can unpalatability evolve?

Costs	Benefits
Making and sequestering toxic compounds	Protection from predators
Teaching predators	

Toxins from host plants
Maybe easier to sequester in cuticle than excrete

Inversely proportional to the population size
Don't have to die when teaching!

How can unpalatability evolve?

Costs	Benefits
Making and sequestering toxic compounds	Protection from predators
Teaching predators	

cost to individual < **benefit** to individual
NOT altruistic

Unpalatability can evolve through individual selection
(helped by kin selection)

Why are some unpalatable caterpillars gregarious?

Why are some unpalatable caterpillars gregarious?

Selfish reasons why unpalatable species should live in groups:

- Predator satiation by groups.
- Group defence, coordinated signalling.
- By aggregating, avoid some predators entirely.

How can warning colours evolve?

(assuming species already unpalatable)

Costs	Benefits
Making the colours - cheap	Protection from predators
Teaching predators	

When warning colour is common is pays to have it

Frequency-dependent selection against rare colours

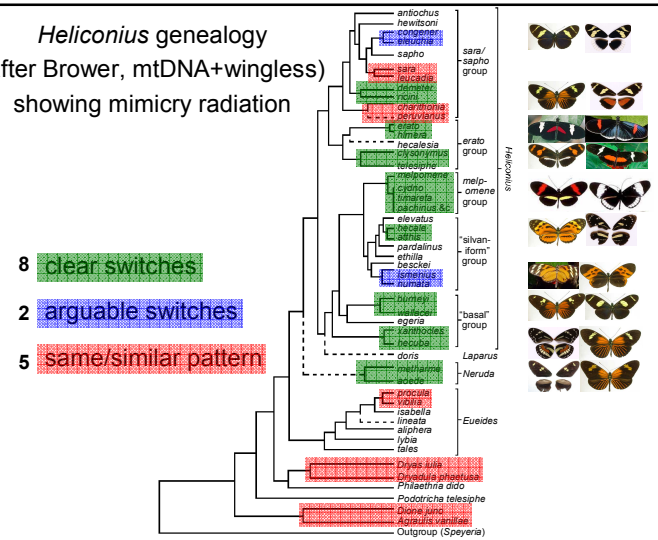
Problem is, how does it first evolve as:

i) conspicuous

ii) predators have not learnt

SHOULD BE VERY DIFFICULT TO EVOLVE NEW WARNING COLOURS

Heliconius genealogy (after Brower, mtDNA+wingless) showing mimicry radiation

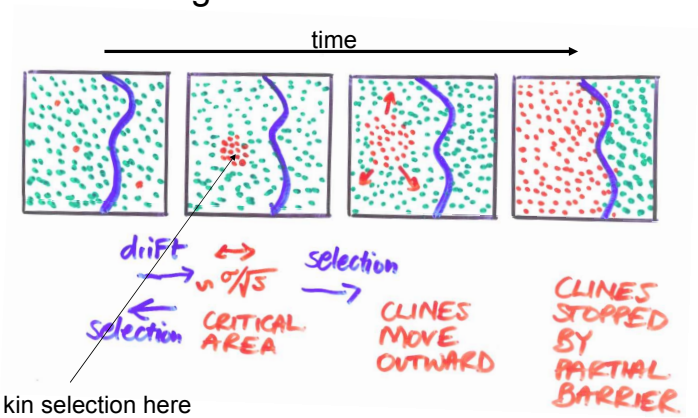


8 clear switches

2 arguable switches

5 same/similar pattern

New warning colour evolution by shifting balance + kin selection



kin selection here

So how could new warning colours evolve?

... after evolution of unpalatability

- **shifting balance/kin selection**
- **individual selection**
  - ***preadaptation to signalling:***
    - sexual selection
    - flash coloration
    - Batesian mimicry ("warning colour" before unpalatability)
  - ***Müllerian mimicry*** (unpalatability before "warning colour")

Do mimicry switches play a role in speciation

Heliconius melpomene 

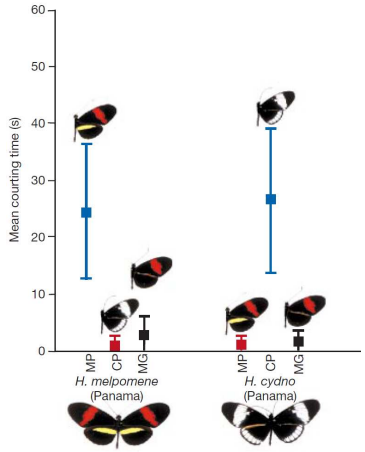
Heliconius cydno 

Barriers to gene flow between species are required

Closely related
&
find occasional hybrids 

Predators do not recognise hybrid pattern

Do mimicry switches play a role in speciation



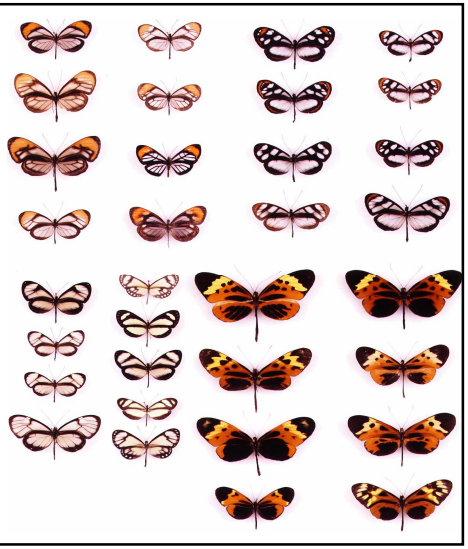
Mimicry – a cause of speciation by pleiotropy

Pleiotropic (by-product) effects of mimicry:

Hybrids are less fit (post-mating barrier)
– Due to attack on non-mimetic hybrids

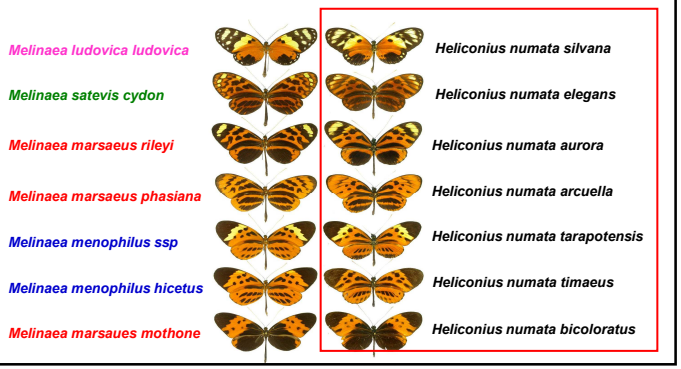
Assortative mating (pre-mating barrier)
– Colour is used in mating

Multiple mimicry rings in one area



Müllarian mimicry: single colour pattern in a pop….. but

***Heliconius numata* populations are polymorphic.**
Up to 11 sympatric morphs.
Spatially and temporally variable model abundance.



MIMICRY AND WARNING COLOUR

Provide examples of more general evolutionary thought:

- Social evolution and kin selection (possibly)
- Linkage disequilibria and evolution at >1 gene
- Evolutionary developmental genetics ("evo-devo")
- Drift/shifting balance in evolution
- Evolution of genetic diversity
- Race formation and speciation
- Biogeography

Reading

- Sternburg JG, Waldbauer GP, Jeffords MR (1977) Batesian mimicry: Selective advantage of color pattern. *Science*: 195, 681-683.
- Joron M, Mallet JLB (1998) Diversity in mimicry: paradox or paradigm. *Trends in Ecology and Evolution*: 13, 461-466.
- Futuyma (2005) Evolution. Chapter 18, p445-446.