Lecture 23. Speciation Mechanisms

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Last time …

- Species concepts
  - Typological
  - Evolutionary
  - Biological
  - Phylogenetic
  - Genealogical
  - Genotypic cluster
  - Cohesion
  - Unified

This time …

- DNA barcoding
- Speciation mechanisms
  - Spatial/Temporal vs Mechanistic Categories
  - Allopatric vicariance vs peripheral isolate
  - Founder event speciation, transilience
  - Butlin et al. 2008 temporal framework for speciation
  - Consequences of secondary contact
  - Reproductive character displacement
  - *Magicicada* case study

http://nature.berkeley.edu/~hwood/Chile
%202008.html

http://www.close-up-photolibrary.com/about2.htm, http://www.nhm.ac.uk/research-curation/research/
projects/chalcids/

Holometabolan Insect Diversity

- Orders Lepidoptera (moths & butterflies) & Hymenoptera (bees, ants, & wasps): **180,000 described species** each
- Order Diptera (flies): **154,000 spp**
- Order Coleoptera (beetles) **400,000 spp**
  - 20,000 species tenebrionid flour beetles
  - 60,000 species chrysomelid leaf beetles
  - Compare to ~65,000 vertebrates (only 5,415 mammals, ~ 30,000 fish)

Problems w/ rapid surveys and mass collecting

No information on ecology or behavior

Alcohol preserves DNA for phylogenetic studies but ruins some morphological characters.

Many proposed new taxa may exist as single specimens (no idea of variation within species).

What actually happens in practice? **Example 2**

"DNA barcoding," "DNA taxonomy"

•~600bp segment of the COI mtDNA gene

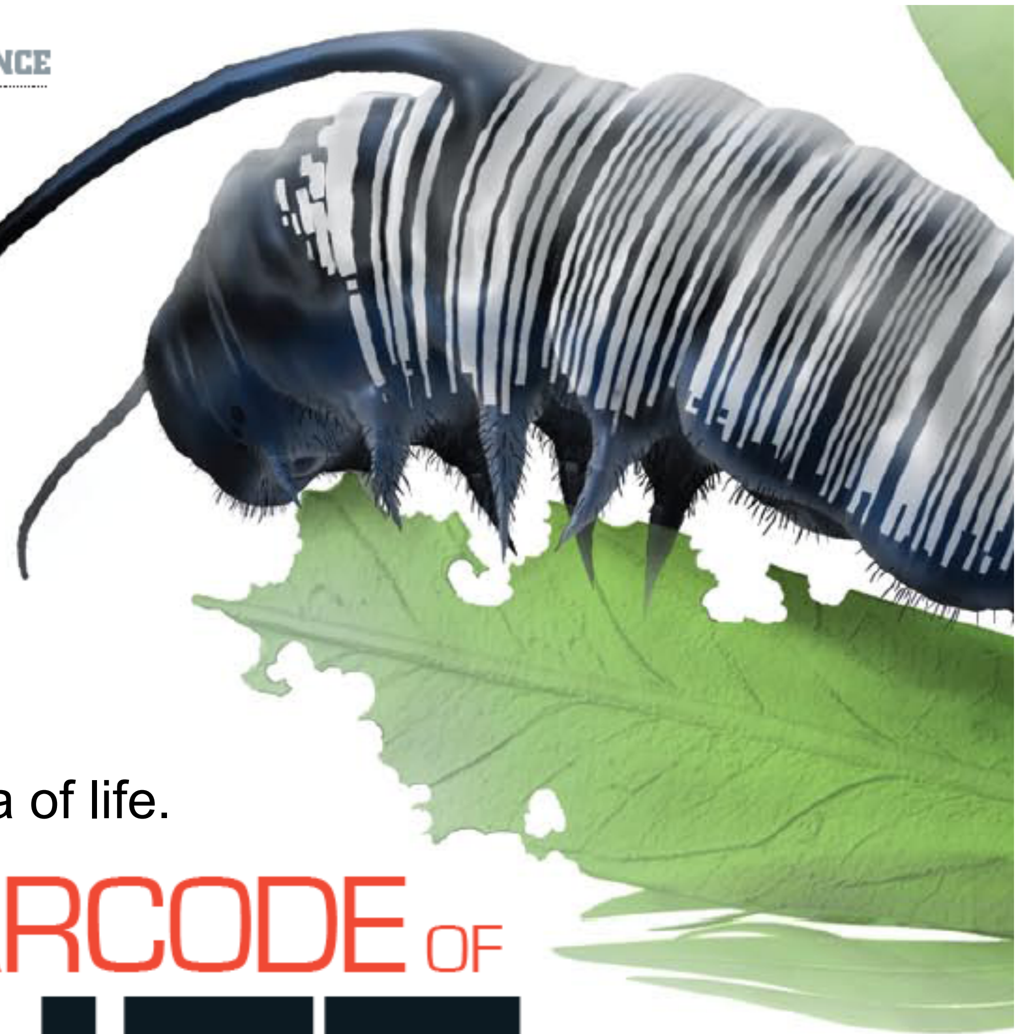
•Linked to a photograph and a specimen identified by an expert taxonomist

- On-line BOLD (Barcode of Life Database)

LIFE SCIENCE

BOL's Ten Reasons for Barcoding

1. Works with fragments
2. Works for all life stages
3. Unmasks look-alikes
4. Reduces ambiguity
5. Makes expertise go further
6. Democratizes access
7. Electronic field guide
8. Speeds species discovery
9. Adds value to collections
10. Speeds writing the encyclopedia of life.



BARCODE OF LIFE

Inspired by commercial barcodes, DNA tags could provide a quick, inexpensive way to identify species

Uses of Barcoding

- Identify species
  - Identify previously described taxa
  - Finding unknown species that need work
- More controversial uses
  - Defining species based on a defined cut-off level of 2% genetic divergence
  - Phylogenetics

Barcoding Problems

- Not enough information!
- Hybridization & mitochondrial capture
- Polyploids not recognized as different species from diploid progenitor.
- “numts” (nuclear copies of mtDNA)
- Arbitrary boundary between species (3% invertebrates, 2% mammals & birds)

The ideal method for studying speciation

- Study organisms are chosen that relate to interesting evolutionary questions
- A phylogeny is constructed for multiple species in a genus and multiple populations per species
- A phylogeographic tree is constructed to study within species variation
- Every aspect of the species biology is studied
- If multiple generations can be raised, inheritance is also studied.

Categories of Speciation Mechanisms

I. Classified by Spatial or Temporal framework

- A) Involving spatial isolation
  - A) Allopatric (vicariance vs peripheral isolate = founder =peripatric)
  - B) Parapatric
  - C) Sympatric
- B) Temporal Isolation (allochronic)
- C) Instantaneous (chromosomal)

Categories of Speciation Mechanisms

II. Classified by Causal Mechanism

A) Genetic divergence
  1) Drift or drift + selection
  2) Selection
    a) ecological
    b) sexual selection
B) Cytological divergence
  1) Polyploidy
  2) Chromosome rearrangement
C) Cytoplasmic Incompatibility
D) Recombinational (Hybrid) Speciation

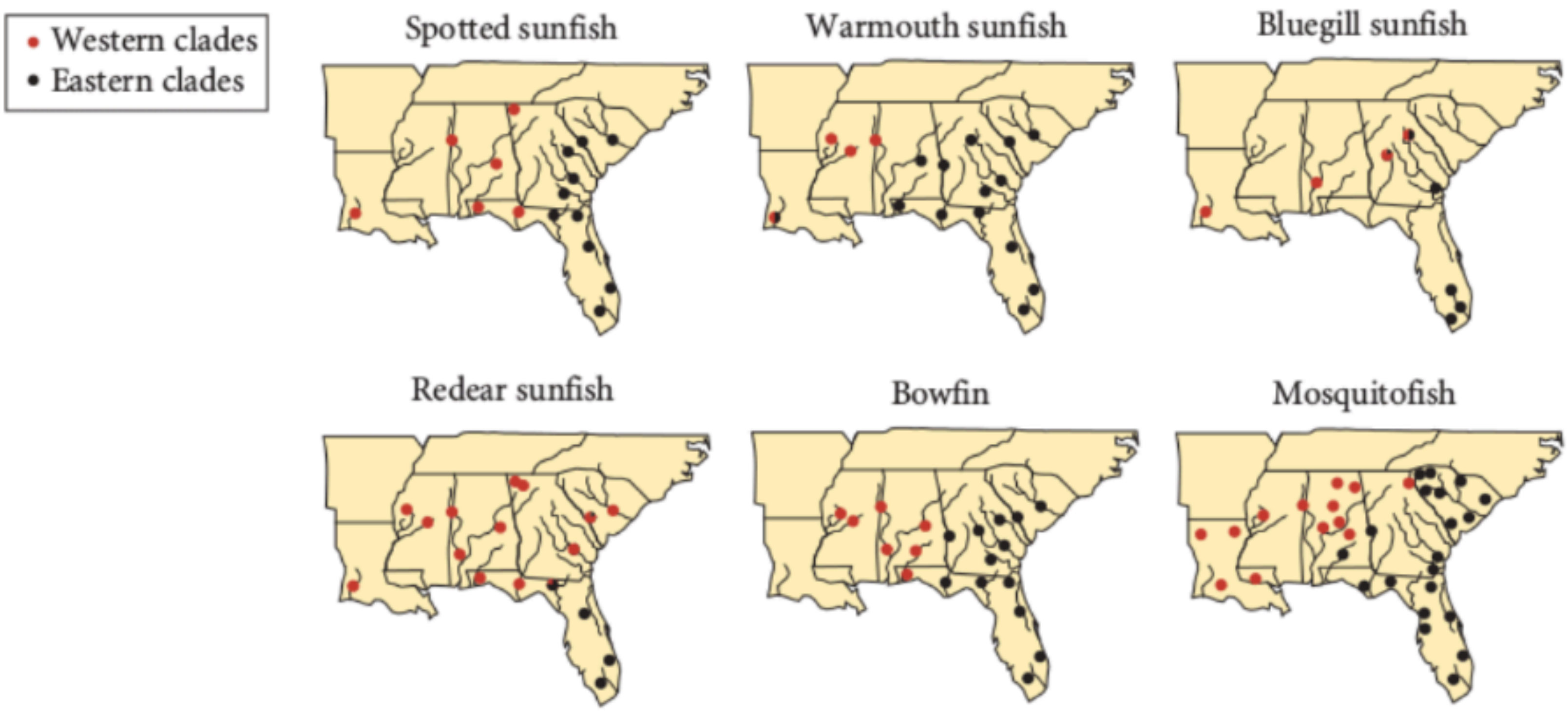
Allopatric Speciation

- Speciation by vicariance
- Founder effect speciation

Allopatric Speciation

- Speciation by vicariance: a large population is split into two parts by a barrier
  - Speed of genetic drift will depend on population size & amount of gene flow
  - Selection may be strong (fast) or weak (slow); do environments differ on either side of barrier? How fast does the barrier arise?

Allopatric speciation



Futuyma 3e. Figure 18.3

Allopatric Speciation

- Founder effect speciation- colonization of a new territory by dispersal across a barrier by a small number of individuals → Genetic revolution due to…
  - Reduction in number of alleles
  - Genetic drift & inbreeding if extended bottleneck
  - Selection in a new island environment

Review from past lecture….

Founder Events

Assume 2 founders…

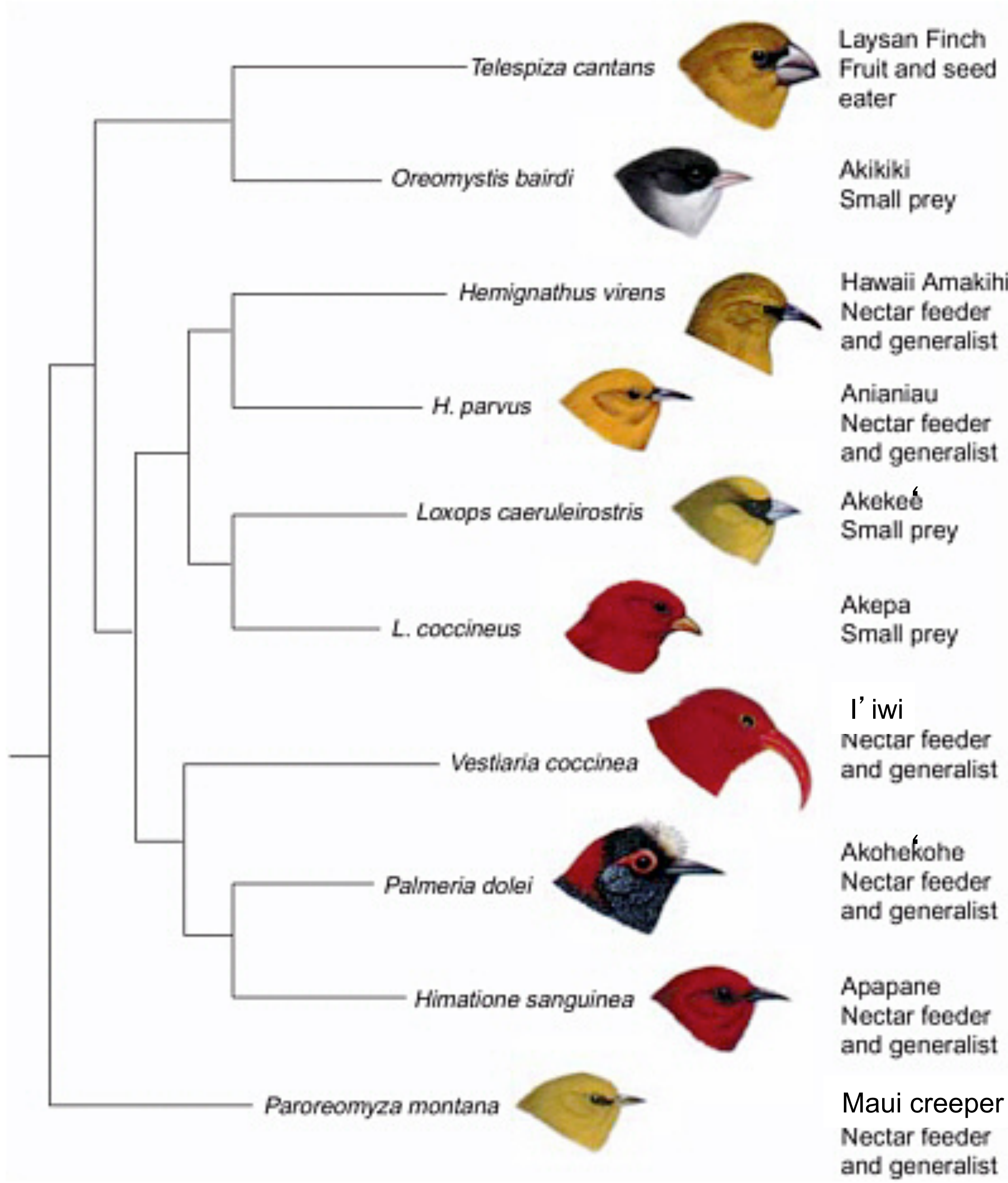
- # Alleles
  - max 4 alleles/locus
  - most common alleles most likely
  - Many parental alleles lost

- Heterozygosity
  - Long bottleneck- drift lowers H
  - Short bottleneck- not much loss
    - $H_f = (1 - (1/(2 \times N_f)))\ H_0$
    - $H_f = (1 - (1/(2 \times 2))\ )H_0$ or $H_f = 3/4\ H_0$

Hawaiian honeycreepers founder speciation

Single colonizing ancestor > 50 species adapted to different feeding niches

(more than half extinct! Many endangered or threatened)



http://ncse.com/image/honeycreeper-phylogeny

Speciation as a dynamic process rather than one point in time

Table 1. Modes of Speciation. Butlin et al. 2008. Phil. Trans. Roy. Soc. B. A temporal framework for speciation.

Three Stages in the speciation process

- Initiation of intrinsic reproductive isolation
- Strengthening and increased genomic extent of isolation.
- Completion of reproductive isolation

For each above stage: Mode can vary over time/stage

Spatial context?	allopatric parapatric sympatric	} from zero to high gene flow.
Driving forces for Divergence	Chance (mutation, drift, hybridization) Selection (sexual selection or other natural selection)	

Possible consequences of secondary contact:

1) Individuals come in contact but do not interbreed (e.g., *Ensatina*)

2) Unrestricted interbreeding (hybrids fit)

3) Interbreeding occurs but hybrids less fit (possible selection for reproductive char. displacement).

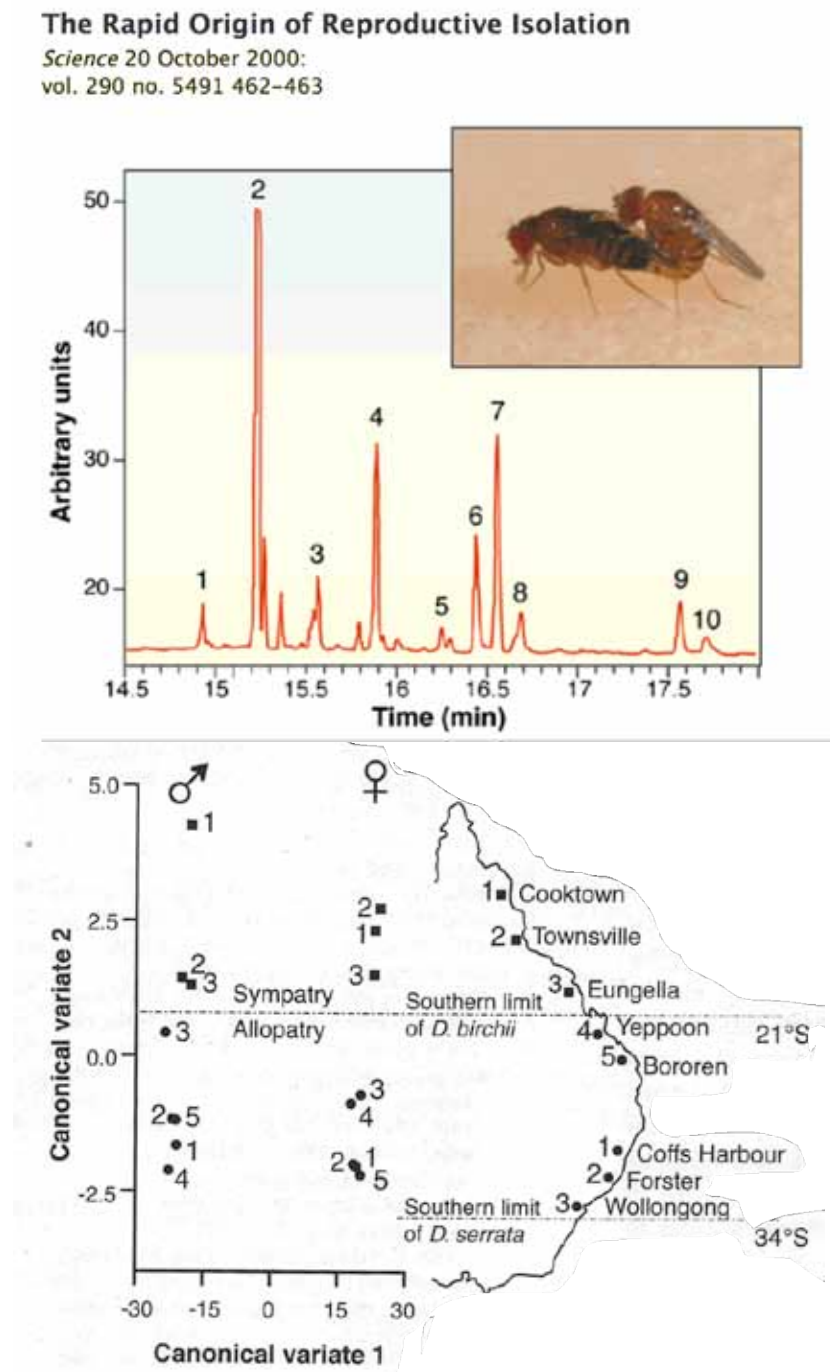
4) Hybrids could be fit in narrow hybrid zone but not survive well outside; some alleles at some loci may cross boundary easier than others into one or both parental populations.

Reproductive Character Displacement

- Selection favors individuals that leave the most offspring
- Hybridization lowers fitness
- Strong evidence for character displacement in mate recognition characters when closely-related species present.
- **Displaced characters are more different in sympatry than allopatry.**
- “Reinforcement” (A.R. Wallace) = selection for reproductive isolation. Completes the speciation process.

Higgie et al. 2000.
20 Oct. Science.

- *Drosophila birchii* in north
- *D. serrata* in north and south
- Differences in cuticular hydrocarbons, used in mate recognition, accentuated in overlapping populations.
- This result was repeated in lab experiments that combined undisplaced *D. birchii* from N extreme of range with *D. serrata*.
- Undisplaced flies produce viable/fertile hybrid offspring
- Reproductive character displacement in hydrocarbons developed in just 9 generations!



End of Lecture 23, 20 April 17