Abiogenesis, Genetic Drift, Neutral Theory, and Molecular Clocks

Paleobiology

February 01, 2016

The history of evolutionary thought

- Charles Darwin and the Origin of Species (1859)
  - Georges Cuvier (Catastrophism)
  - Thomas Malthus (Density Dependence)
  - The Struggle for Existence
  - Survival of the ***Fittest***
  - Selection of Traits Associated with ***Fitness***

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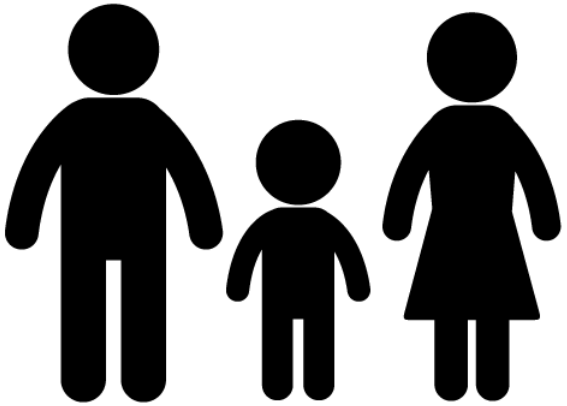

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- A side note on Alfred Wallace
  - Wallace independently derived the idea of evolution from biogeography.
  - Biogeography is the study of how organisms are geographic distributed.
  - Geographic speciation (covered next week) is easier to study in the fossil record.

The history of evolutionary thought

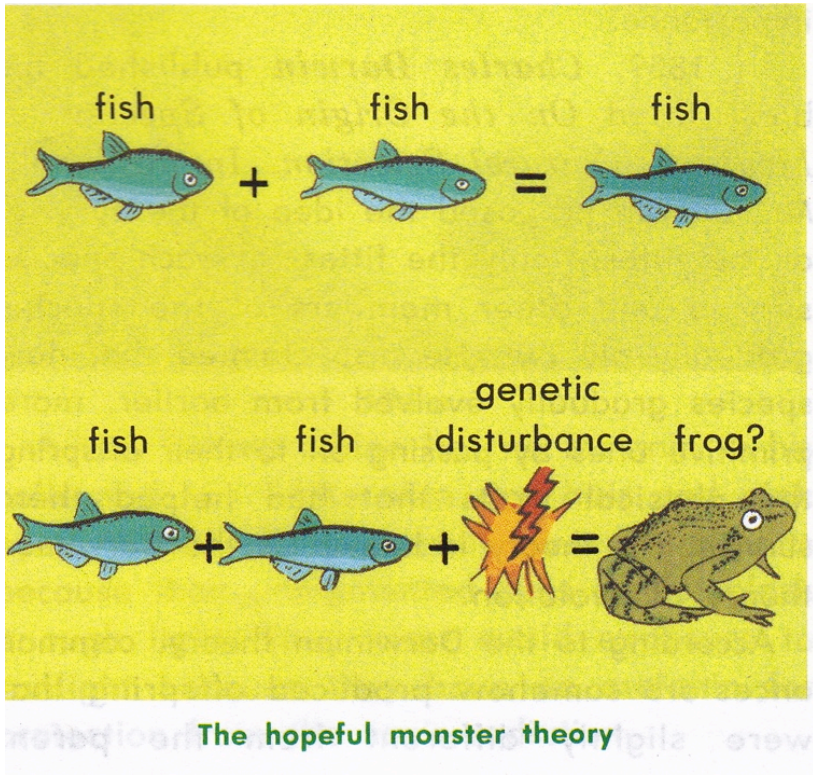
- The Darwinian model of evolution was met with disbelief
  - The general public was skeptical of the whole thing
  - The scientific community did not accept natural selection

Early alternatives to Darwin

- Saltationism
- Hugo Dervries and Mendel
  - Chromosome – the blueprints necessary for building an individual
  - Pangene – the subset of a chromosome that controls a particular trait.

Early alternatives to Darwin

- Saltationism
  - Richard Goldschmidt and the hopeful and hopeless monsters.
  - Proposed that mutations in “rate genes” were the principle driver of speciation.



Early alternatives to Darwin

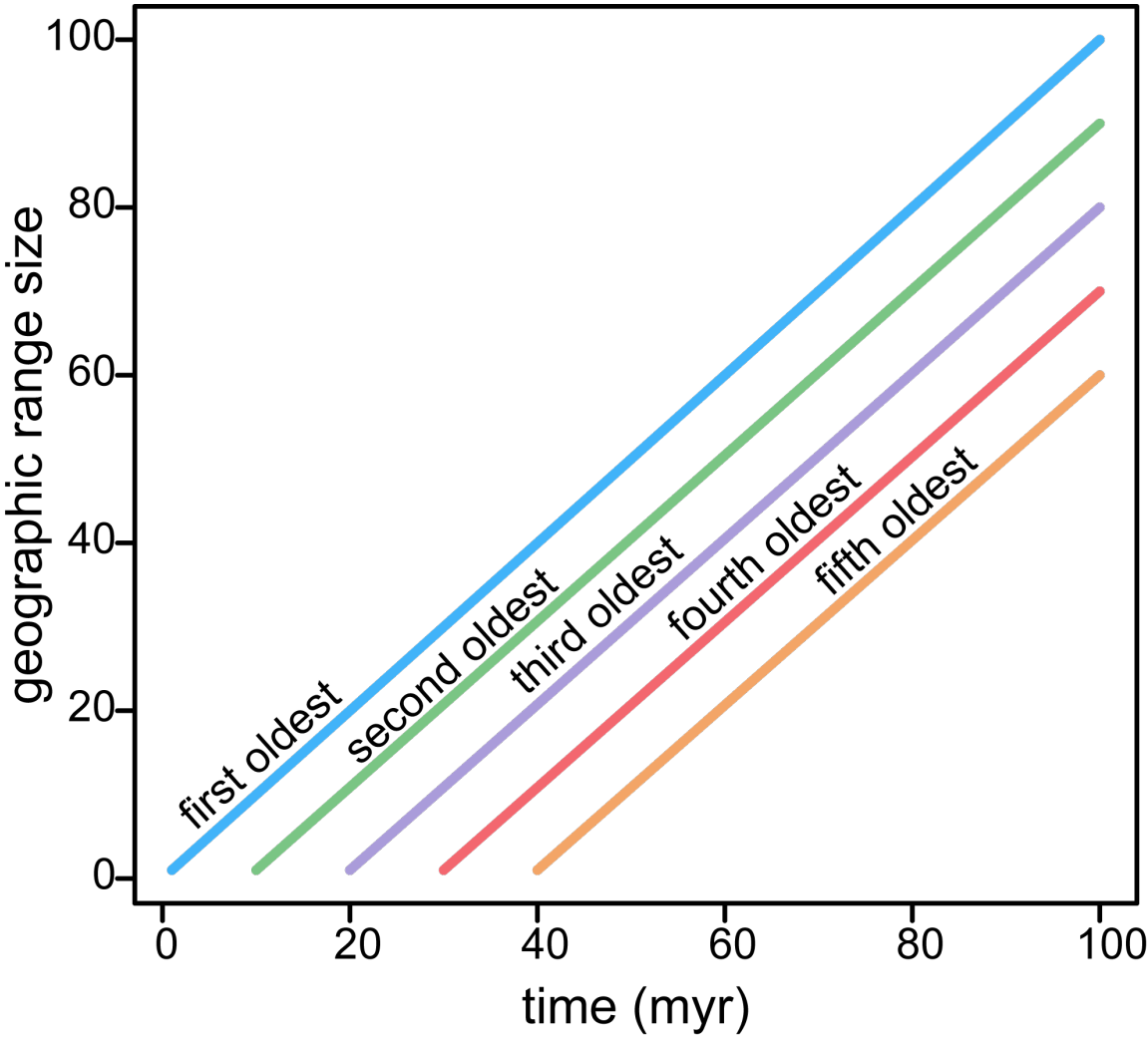
- Mutationism
  - Thomas Hunt Morgan realized that mutations – of the type DeVries was describing – did not necessarily create a new species.
  - Morgan bred thousands of fruit flies, and tried to create mutants using x-rays, acids, and other toxic substances.
  - Interestingly, it was in one of the control groups that he observed his first mutation, a change from red eyes to white yes.
  - He later learned that he could breed these white-eyed flies back in with the red-eyed flies.

Early alternatives to Darwin

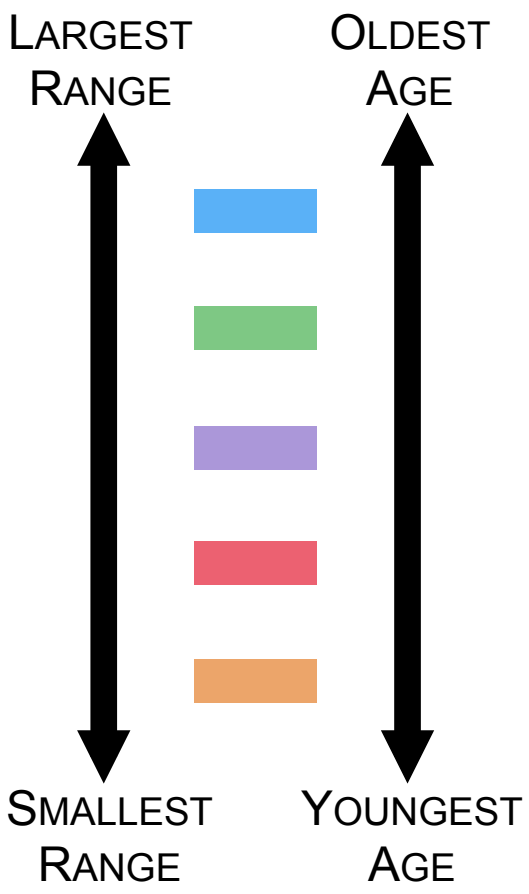
- Mutationism
  - Morgan still believed that mutation was the primary force behind evolution, and that natural selection is merely a sieve to save advantageous mutations and eliminate deleterious mutations.
  - Instead of giant leaps though, he believed in continuous small-scale mutation.
  - The problem with this was that most observed mutations are deleterious, which made people doubt that mutation alone could lead to advantageous changes.
  - Neutral Mutation – “If the new mutant is neither more advantageous than the old character, nor less so, it may or may not replace the old character, depending partly on chance: but if the same mutation recurs again and again, it will most probably replace the original character.”

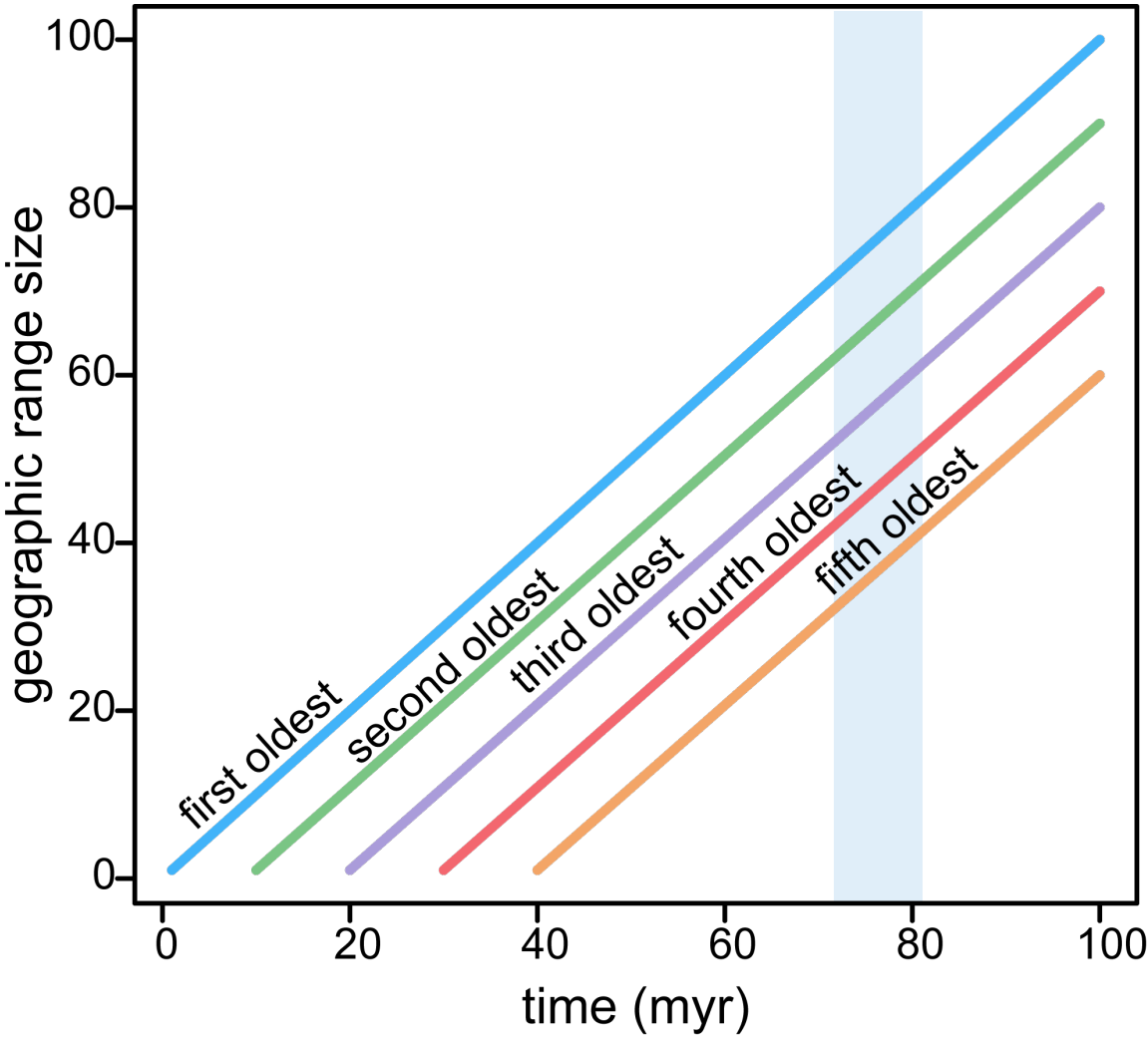
Early alternatives to natural selection

- Senescence
- John Christopher Willis
- Age-Area Hypothesis



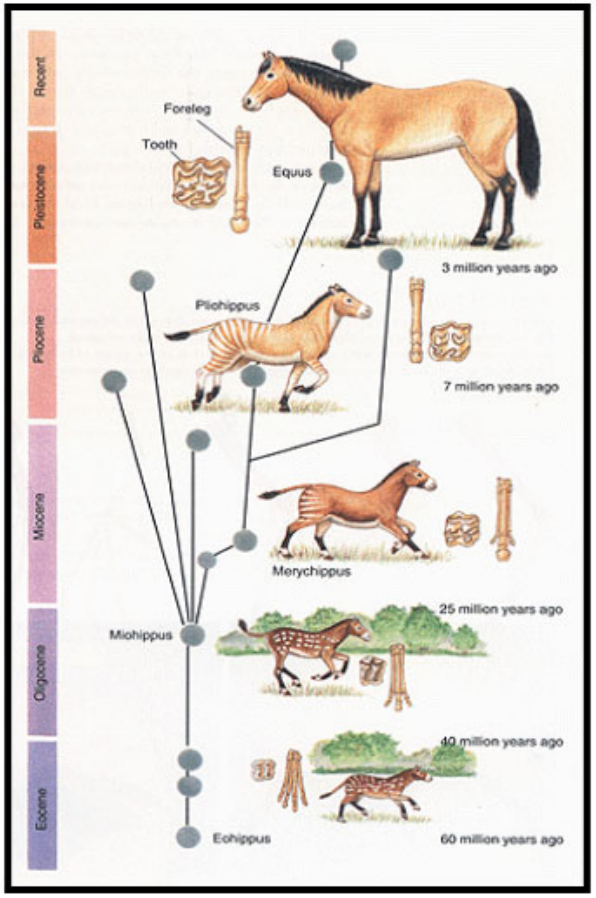
Early alternatives to natural selection

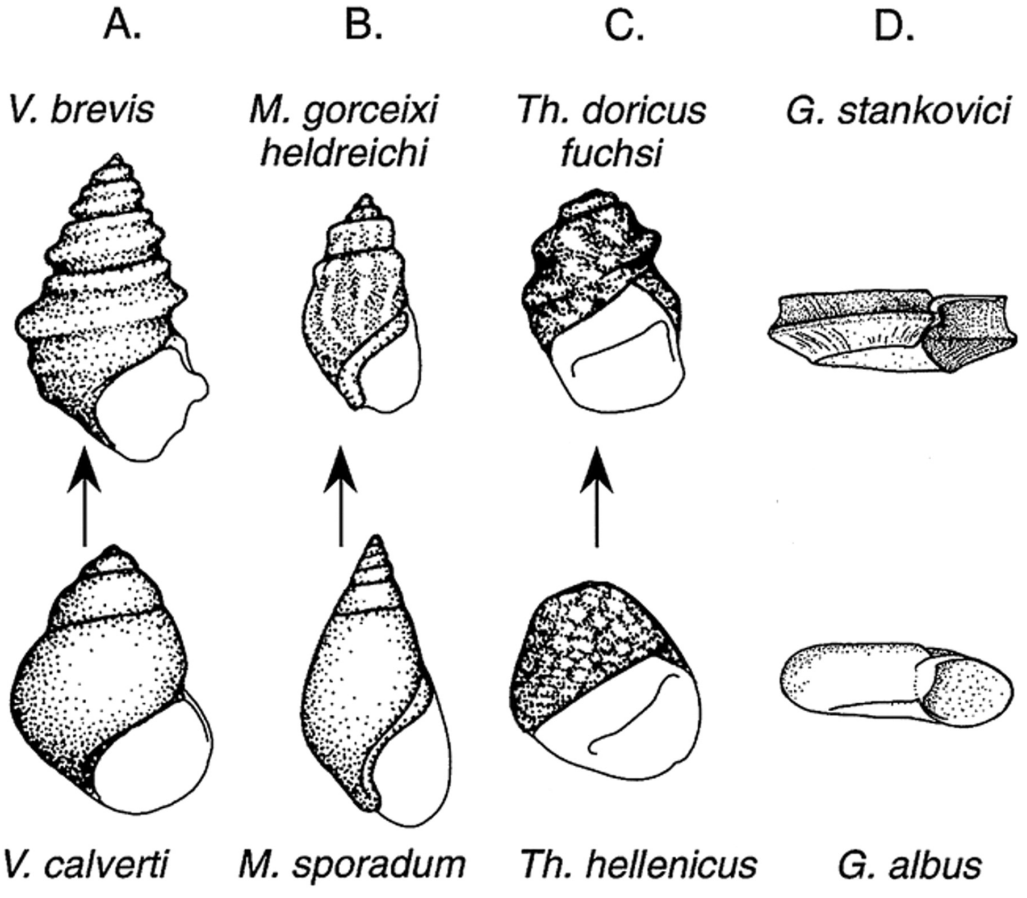




Early Alternatives to Darwin

- Directionalism
  - Edward Drinker Cope's Law of the Unspecialized – The primitive form comes before the more advanced form.





Early alternatives to natural selection

- Directionalism
  - Jean-Baptiste Lamarck
  - Even Darwin believed in a weak form of Lamarckism

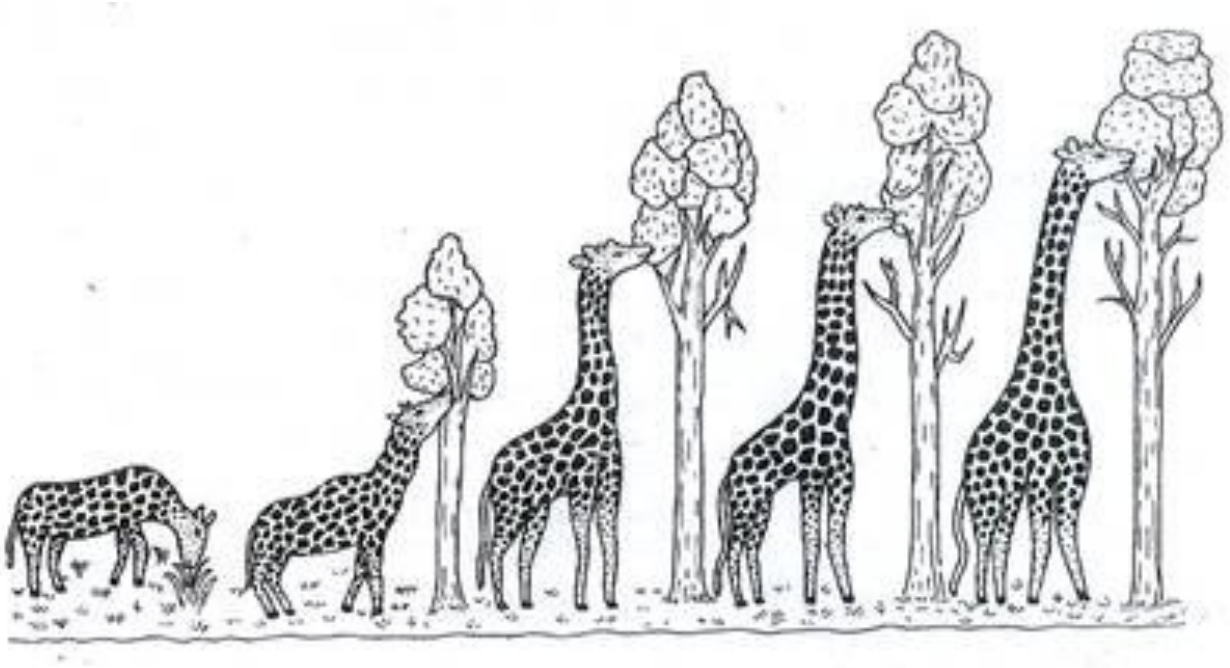
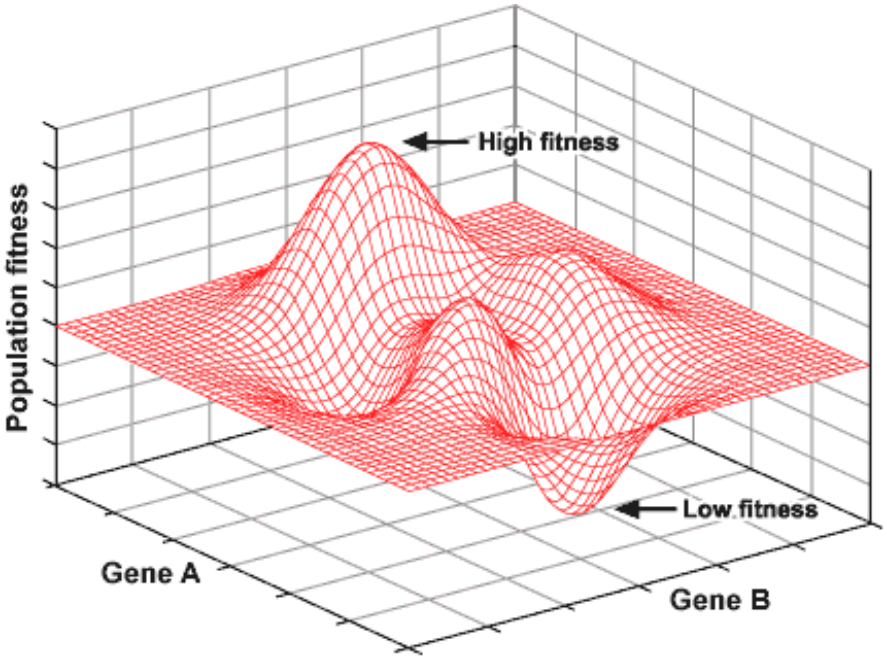


Diagram showing elongation of neck in giraffe according to Lamarck.

Modern evolutionary synthesis

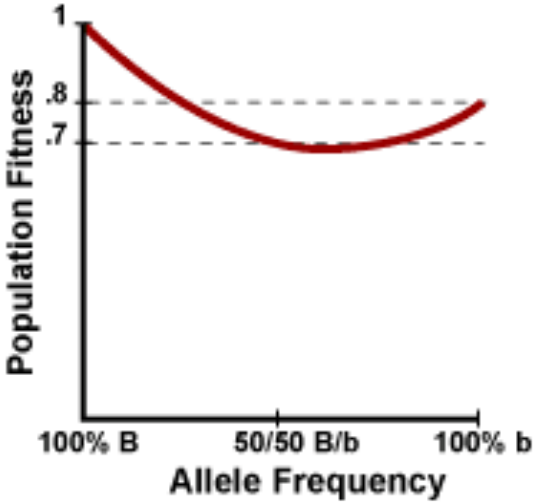
- Wright, Haldane, Fisher
  - Haldane – Originator of primordial soup model
  - Fisher – The most influential scientist of the 20th century.
  - Wright– Created the adaptive landscape model.

- Population genetics
  - The size of a population affects the probability a gene will “fix”

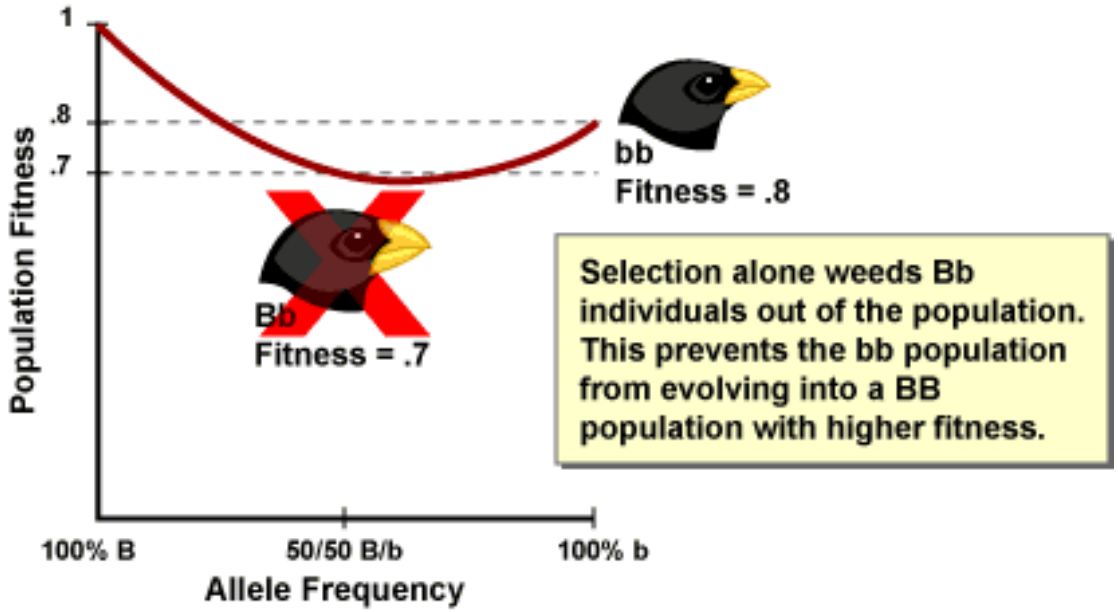


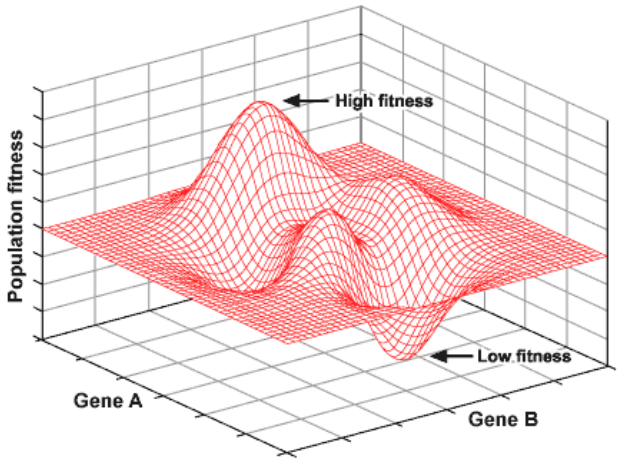
Genetic drift

Genotype	Phenotype	Fitness
BB		1
Bb		.7
bb		.8

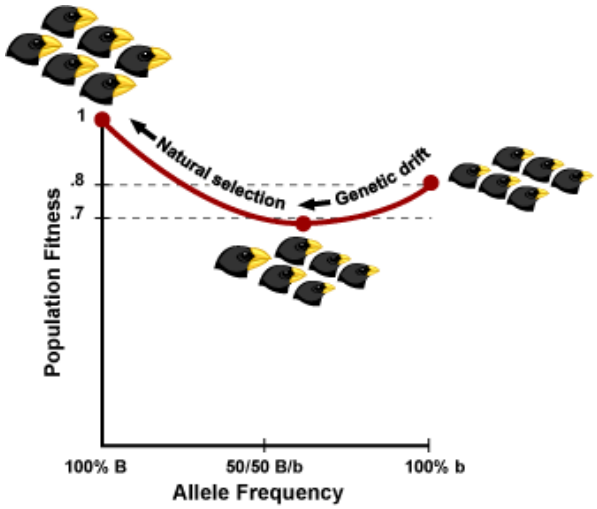


Genetic drift





- Genetic drift can push the small-beaked population off of its local peak in the adaptive landscape if its ***population is sufficiently small*** and the ***fitness difference*** between medium and small beak is not too great.



Modern evolutionary synthesis

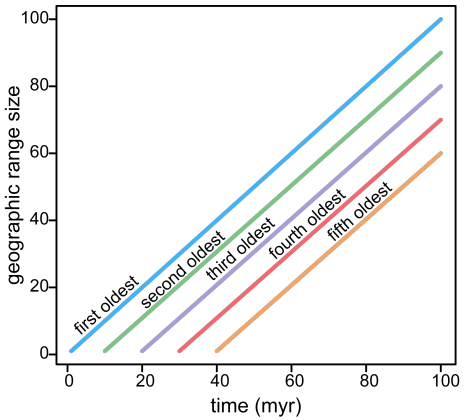
- The modern evolutionary synthesis
  - Recognizes several mechanisms of evolution in addition to natural selection – e.g., genetic drift.
  - Characteristics (traits/genes) are inherited. Variation within a population is due to the presence of multiple versions of a single gene (an allele).
  - It postulates that speciation is generally due to the gradual accumulation of small genetic changes (allele substitutions).

The modern synthesis is over-stated

- The Modern view of Lamarckism
  - Trofim Lysenko pushed a unique form of Lamarckism following World War II
  - Vernalization – The exposure of seed to extreme conditions to increase their flowering potential.
  - Scientists that disagreed were executed or sent to labor camps.
  - Genetics research was banned.
  - Crop yields declined.

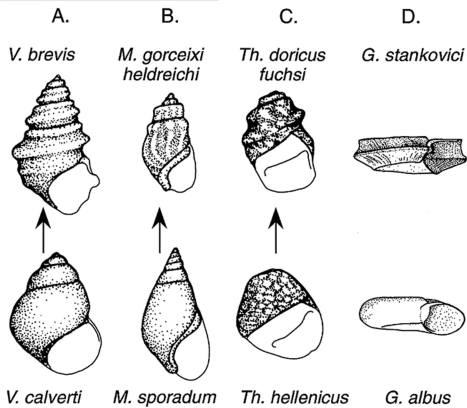
The modern synthesis is over-stated

- Modern View of Senescence
  - Species continuously expand their geographic extent.
  - After some time the species will fragment like a broken plate into new species.
  - These species will have smaller range sizes and be more specialized than the original parent species – in accord with Cope's law.
  - These new daughter species, with their smaller ranges and "overspecialized" forms will be more susceptible to extinction.
  - The entire clade (group of species) will go extinct.



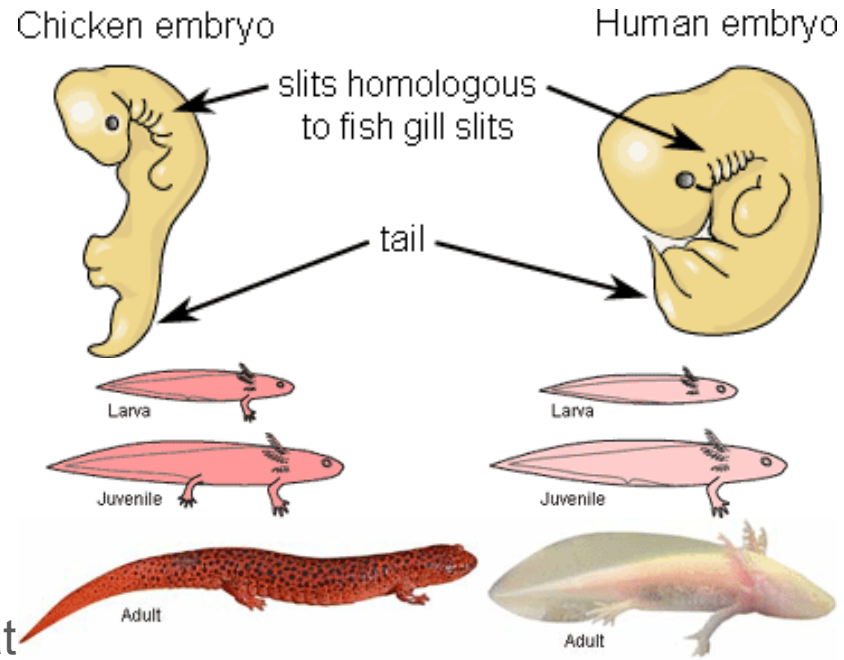
Age-Area

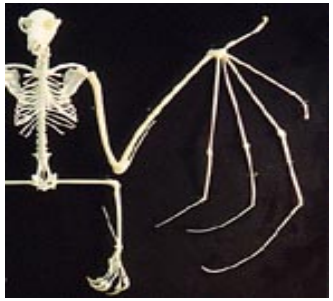
Cope's Law



The modern synthesis is over-stated

- Modern View of Recapitulation
  - Evolutionary Developmental Biology
  - Evo-Devo is NOT the same as recapitulation.
  - However, we do see elements of a taxon's evolutionary history in its ontogenetic development at the Embryonic stage.
  - Goldshmidt's explanation for hopeful monsters – i.e., mutations in genes that control developmental *rates* – is basically the basis of evo-devo.
  - Allometry – a change in the rate of growth of a dimension or feature relative to other features



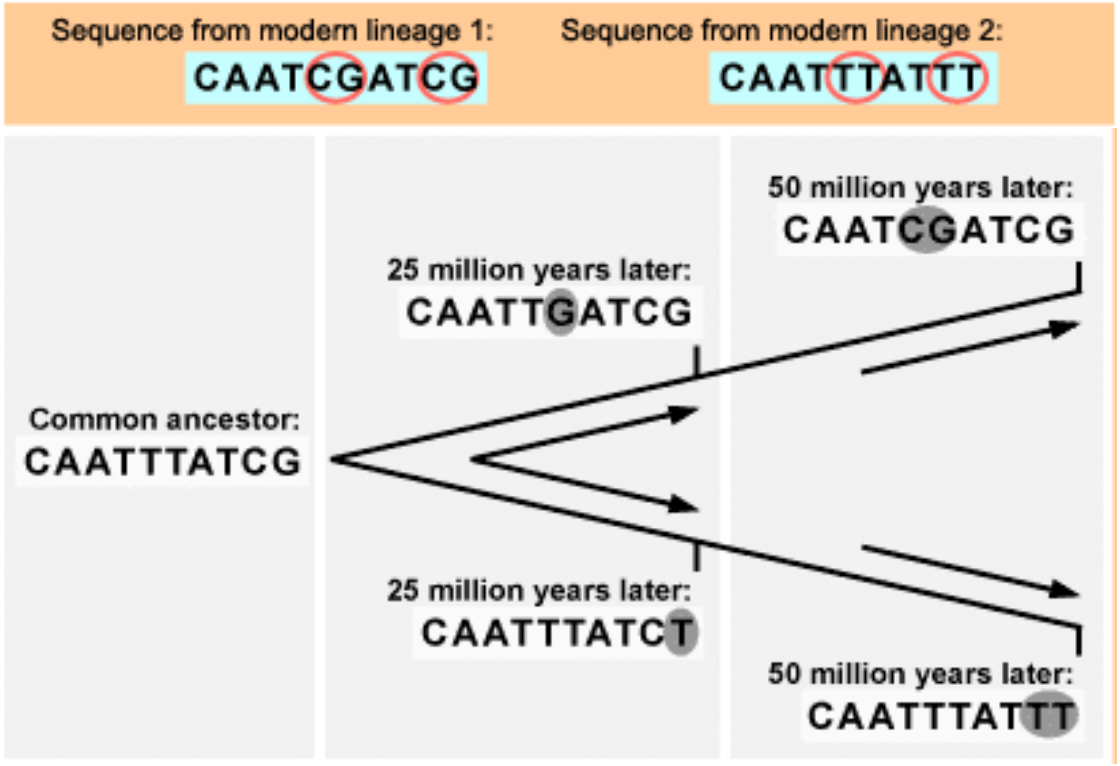


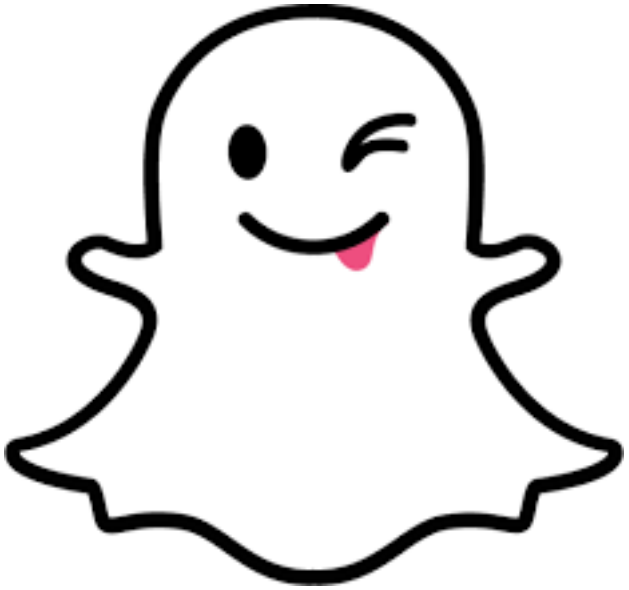
The modern synthesis is over-stated

- Modern View of Mutationism
  - Genetic Neutral Theory
    - A neutral (silent or synonymous) mutation occurs when the change of a single DNA nucleotide (A, T, C, G) within a gene does not affect the sequence of amino acids that make up the gene's protein.
    - In other word's most allele substitutions and polymorphisms do not affect an organisms' ***fitness***.

The modern synthesis is over-stated

- Modern View of Mutationism
  - Genetic Neutral Theory Gives us the molecular clock and molecular phylogeny





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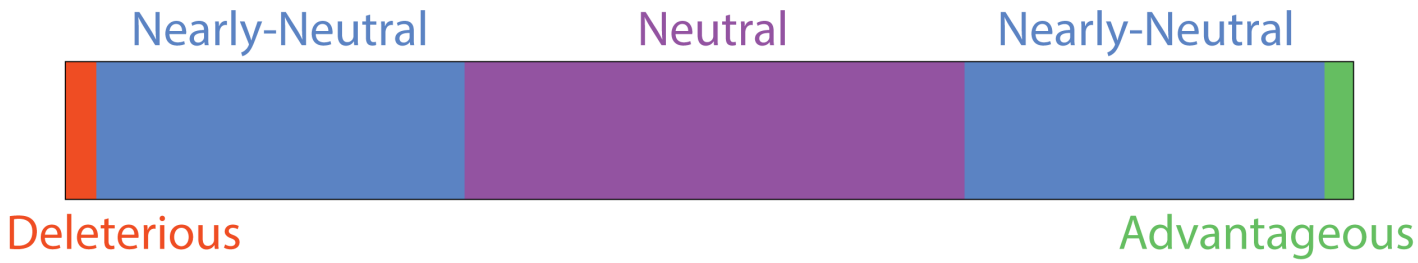
- Nearly-Neutral Theory and Neo-Mutationism



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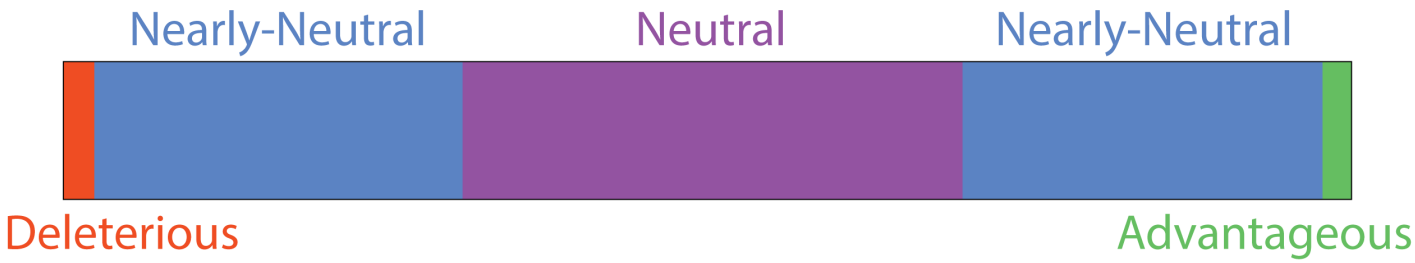

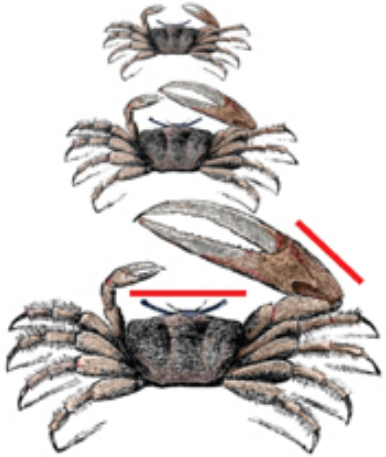

The modern synthesis is over-stated

- It allows us to think of natural selection as intermittent state changes as opposed to a continuous process

The modern synthesis is over-stated

- Modern view of Catastrophism
  - “Sloshing Bucket” model – The degree of evolutionary innovation is roughly proportional to the degree of severity of extinction.
  - Two end-member states of extinction that we know well from empirical observation.
    - Local Extirpation from short-term catastrophes: wildfires, volcanoes, floods.
    - Mass extinctions from dramatic global castasrophes: extraterrestrial bolides, mass volcanism, mass cooling.
  - We can therefore interpolate that most extinctions are driven by intermediate-level catastrophes between these two extremes.

The great war that paleontologists fight

- Environmental perturbations (state changes) are more important drivers of evolution than biological interactions.
- This is a very different picture of evolution than what is generally presented to the public.
- Do paleontologists believe this because we are biased by the nature of the geological record?