The evidence…..

In the nearly 20 years between his travels on the H.M.S. Beagle and his publication of “On the Origin of Species by Natural Selection,” Darwin drew on several lines of evidence…

Lamarck - Darwin's "starting point"

- Similarities among organisms: "species" are artificial groupings; the observable "gaps" between species (and all other taxonomic levels) are artificial; the intermediate forms exist somewhere on Earth; because all organisms are adapted to the needs of their environments, species don't become extinct, they evolve into one another

- Principle of “use and disuse” - frequent and continued use of any organ gives it a “power” while permanent disuse of an organ weakens and deteriorates it, progressively diminishing functional capacity until it finally disappears

- Inheritance of Acquired Characteristics - all the acquisition and loss of morphology as a result of influence of environment are preserved by reproduction to new individuals which arise (both male and female must possess the trait); *all animals are part of a continual scheme of progressive improvement*…”adaptive direction”

- Acquired characteristics are passed on by “pangenesis-like” processes.

  Pangenes = unit derived from all tissues of parent and are incorporated into parental gametes. When these gametes are incorporated in offspring they spread out to form offspring’s tissues.

key themes of Lamarck's that informed Darwin's thinking:

- Mutability of species, continuity of changes
- Geographic variation
- Teleology "teleos" - Greek for "goal" or "endpoint" or"preferred state" - functional perfection
- "pangenes"

Key differences:

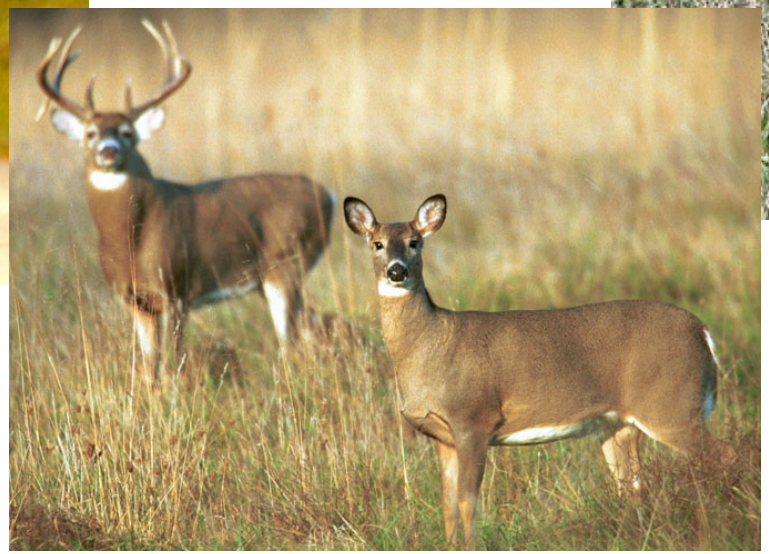
How do new species arise? Significance of variation?
Incremental change over time

6 lines of evidence that Darwin drew on:

- Comparative anatomy
- Artificial selection
- Fossils
- Geographic variation
- Embryology
- systematics

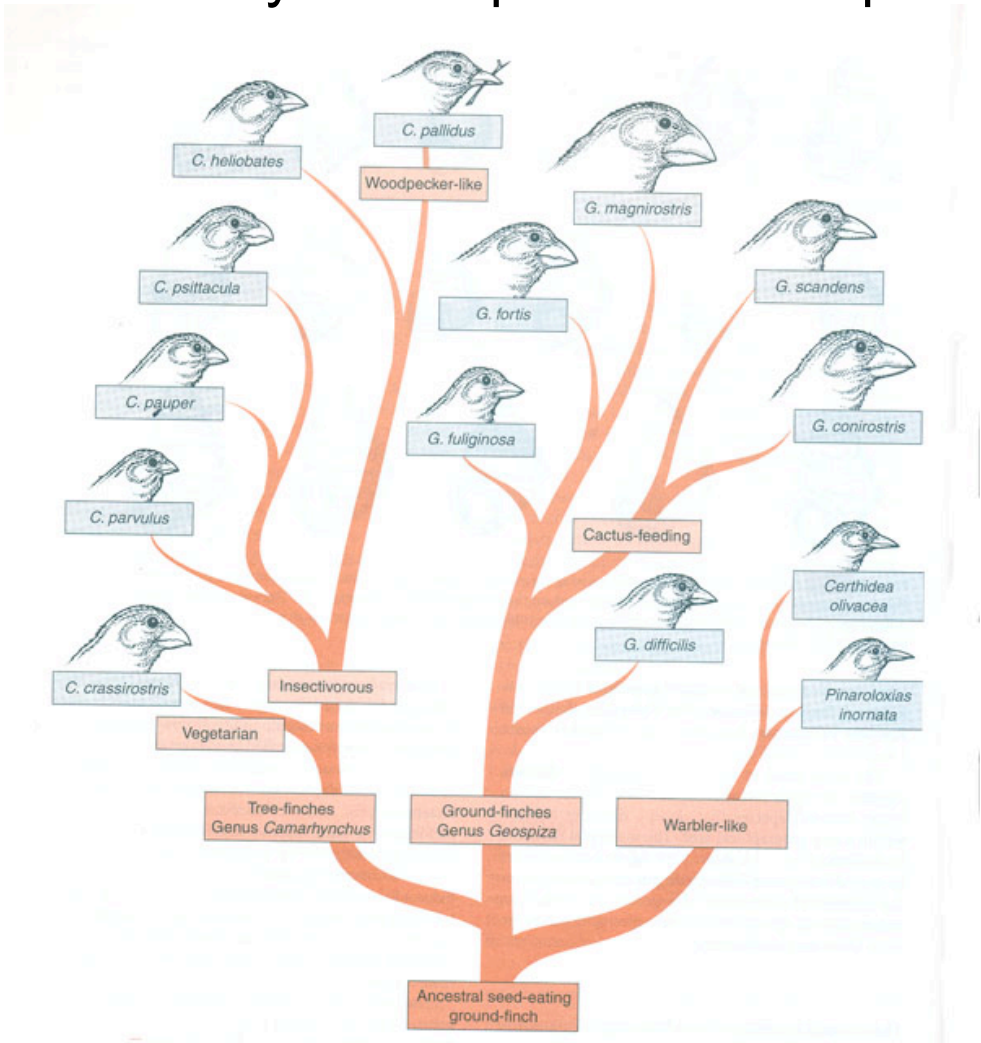
Geographic variation

- Ex: coral species on opposite sides of the Isthmus of Panama (similar Families and Genera,different Species); mammals of South America and their similarity to those of North Am.



Extreme geographic variation can lead to "**adaptive radiation**"

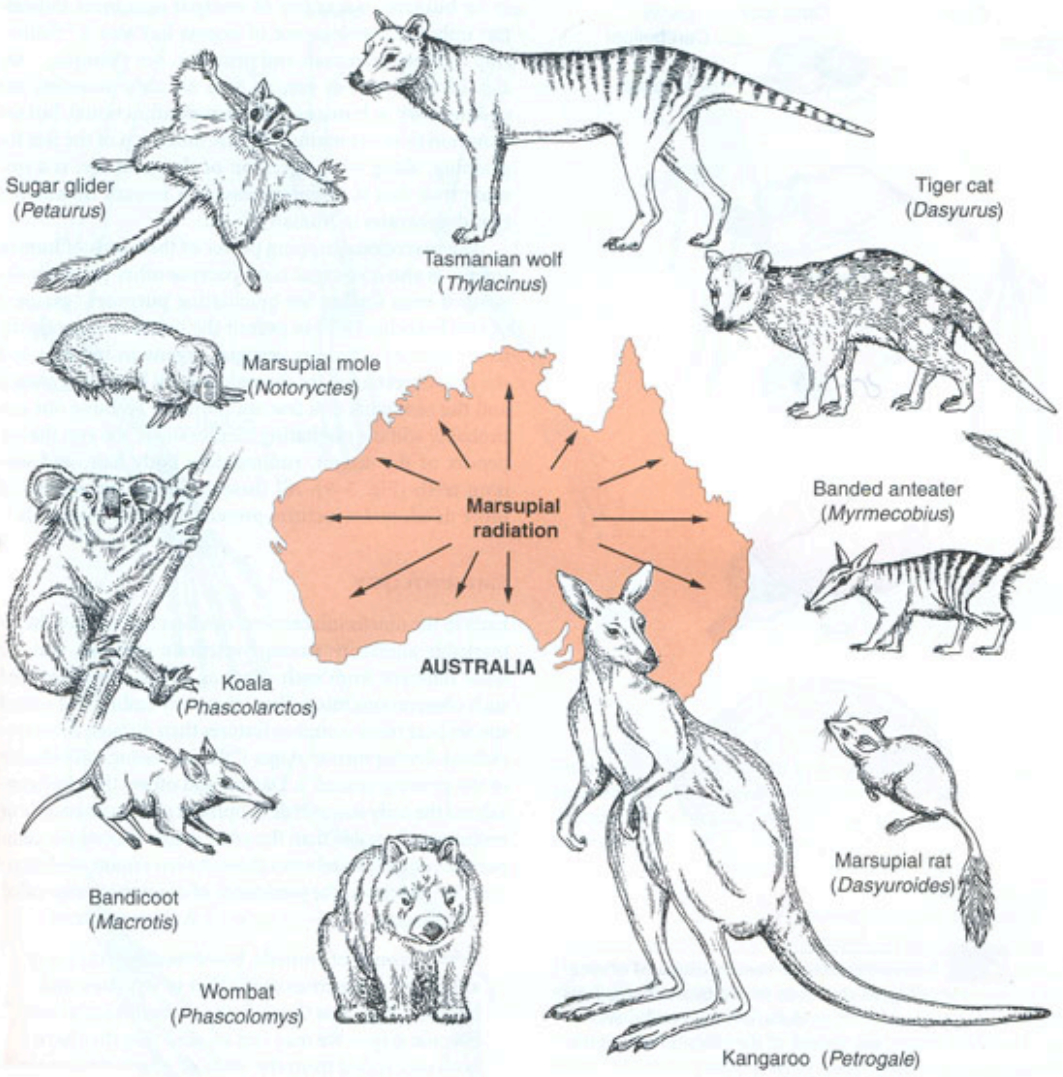
•Ex: finches of the Galapagos - colonizers of new territory led to adaptations into niches that, on the mainland, were occupied by other species = "adaptive radiation"



Note that the finches are adapting to competition for food by exploiting different food resources

How is this an example of Malthus's ideas?

Example of an adaptive radiation: diversification of marsupials in Australia in the Cenozoic



After Australia broke apart from Pangea in the Cretaceous, it remained isolated. The subsequent radiation of placental Mammals in the Paleogene did not Spread to Australia. Instead, marsupials diversified.

Examples of adaptive radiations in the fossil record:

1. The diversification of mammals in the Paleogene, following the extinction of the dinosaurs
2. The diversification of land plants in the Devonian, following the evolution of vascular plants
3. The diversification of pelecypods in the Triassic, following the major extinction of the brachiopods at the end of the Permian
4. Diversification of coral Orders and Families since the Triassic (text fig 7.9)
5. The radiation of benthic invertebrates in the Cambrian

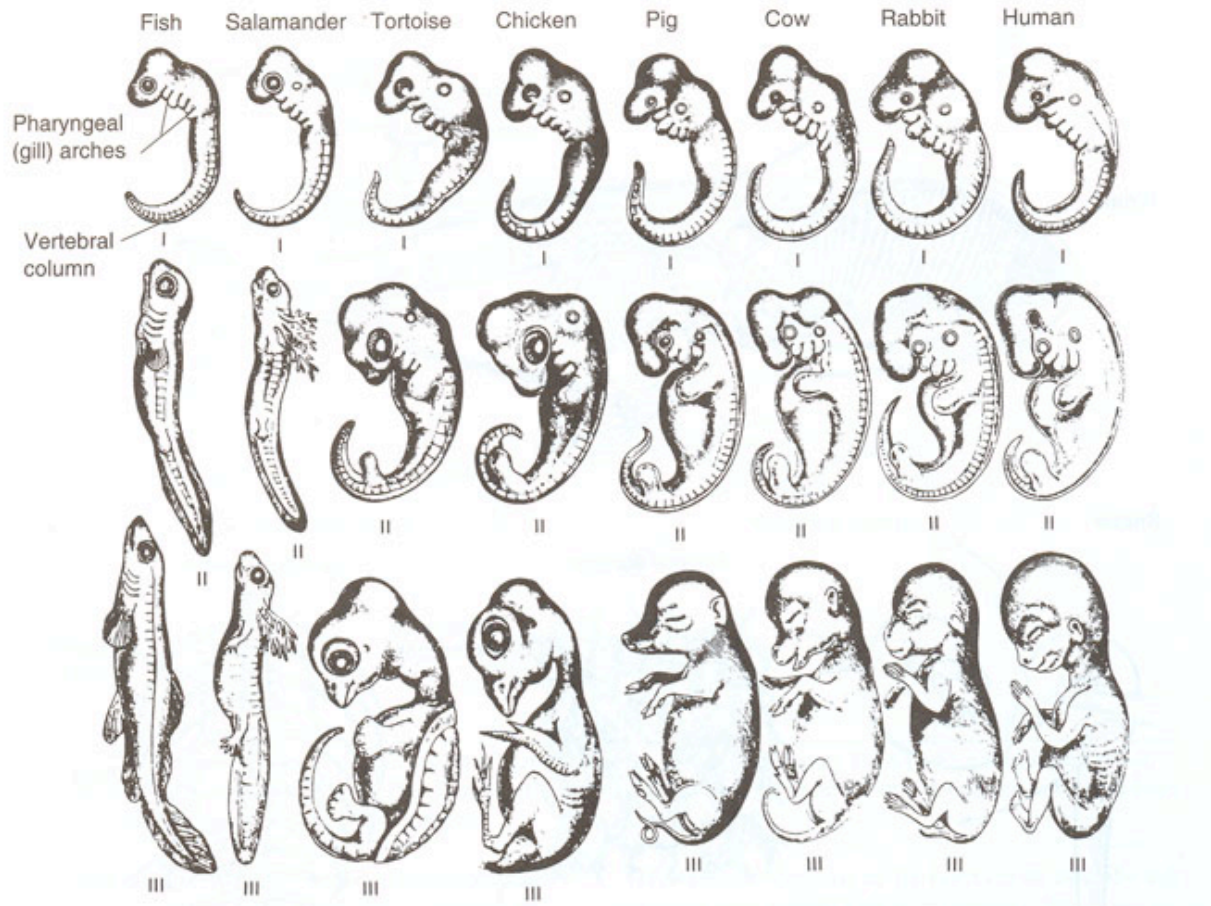
Under what conditions do adaptive radiations occur?

embryology

- Similarity of vertebrate fetuses during development
- Ex: human embryos have a stage with a two chambered heart like that of a fish
- Ex: the position of some nerves and blood vessels in many vertebrates is puzzling (not the shortest path but cranium to thorax to larynx) but it reflects original orientation in fish (fish head to gill slits)

The idea of embryologic stages reflecting evolutionary ancestry was explored by Ernst Haeckel

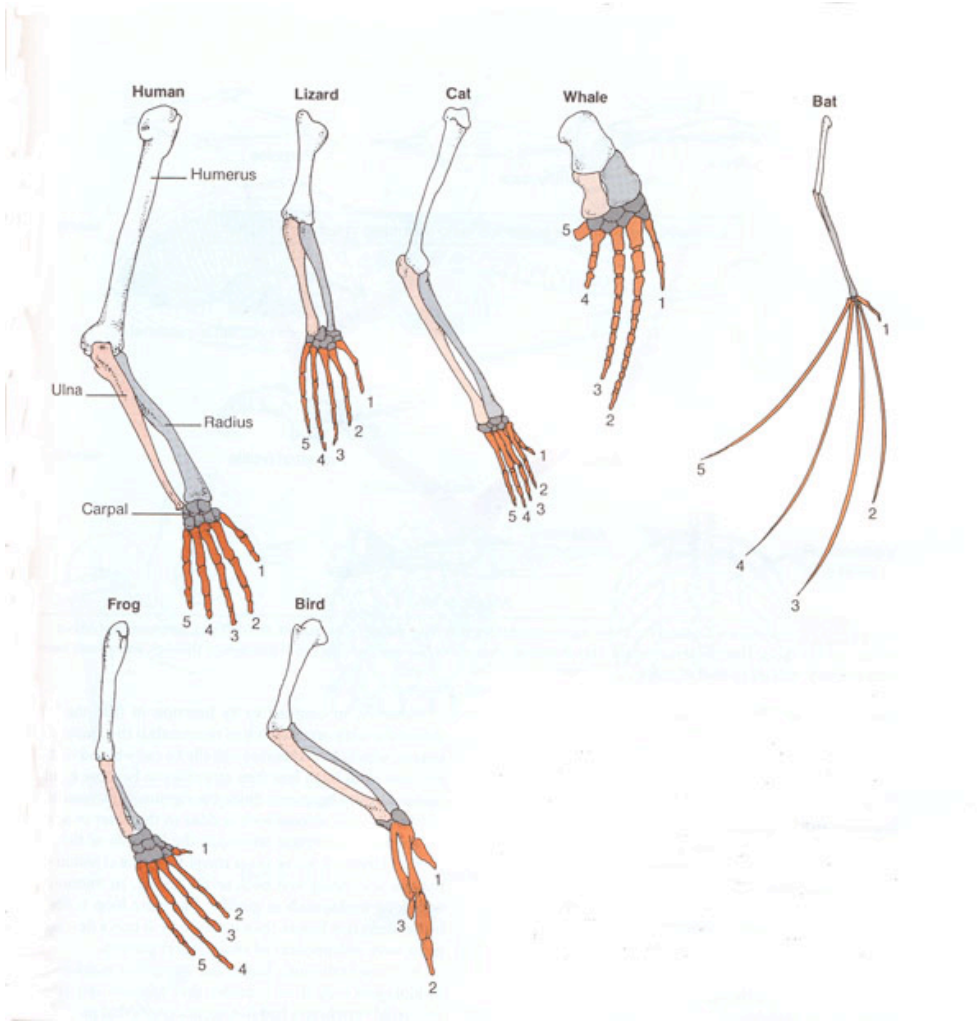
- "Haeckel's Law" - "ontogeny recapitulates phylogeny" = early stages of development in embryos reflect those of ancestral adults. A gross oversimplification (ex, human embryos never have gill silts). However, there ***is*** evolutionary persistence of underlying patterns, for example bilateral symmetry, sequence of development of cranium and thorax, etc.



Ernst Haeckel's illustration supporting the idea that the embryos of organisms exhibit similar stages of development. Haeckel went on to say that the embryos of "more advanced" organisms, like mammals, go through the stages of development of *adult forms* of ancestors, which is not true.

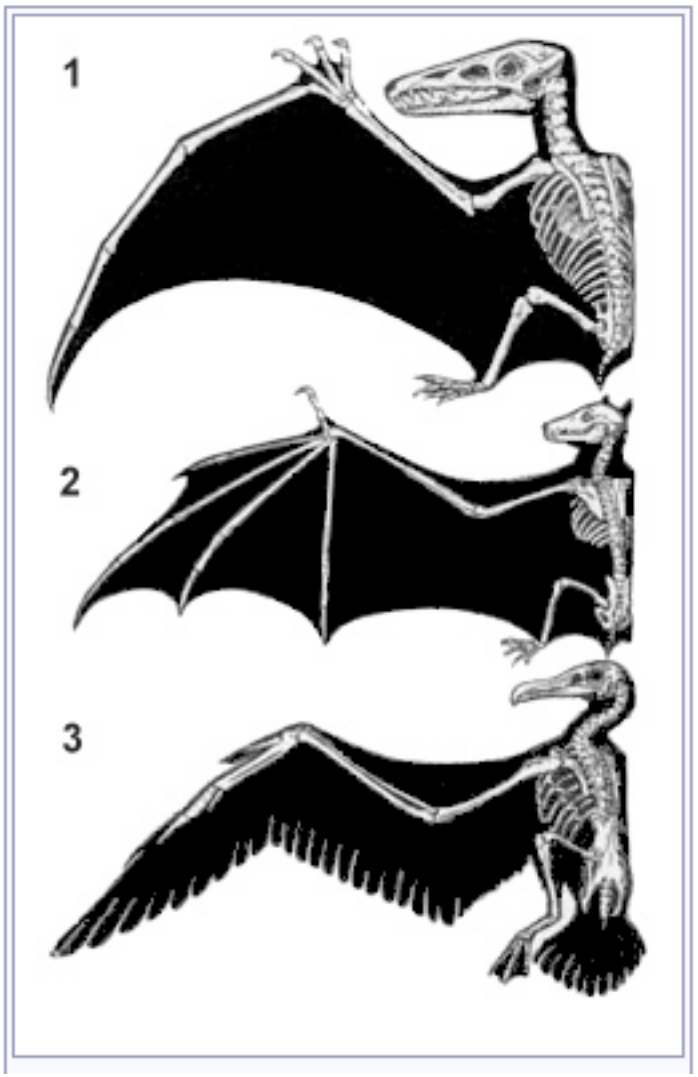
Comparative anatomy

Homologous structures - same structure but different function



Forelimb structure: humerus radius, ulna and carpels

Homology in action: modification of forelimbs for flight



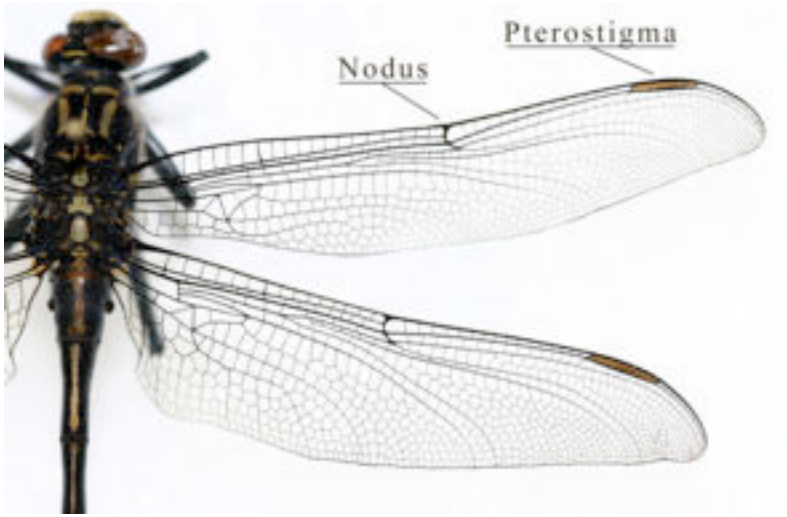
pterosaur

bat

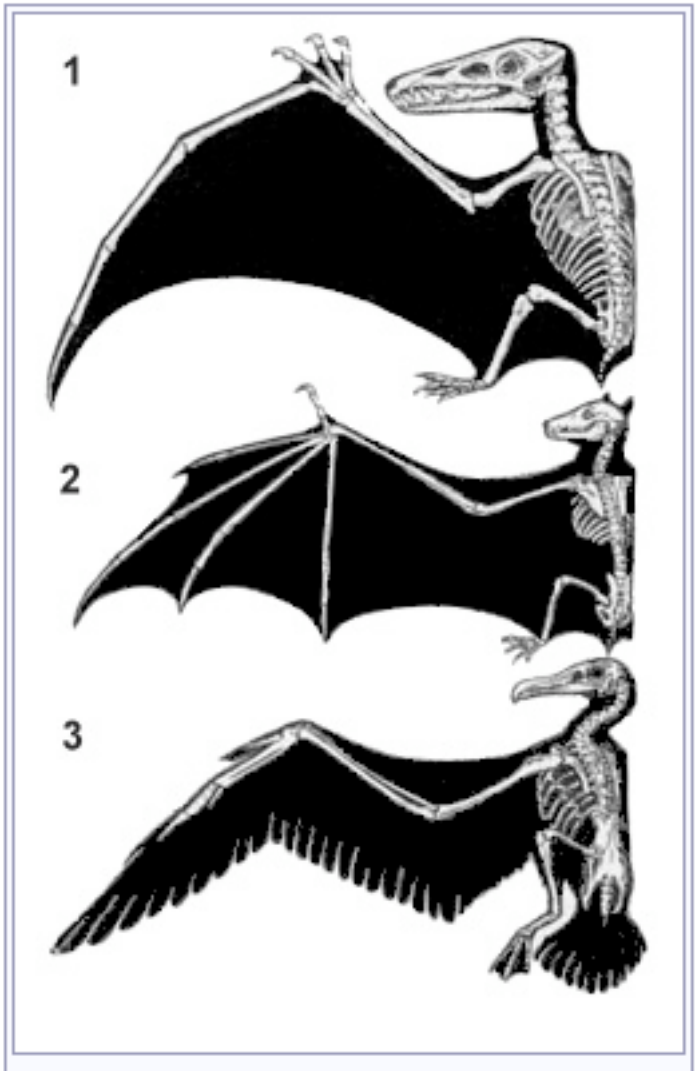
bird

These similarities imply shared ancestry

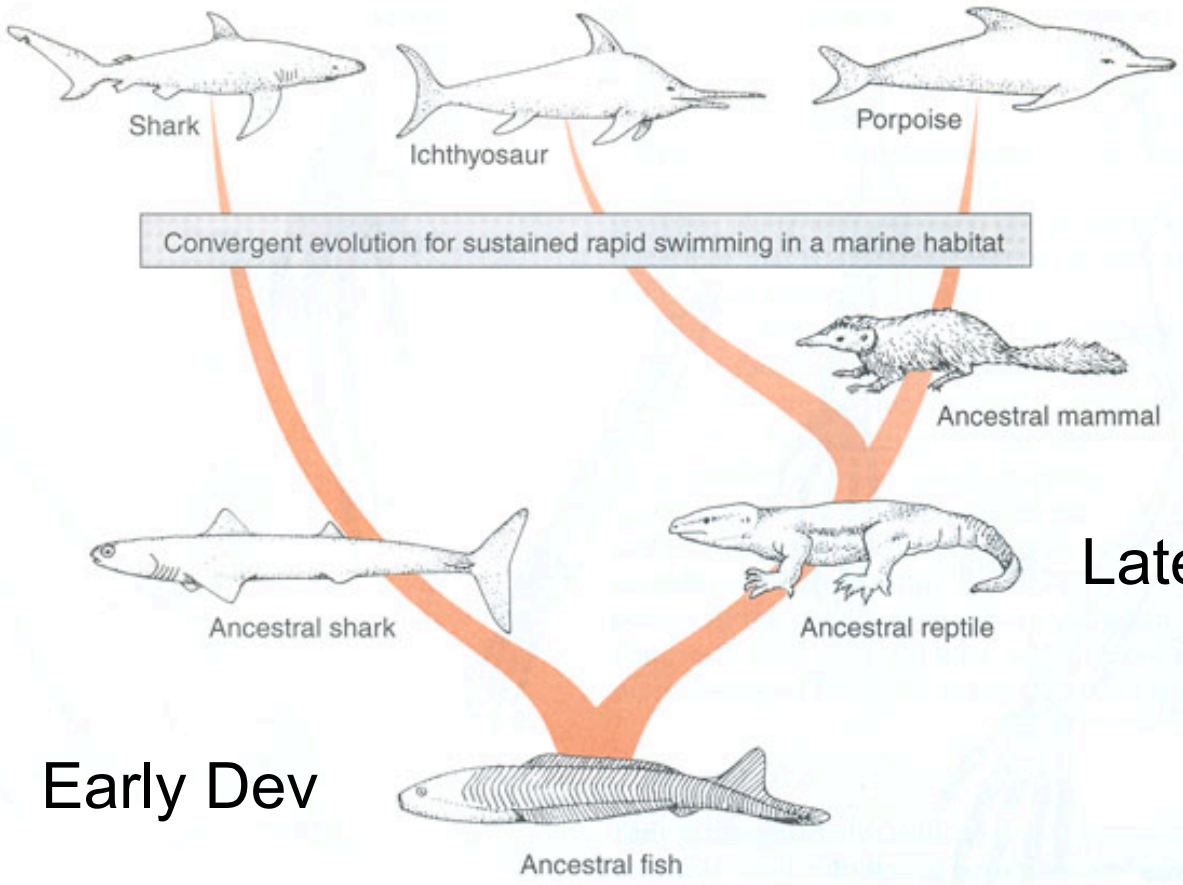
Analogous structures - similar function but different structure
Ex: insect wings and bird wings. Both evolved for flight, but from different antecedents



Wing from modified exoskeletal segment (appendage)



Convergent evolution - development of similar structural response to similar environment; ex: porpoises (mammals) and sharks

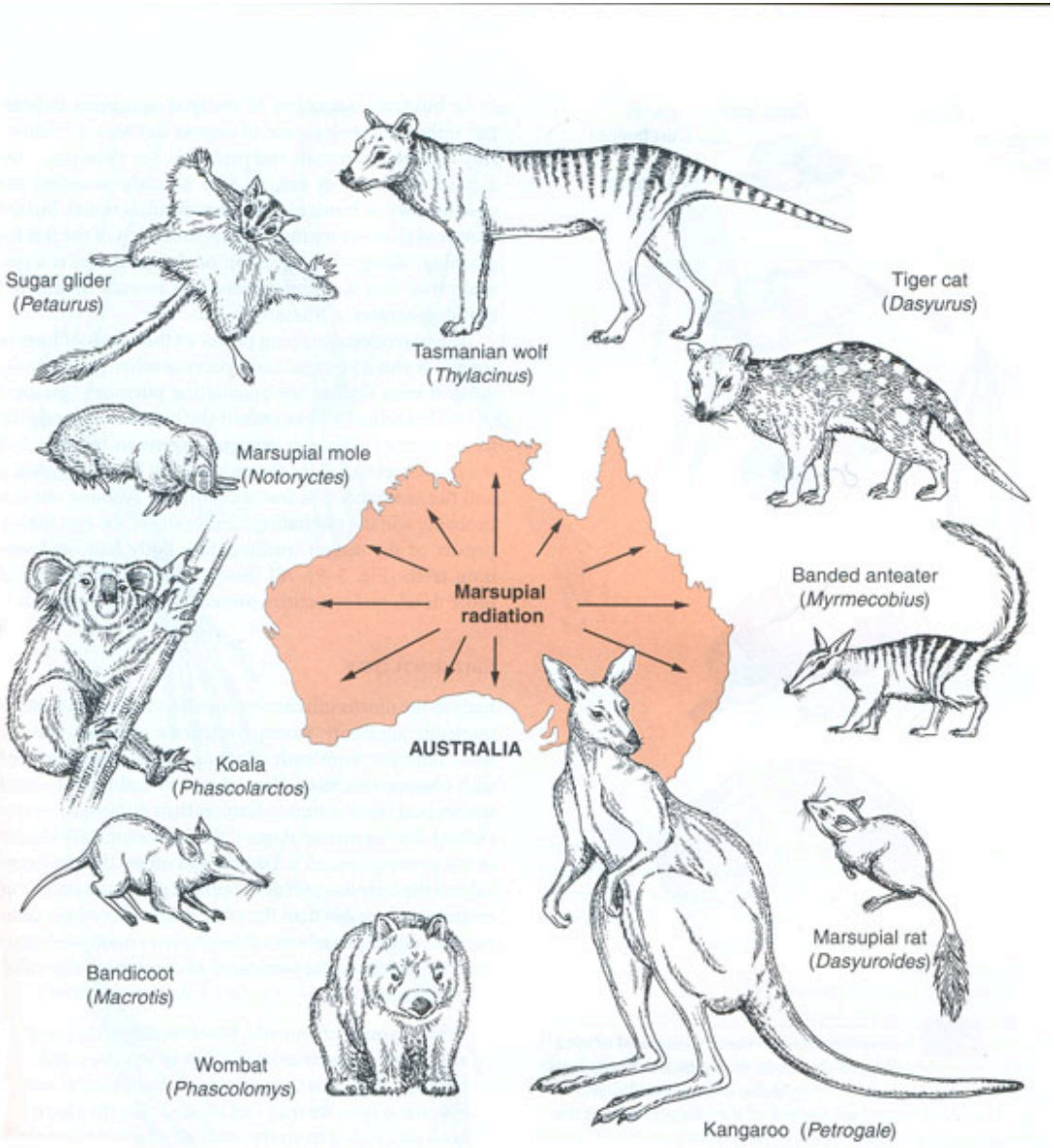


Early Tri

Late Dev

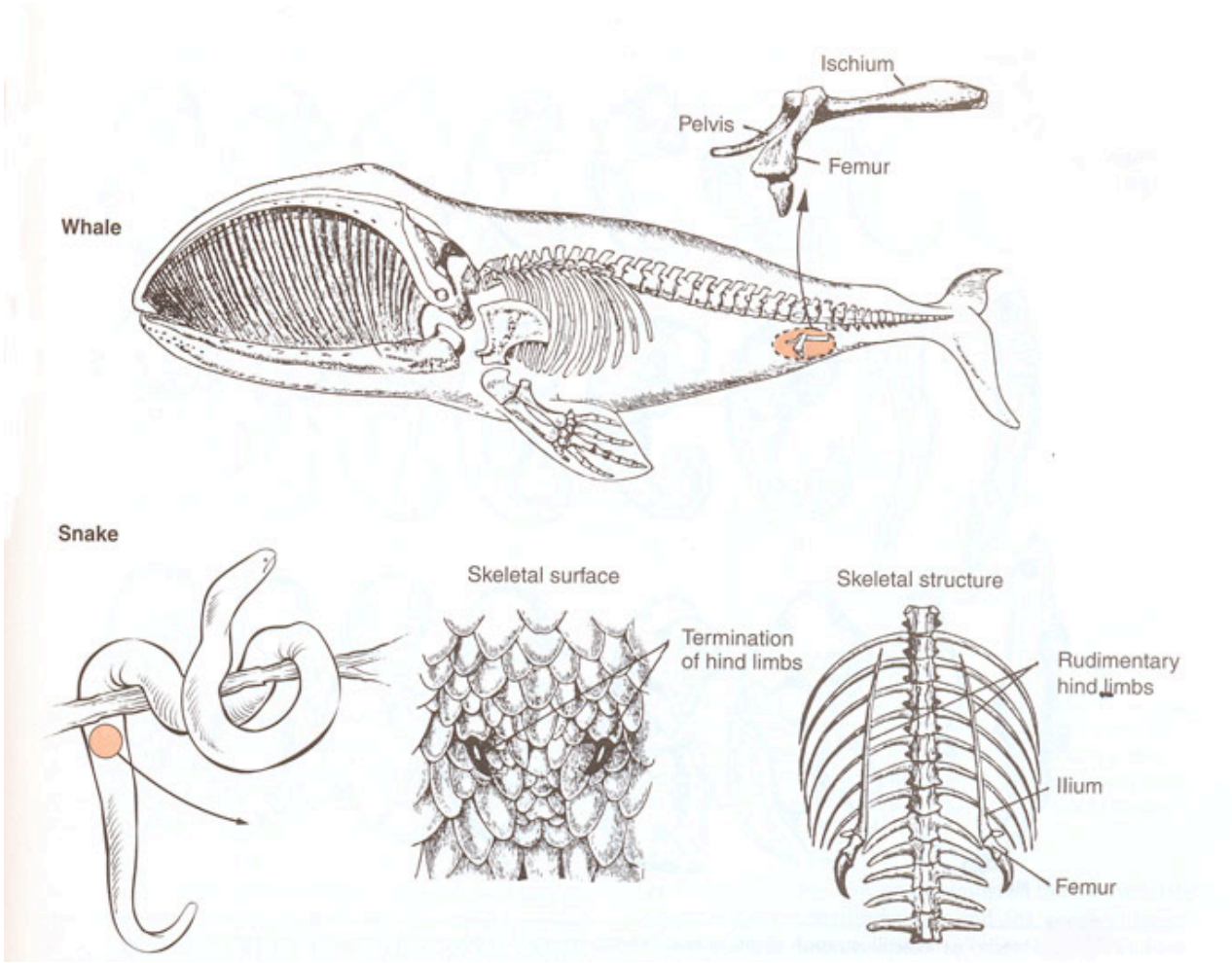
Late Dev

Early Dev



Marsupials exhibit convergent evolution: they occupy the same niches that placental mammals occupy elsewhere… Given the mammal body plan, there are only so many different ways to feed, reproduce, move, etc.

Vestigal structures - an organ with no current function
Ex: hind limb on whales



Hind limbs in whales and snakes

Artificial selection

Breeding of domestic animals so as to enhance certain characteristics (milk yield in cows, wool color in sheep, etc)

fossils

- Similarity of ancient life forms to living

Modern coelocanth

240 Ma

- “missing links” - intermediate forms, ex:

  lungfish (intermediate organ between fish and amphibians); Archaeopteryx -

  bird-like reptile of Jurassic age

Archeoptryx spp.
A Jurassic flying reptile,
ancestor to the birds

systematics

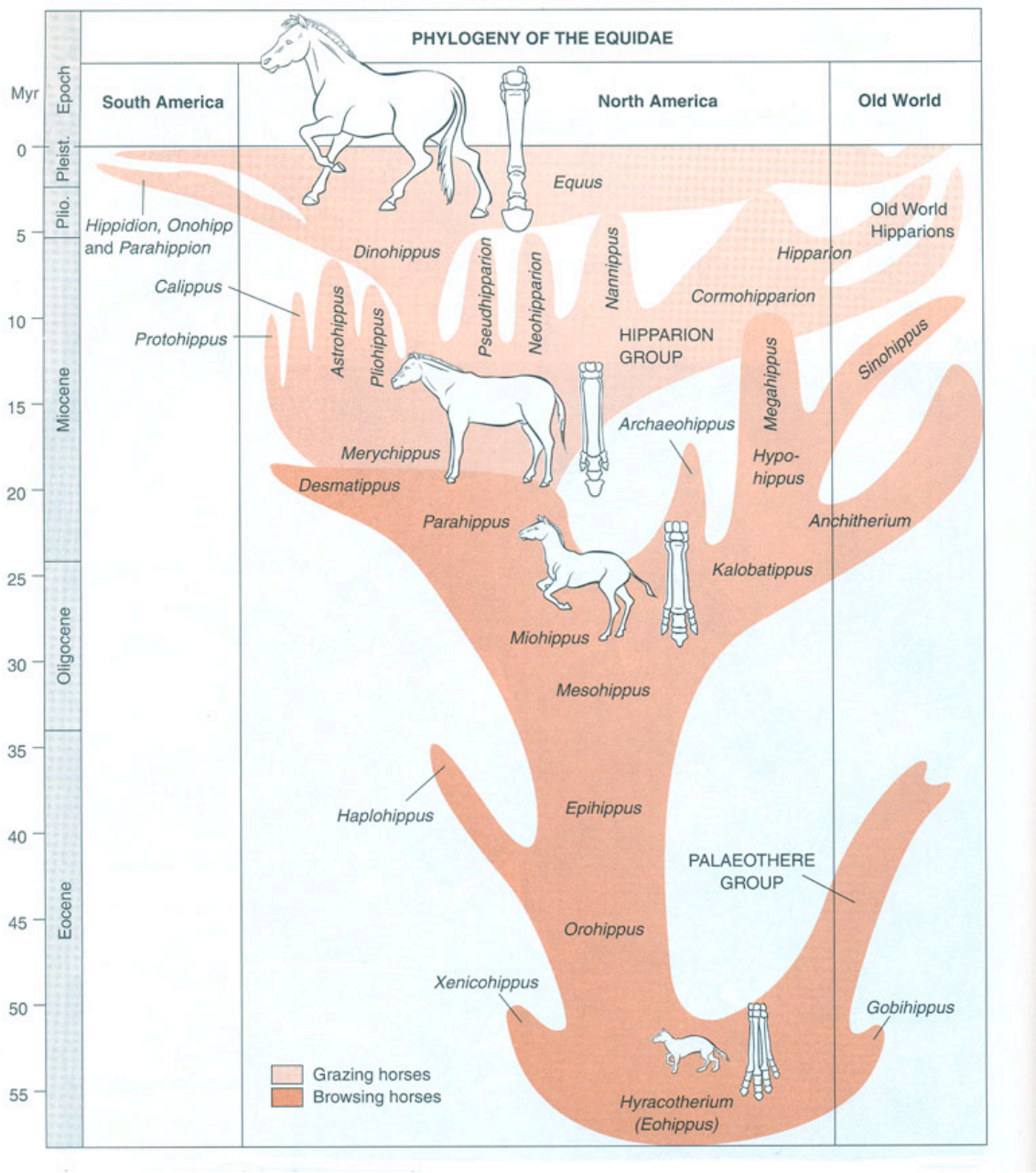
- The Linnaean system of nomenclature groups together organisms with shared traits. The broadest shared traits (body plan) = Phyla; Class = organisms (ex.,all clams), etc

When Linnaeus developed this classification system it was for precisely this (classification), not for showing evolutionary relationships.

What natural selection says:

"As many more individuals of each species are born than can possibly survive; and as, consequently, there is a frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance, any selected variety will tend to propagate its new and modified form"

* Continual process - small, incremental cumulative changes
* "fueled" by variation, which is also continuous



Horse evolution is often cited as an example of continuous, long-term modification of morphology (teeth, toes, body size)

Issues:

- Darwin did not have a mechanism for inheritance, he proposed the existence of "gemmules" (similar to Lamarck's "pangenes"); considered both "particulate" (from "gemmules") and "blended" (mixing of parental traits) inheritance
- Focus on transformation of one species into another (= **phyletic evolution**) as a result of geographic isolation (**=allopatric speciation**) but not for multiplication of species; also did not focus on speciation (=reproductive isolation) of populations living in the same geographic area (**=sympatric speciation**)
- The "*Origin*…." did not consider human evolution or the evolution of life

“Darwinism” - what is it?

- Darwin said the *Origin of the Species…* was “one long argument” for “descent with modification,” by this he meant against special creation. Darwin believed in natural explanations for the diversity of life on Earth and its history
- Darwin referred to the *Origin* as his “species book,” not his natural selection book - his focus was on providing examples of, and an explanation for, the inconstancy of species and their “common descent”

Darwinism is “anti-ideological”

- Anti- special creation and design… Rev William Paley’s metaphor that “a watch must have a watchmaker,” *i.e.,* complexity requires a designer (Darwin: complexity is developed from adaptation over time)
- Anti- “essentialism”…the idea that every species is fulfilling a “type” or ideal
- Anti-reductionist…the idea that natural history can be reduced to an algorithm or predictable set of steps (Newtonian)
- Anti-teleological…the idea that a species represents the final solution to a “problem”

The second Darwinian Revolution: the rise of genetics

- Following Gregor's Mendel's (1880's) elegant experiments on peas that documented (1) the difference between an organism's phenotype (physical appearance) and genotype (genetic makeup) and (2) genetic information was particulate ("factors"), not blended information from parents…
- Chromosomes in the nuclei of cells bear genes; genes from both parents are exchanged during reproduction; The chemical identity of genes: recognition of DNA (1950's)
- The role of genes in generating variation-shuffling of genes during reproduction; mutations (1950's-60's)

The third Darwinian revolution: the evolutionary synthesis

- individuals as the targets for selection as well as populations (as incipient species)
- Focus on probabilities (mutation, genetic variation) and rates (changes in gene frequencies)
- Focus on geographic speciation, the importance of sexual selection
- Microevolution (changes within populations that result in speciation) and macroevolution (appearance of new higher taxa)
- Mode and tempo of evolution: phyletic gradualism vs. punctuated equilibrium