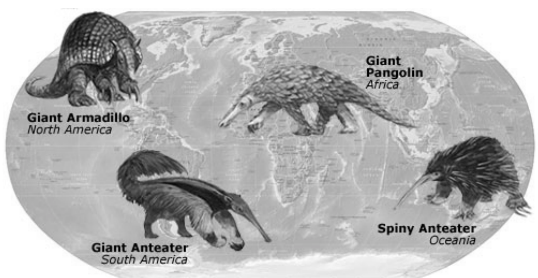

ESRM 350

Evolution: a brief review

Autumn 2014

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

What is Evolution?

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- Modification through descent*
- **Modern definition:** Changes in gene frequencies within populations over time

*Darwin (1859) *On the Origin of Species*

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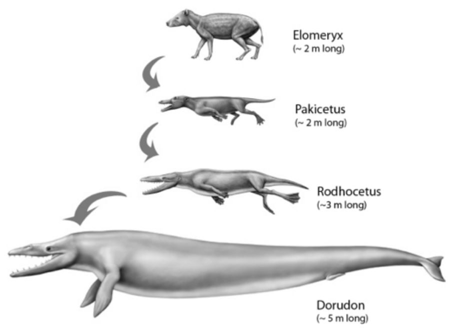
e.g., cetacean evolution



*Darwin (1859) *On the Origin of Species*

Modes of Evolution

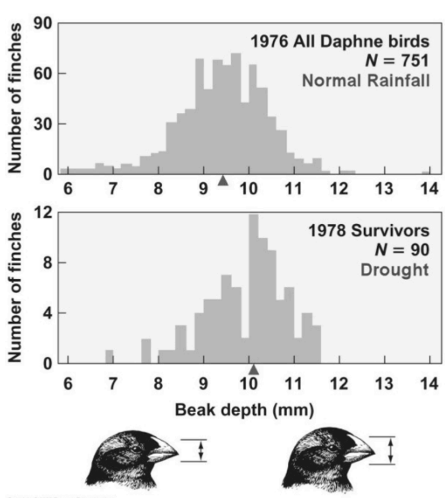
Six ways to change gene frequencies in populations

- **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?

Is Evolution by Natural Selection Random?

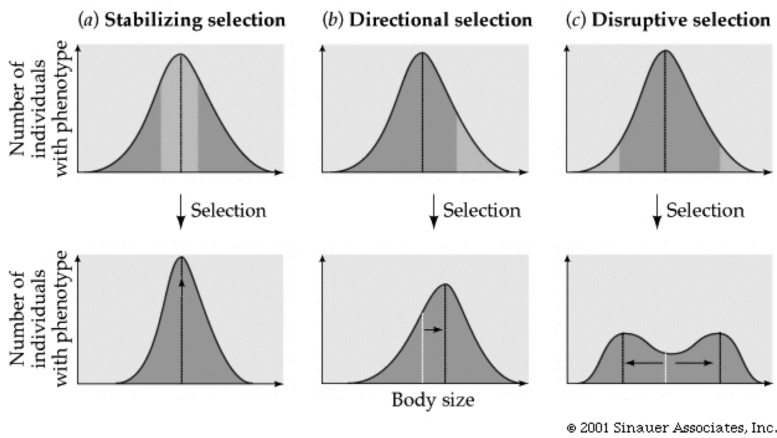
- **No**
  - Mutation (creation of new genetic variation) is random
  - Selection is deterministic (non-random)
    - i.e., in time, without additional perturbation, genotypes conferring the highest fitness will become fixed in a population
    - In other words, natural selection can push populations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



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*)

Proc. R. Soc. Lond. B **205**, 581–598 (1979) 581
Printed in Great Britain

The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme

By S. J. Gould and R. C. Lewontin
Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138, *U.S.A.*

An adaptationist programme has dominated evolutionary thought in England and the United States during the past 40 years. It is based on faith in the power of natural selection as an optimizing agent. It proceeds by breaking an organism into unitary 'traits' and proposing an adaptive story for each considered separately. Trade-offs among competing

Lesson from the "Spandrels" Paper

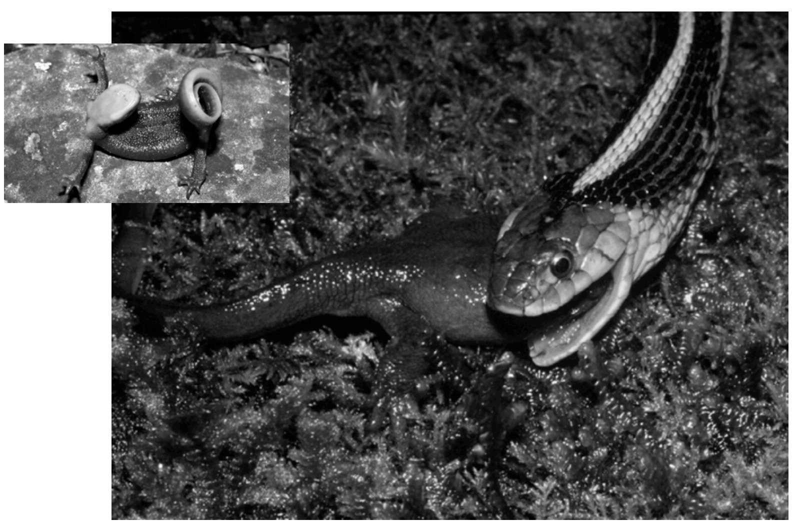
- Don't assume that all individual traits in wildlife populations are adaptations
  - **adaptation:** a character or suite of characters that helps an individual cope with its environment (improves fitness)
- Rather, some traits may be the product of drift
  - sampling error due to small number of breeders
  - 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 <u>is not</u> 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 <u>is</u> 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

*Dawkins and Krebs (1979) *Proc. Roy. Soc. B*

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



Video: http://www.youtube.com/watch?v=kvBi5Wv8-qg

Gross L (2008) Predators Make (Temporary) Escape from Coevolutionary Arms Race. PLoS Biol 6(3): e75. doi:10.1371/journal.pbio.0060075

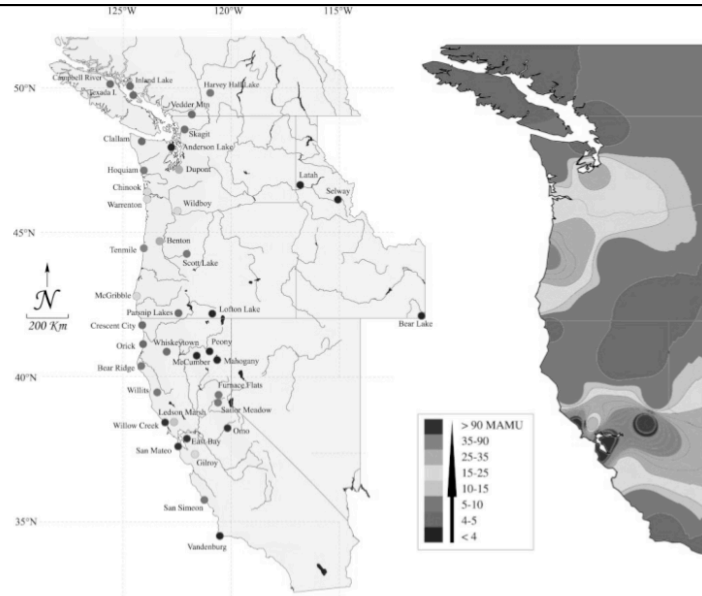


FIG. 4. Geographic distribution of TTX resistance in western North America. (Left) Forty populations of *Thamnophis sirtalis* sampled throughout western North America are shown (Whiteside, IL, not shown). Colors indicate resistance level as denoted in legend and based on 50% dose in Figure 3. The range of the genus *Taricha* is shown in gray, but extends beyond the area shown in the map to the north along the coast of British Columbia. (Right) Isoclines of TTX resistance in western North America as estimated from inverse distance weighted interpolation of the data shown in the graphic on the left. Two geographic areas of extreme TTX resistance (''hotspots'') are apparent with radiating clines of decreasing resistance values emanating from them.

Brodie et al. (2002) *Evolution*

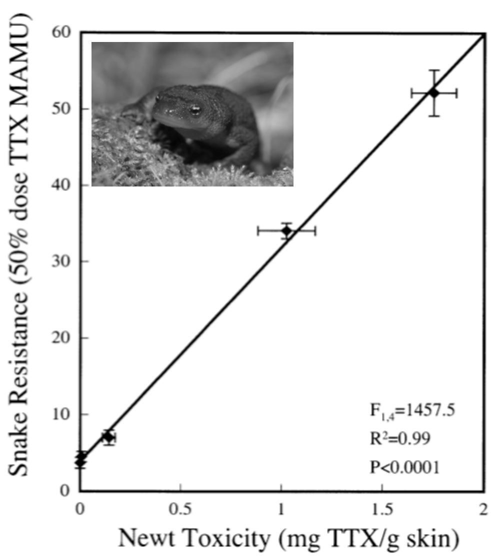


FIG. 5. TTX resistance relative to sympatric newt toxicity. TTX resistance (50% dose) for five populations of snakes is plotted against newt toxicity (mg TTX/g skin; Hanifin et al. 1999) from the same localities. Resistance is tightly predicted by toxicity of newts as shown by regression line (model: 50% dose = 3.8 + 28.03[mg TTX/g skin of newts]).

- 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!