“Nothing in biology makes sense except in the light of evolution.”
- Theodosius Dobzhansky, 1973
What is Evolution?

• Modification through descent*

• Modern definition: Changes in gene frequencies within populations over time

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- e.g., cetacean evolution

Modes of Evolution

Six ways to change gene frequencies in populations

- **Mutation** – permanent change in the DNA sequence making up a gene (substitution, insertion, inversion, deletion)

- **Recombination:** Reshuffling of genetic information during sexual reproduction

- **Meiotic drive** (segregation distortion) – More gametes of a certain type produced than would be expected at random

- **Gene flow** – Genetic exchange through immigration and emigration
Natural Selection

• Differential genotype reproduction

• Evolution though natural selection requires
  - heritable genetic variation
  - differential survival and/or reproduction based on variation in heritable traits

• Individuals with genotypes that confer high survival/reproduction are selected
  - i.e., have high “fitness” (lifetime reproductive success)
  - genetic composition of population changes over time (populations evolve, not individuals)

The Example of Darwin’s Finches

• Galapagos Islands
• Medium ground finch (Geospiza fortis)
  - Discovered by Darwin during the voyage of the Beagle
• On island Daphne Major, average beak depth increased after a drought
• Why? Drought reduced number of small, soft seeds, leaving only large, hard ones
  - finches with bigger beaks able to eat larger seeds; survived
Natural Selection

- Primary mechanism for evolution when population size is large
  - Fitness advantage for particular genotypes allowed to manifest

Is Evolution by Natural Selection Random?
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• No
  - Mutation (creation of new genetic variation) is random
  - Selection is deterministic (non-random)
    • i.e., in time, without additional perturbation, genotypes conferring the highest fitness will become fixed in a population
    • In other words, natural selection can push populations toward genetic uniformity

Why Hasn’t Natural Selection Made All populations Uniform?

• Mutation, gene flow introducing new genetic material
Why Hasn’t Natural Selection Made All populations Uniform?

• Some types of selection actually promote diversity

(a) Stabilizing selection  (b) Directional selection  (c) Disruptive selection

Why Hasn’t Natural Selection Made All populations Uniform?

• “Fitness landscape” (pattern of fitness variability in a population) is dynamic
  - when the environment changes, a new genotype may be selected
  - e.g., Darwin’s finches

• And…
Genetic Drift

- Chance change in gene frequencies
- In each generation, some individuals may by chance alone leave behind more offspring than others
  - Gene frequencies of the next generation become a function of “luck” rather than fitness
- Strength of genetic drift increases as number of breeding individuals in a population diminishes
  - chance events are more likely when sample size is small
  - e.g., a run of all heads with only a few coin flips
  - importantly, the number of breeding individuals can be small even in large populations

Northern elephant seal (*Mirounga angustirostris*)
Lesson from the “Spandrels” Paper

- Don’t assume that all individual traits in wildlife populations are adaptations
  - adaptation: a character or suite of characters that helps an individual cope with its environment (improves fitness)

- Rather, some traits may be the product of drift
  - sampling error due to small number of breeders
  - founder effect (areas colonized by small number of individuals with particular genotypes)
  - bottleneck (large population was small and subject to strong drift in the past)
Co-evolution

- Evolution of two interacting populations in response to their *reciprocal* effects on one another

- Identifying co-evolutionary relationships
  - the existence of strong jaws and associated muscles of hyenas to crack the strong bones of their prey is *not* co-evolutionary because the bones of the prey have not evolved to resist being eaten
  - Ability of an herbivore to detoxify substances produced by a plant specifically to deter that herbivore is an example of co-evolution

- Escalating co-evolutionary relationships between predators and prey are called “arms races”*
  - Predatory abilities and defenses become better and better


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*Thamnophis sirtalis* eating a tetrodotoxic *Taricha granulosa* (Yachats, Oregon, United States).
(Photo: Edmund D. Brodie III)

*Video:* http://www.youtube.com/watch?v=kvB15Wv8-qq

Snake resistance is predicted by rough-skinned newt toxicity.

Ongoing arms race:
- In any area, some snakes don’t have enough resistance.
- Whether to attack or not to attack is a dangerous choice!