

“There is grandeur in this view of life ... from so simple a beginning endless forms most beautiful and wonderful have been, and are being, evolved”
- Charles Darwin

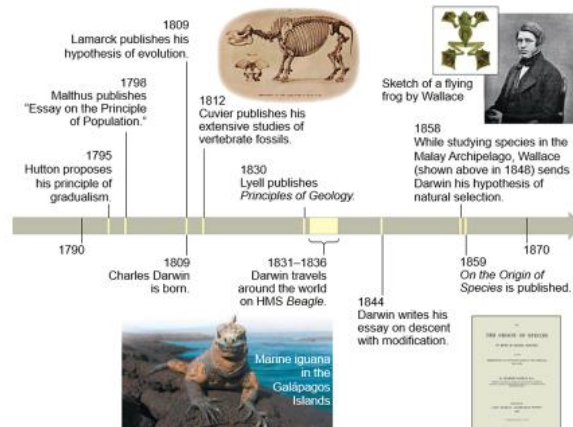
Evolution and Phylogenetics

Chapters 24, 25 and 26

Importance of Understanding Evolution

- ▶ Evolution unites all living things
 - ▶ Common ancestor
 - ▶ All living things have evolved and are evolving
- ▶ Theory of evolution provides actual evidence for understanding the diversity of nature
 - ▶ Everything can be explained through the processes of evolution
- ▶ Understanding evolution you will give you a greater appreciation for...
 - the way plants and animals survive
 - why plants and animals look the way the do
 - why species are found only in certain areas
 - the natural world!!!

History of Evolutionary Thought



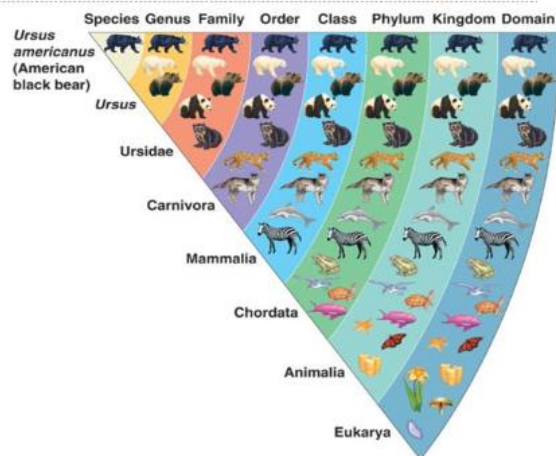
Precursors to Evolutionary Thought

- ▶ Carl Linnaeus (1707 – 1778)
 - ▶ Swedish botanist, zoologist, and physician
- ▶ Father of _____ (classifying organisms)
 - ▶ Binomial nomenclature
 - ▶ Ex. *Homo sapiens*



Classifying Organisms: Taxonomy

- ▶ Domain
- ▶ Kingdom
- ▶ Phylum (plural, *phyla*)
- ▶ Class
- ▶ Order
- ▶ Family
- ▶ Genus (plural, *genera*)
- ▶ Species (no specie!)



Precursors to Evolutionary Thought

- ▶ Jean-Baptiste de Lamarck (1744 – 1829)
 - ▶ French naturalist
- ▶ Proposed that organisms could _____ acquired traits
 - ▶ Changes that occurred during an organisms life could be passed on



Lamarck on Giraffes

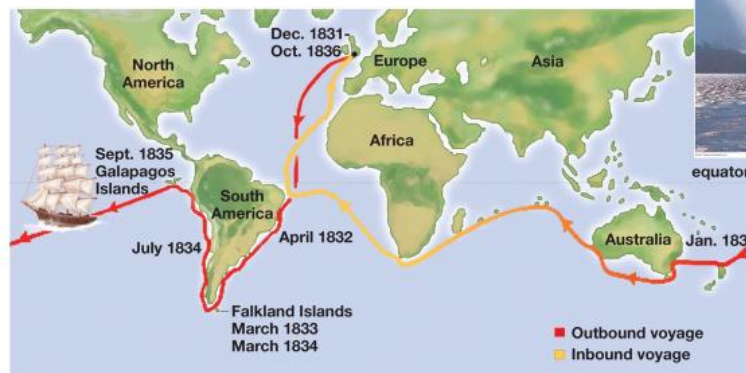
- ▶ Giraffes that stretch their necks to reach higher branches will elongate their necks.
- ▶ Giraffes will pass on longer necks to offspring.
- ▶ Traits acquired through _____



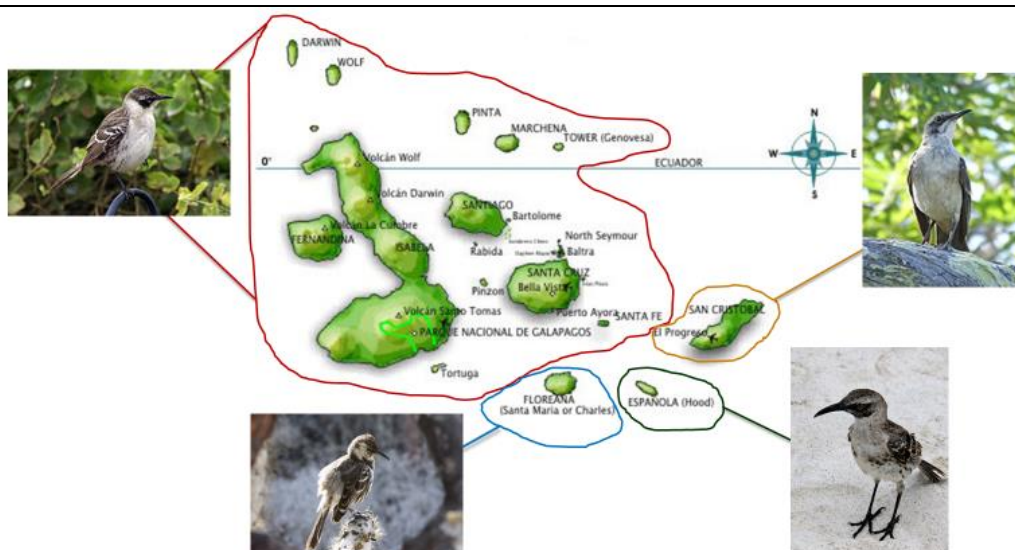
Stretching

Charles Darwin's Voyage

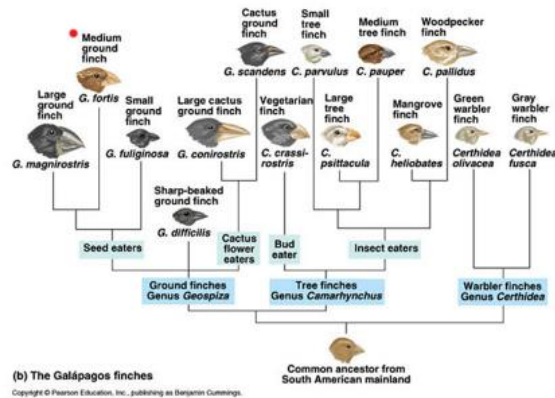
5 year trip around the world aboard H.M.S Beagle from 1831-1836



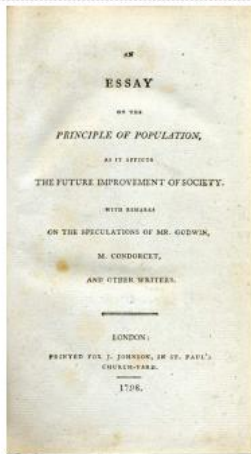
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The Galapagos Finches



Crystallization of an Idea



- ▶ Darwin read Thomas Malthus's *An Essay on the Principle of Population* 6th ed. (1826)
- ▶ _____ will be checked by limited resources, disease, famine
- ▶ _____ of birds after a cold snap near Down House



Alfred Russel Wallace

- ▶ Collected specimens in Brazilian Amazon the throughout Malaysian Archipelago (Wallacea)

▶ Father of _____

- ▶ Geographic barriers often separated closely related species

▶ Wallace's Line

- ▶ Independently conceived idea of natural selection



IX

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION.

1859

PRESERVATION OF FAVORITED RACES IN THE STRUGGLE
FOR LIFE.

By CHARLES DARWIN, M.A.

DEPOSIT OF THE COPY, MANUSCRIPT, LIBRARY, &c., IN ACCORDANCE
WITH THE "ORDINANCE OF REGISTERING WRITINGS," IN A PUBLIC OFFICE,
WITHIN THE MONTH.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The Origin of *Procyonidae* in 1859.

- ▶ On The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle For Life (1858)
 - ▶ Decent with modification
 - ▶ Natural selection

- ▶ **Common descent with modification:** species of living things can undergo modification in successive generations, with these changes sometimes resulting in the formation of a new species
 - ▶ Species are united by a common ancestor
- ▶ **Natural Selection:** the process through which traits that provide a _____ to an individual organism grow more common in populations of organisms over successive generations
 - ▶ Environmental conditions determines or selects organisms best suited for that specific environment

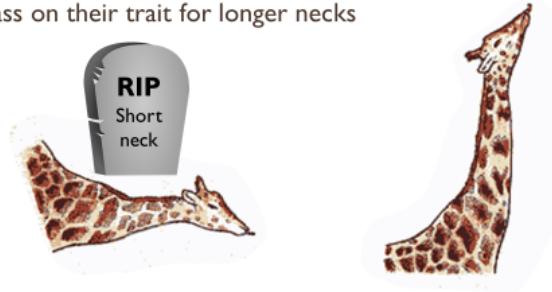
Natural Selection

- 1) Individual organisms in a population _____ in the traits they possess
- 2) Some of the trait differences are _____
- 3) Only some individuals survive long enough to produce offspring and some produce more offspring than others
- 4) The subset of individuals that survive best and produce the most offspring is _____ a random sample of the population

Darwin on Giraffes

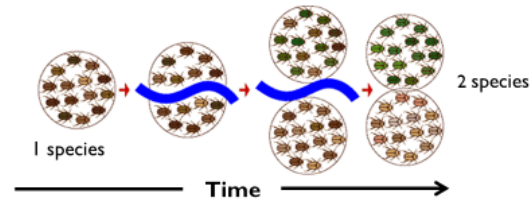
- Variation in neck length within a population of giraffes
 - Those with slightly longer necks will survive better where trees are hard to reach
 - Shorter necked individuals will fail to reach branches and die
 - Longer necked individuals will pass on their trait for longer necks

*No stretching, just death



Evolution of a New Species

- **Macroevolution:** Large-scale evolution occurring over long periods of time (geologic time) that results in the formation of _____ (speciation)
- **Microevolution:** Small-scale evolutionary change resulting from a change of the _____ of a population
- **Speciation:** Development of a new species through evolutionary processes



Geologic Timescale

History of Earth

- 4.6 billion years
- Divided into Eras, Periods, and Epochs
- Boundaries between Eras correlate with _____
- First organisms (_____) arose ~ 3.5 bya
- First eukaryotes arose ~ 2.1 bya
- First fungi arose ~ 1 bya
 - Moved to land around 500 mya

Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Cenozoic	Quaternary	Holocene	0.01	Historical time
		Pleistocene	2.6	Ice ages, origin of genus Homo
		Pliocene	5.3	Appearance of bipedal human ancestors
	Neogene	Miocene		Continued radiation of mammals and angiosperms, earliest direct human ancestors
		Oligocene	23	Origins of many primate groups
	Paleogene	Eocene	33.9	Angiosperm dominance increases, continued radiation of most present-day mammalian orders
		Paleocene	55.8	Major radiation of mammals, birds, and pollinating insects
			65.5	
	Mesozoic	Cretaceous		Flowering plants (angiosperms) appear and diversify, many groups of organisms, including most dinosaurs, become extinct at end of period
		Jurassic	145.5	Gymnosperms continue as dominant plants, dinosaurs abundant and diverse
Paleozoic	Triassic		199.6	Cone-bearing plants (gymnosperms) dominate landmass, dinosaurs evolve and radiate, origin of mammals
			251	Radiation of reptiles, origin of most present-day groups of insects, extinction of many marine and terrestrial organisms at end of period
	Permian		299	Extensive forests of vascular plants form, first seed plants appear, origin of reptiles, amphibians dominant
	Carboniferous		359	Diversification of bony fishes, first tetrapods and insects appear
	Devonian		416	Diversification of early vascular plants
	Silurian		444	Marine algae abundant, colonization of land by diverse fungi, plants, and animals
	Ordovician		488	Sudden increase in diversity of many animal phyla (Cambrian explosion)
	Cambrian		542	Diverse algae and soft-bodied invertebrate animals appear
	Ediacaran		635	Oldest fossils of eukaryotic cells appear
			1,800	Concentration of atmospheric oxygen begins to increase
Proterozoic			2,500	Oldest fossils of cells (prokaryotes) appear
			2,700	Oldest known rocks on Earth's surface
			3,500	
			3,850	Origin of Earth
Approx. 4,600				

Evidence for Evolution

Fossil record

- ▶ Evidence for extinction
- ▶ Evidence for diversification



Evidence for Evolution

Fossil record

- ▶ Organic material replaced by minerals
 - ▶ Petrified wood
- ▶ Organic material: part of the organism was preserved
- ▶ Casts: impressions made by an organism
- ▶ Trace fossils: signs of life that were preserved
 - ▶ Footprints, burrows
- ▶ Entire organisms



Evidence for Evolution

Transitional forms: Intermediate states between ancestral form and its decedents

Archaeopteryx

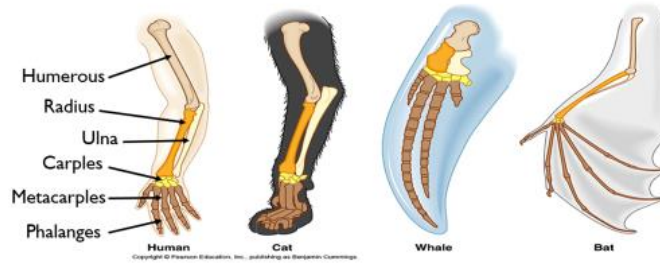
- ▶ Teeth of reptile
- ▶ Feathers of bird
- ▶ Tail with vertebrae like reptile
- ▶ Claws of reptile



Evidence for Evolution

Morphology: study of physical forms of organisms

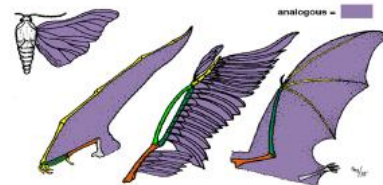
Homologous structures: _____ structures among different taxa due to a common ancestor



Evidence for Evolution

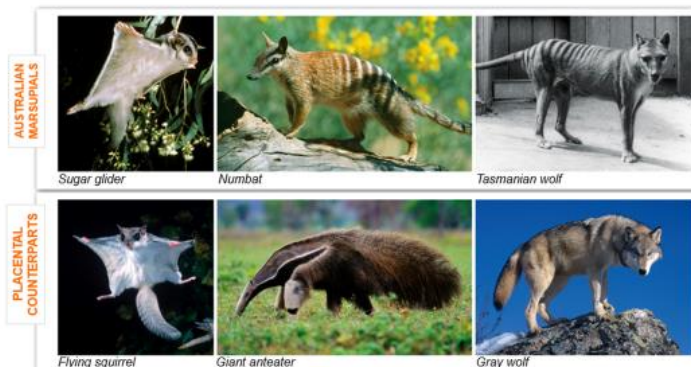
▶ **Analogous structures:** structures from different species with similar function but _____ evolutionary origin

▶ _____: the independent evolution of similar features in species of different lineages



Evidence for Evolution

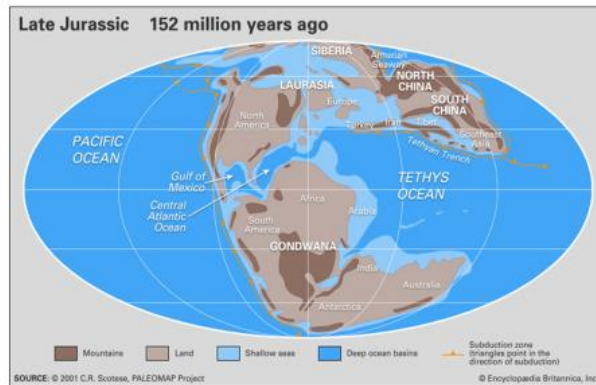
Convergent evolution of Australian marsupials and placental mammals occupying similar ecological niches



Evidence for Evolution

Biogeography: study of the distribution patterns of organisms around the world

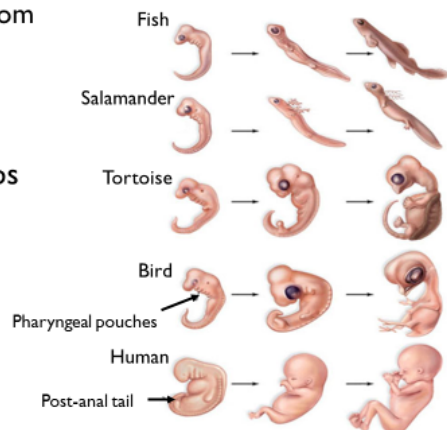
- ▶ Marsupials in South America and Australia



Evidence for Evolution

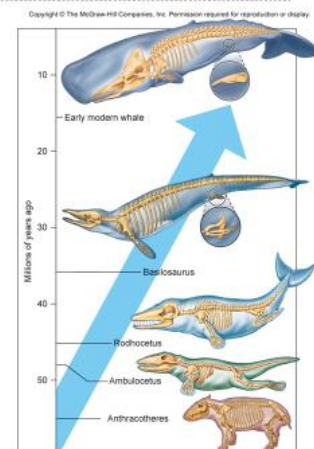
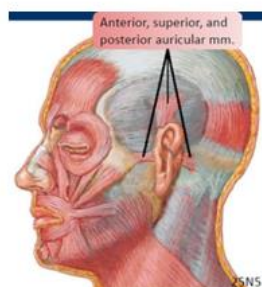
Embryology: study of development from fertilization to fetus stage

- ▶ Similar structures during embryonic development among vertebrate groups
 - ▶ Pharyngeal gill slits
 - ▶ Post anal tail
- ▶ Ontogeny recapitulates phylogeny
 - ▶ Ernst Haeckel



Evidence for Evolution

Vestigial structures: a structure in an organisms whose original structure has been lost during the course of evolution



Evidence for Evolution

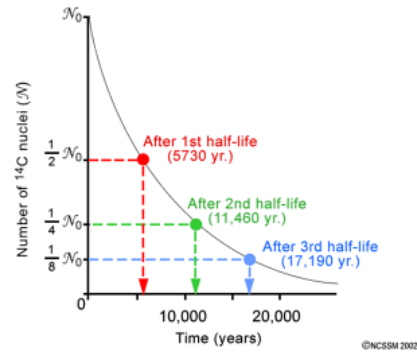
Radiometric dating: a technique used to date the age of an object by measuring the _____ of radioactive elements within the object

▶ **Carbon dating**

- ▶ C^{12} and C^{14}
- ▶ Half life of C^{14} = 5730 years

▶ **Uranium dating**

- ▶ Uranium-238 to Lead-206
- ▶ Half life = 4.5 billion years



Check Your Understanding

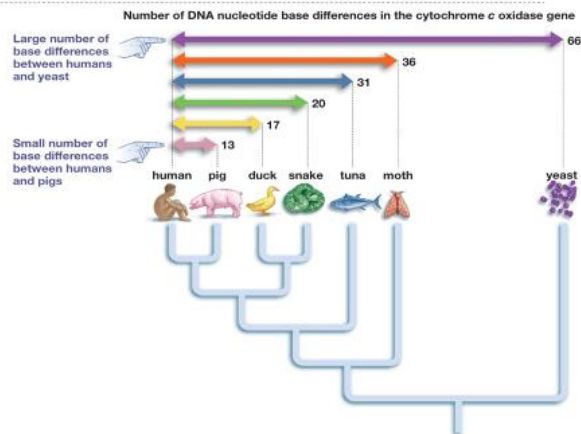
A paleontologist estimates that when a particular organism lived it contained 64mg of the radioactive isotope Carbon-14. The fossil organism now contains 8mg of Carbon-14. The half-life of Carbon-14 is 5,730 years. How old is this fossil?

- a) 0.3 million years old
- b) 11,460 years old
- c) 1,910 years old
- d) 17,190 years old
- e) -5,730 years old

Evidence for Evolution

Similarities in DNA among close relatives

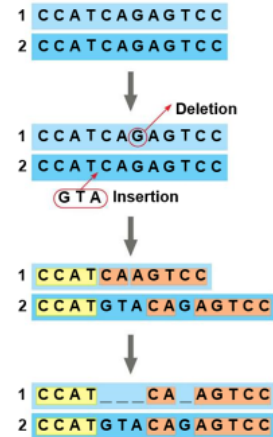
- ▶ Species with similar traits have fewer base differences than species with dissimilar traits



Hypothesizing Evolutionary Relationships

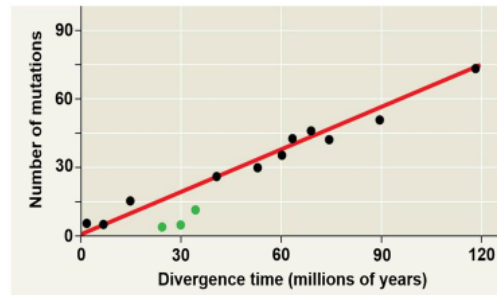
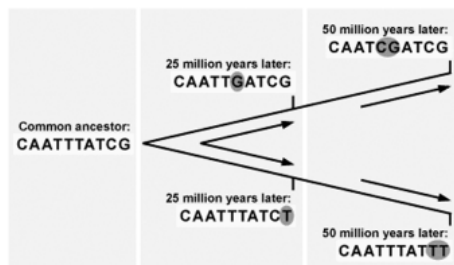
Molecular Data

- ▶ Molecular comparisons
 - ▶ Usually (rRNA or mtDNA)
 - ▶ DNA-DNA Hybridization
 - ▶ Restriction maps
 - ▶ DNA Sequence analysis



Using Molecular Clocks to Track Evolutionary Time

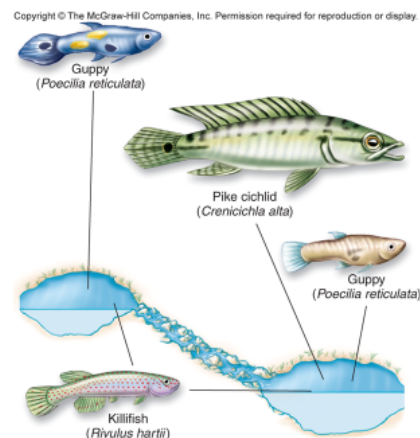
Molecular clock: Using a relatively constant _____ in DNA and protein sequences to estimating the time of evolutionary change



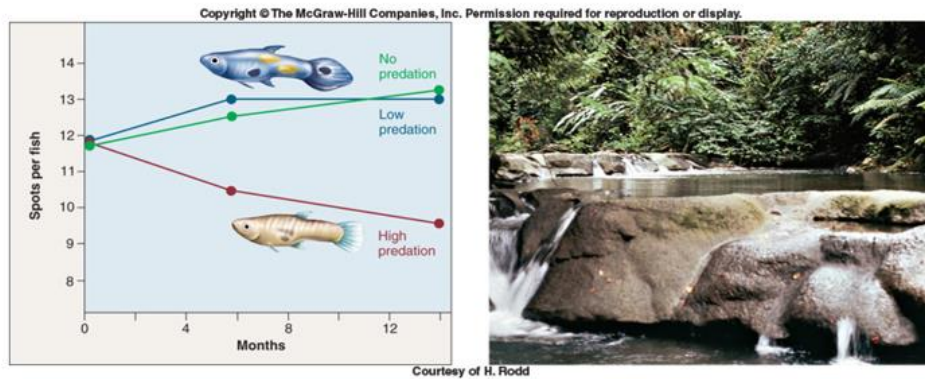
Evidence for Evolution

John Endler's guppy experiments show evolution under different environmental conditions

- ▶ Female guppies prefer brightly colored males
- ▶ Brightly colored males are easier to spot by predator (pike)
 - ▶ No predator = no pressure = bright males
 - ▶ Predator present = drab coloration



Evidence for Evolution



Check Your Understanding

Describe the differences between Lamarck's and Darwin's theories on the means of evolutionary change.

Check Your Understanding

The remnants of pelvic bones in some whale species is an example of _____.

- a. convergent evolution
- b. a vestigial traits
- c. analogous structures
- d. embryology
- e. a transitional form

What is a Species?

_____ : species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups

- ▶ Between 3 million and 15 million species exist on earth
 - ▶ Only 1.8 million species have been described
 - ▶ 99% of all species that have existed are extinct!

Describing Species

Ways species differ

- ▶ Physical appearance
 - ▶ Adaptations
- ▶ Behavior
 - ▶ Mating behavior
 - ▶ Vocalizations
- ▶ Geographic range
- ▶ Habitat type
- ▶ Ecological niche
- ▶ DNA
 - ▶ Molecular differences

(a) Endangered species



(b) Not endangered



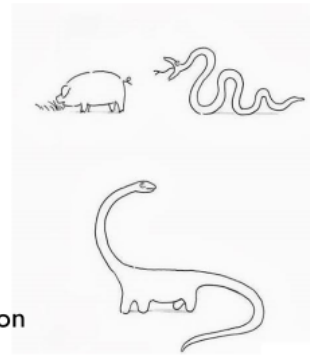
← California gnatcatcher

Black-tailed gnatcatcher →



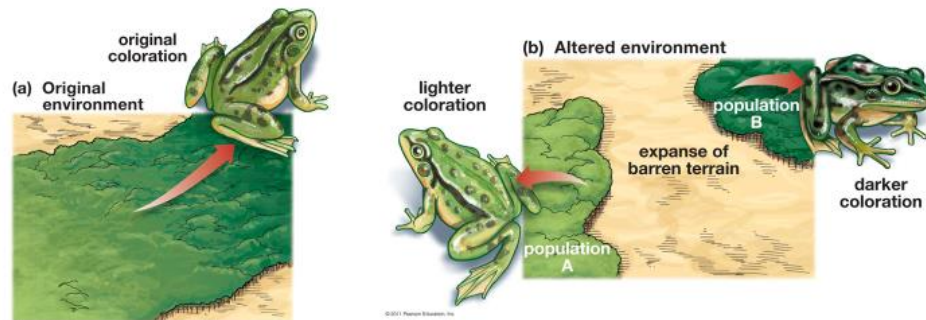
How do new species arise?

1. _____ of population into two or more separate populations that no longer interbreed
 - ▶ Geological event
 - ▶ Migration into a new area
2. Shift in _____ of separate populations
 - ▶ Genetic drift, natural selection, gene flow, sexual selection, mutation
3. Changes in allelic frequencies of populations results in differences that prevent individuals from each population from interbreeding with one another



Speciation with Separation

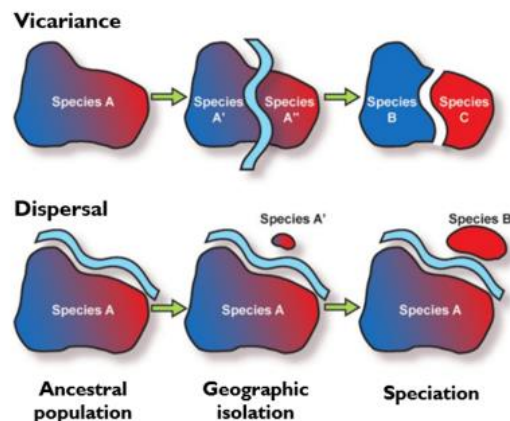
_____ **speciation**: speciation that results from the _____ of populations by a _____ that prevents interbreeding between populations

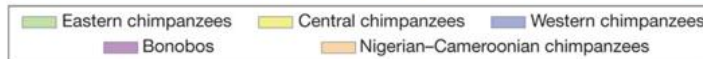
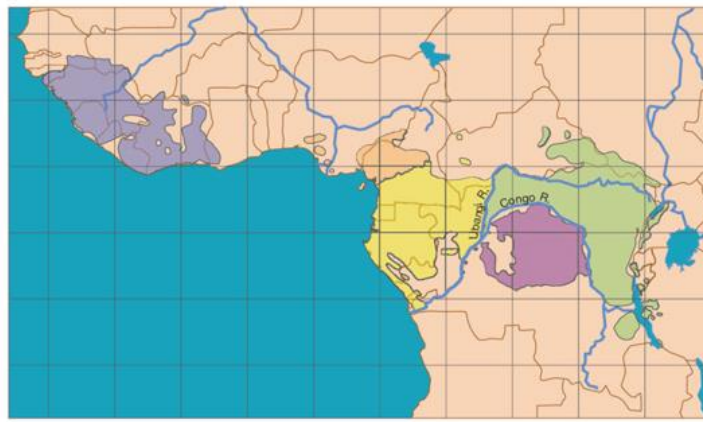


Vicariance vs. Dispersal

Vicariance: splitting of an organisms native range through the formation of a barrier to gene flow

Dispersal: movement of organisms to locations outside of their native range

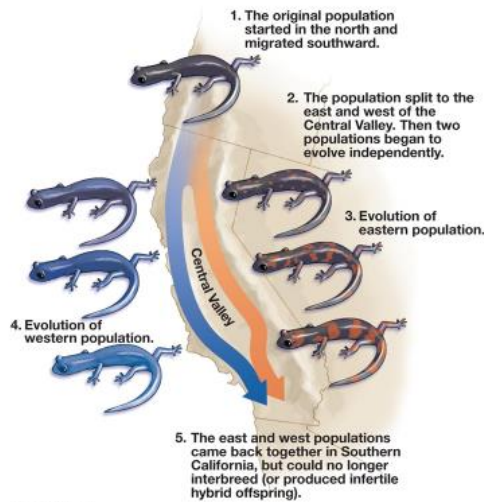




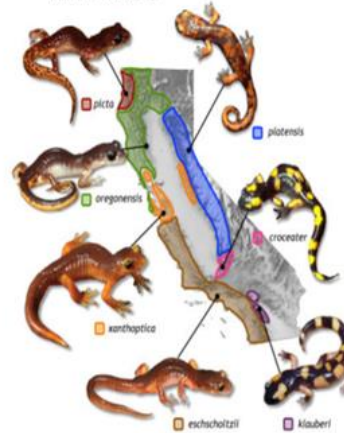
Chimpanzee



Bonobo



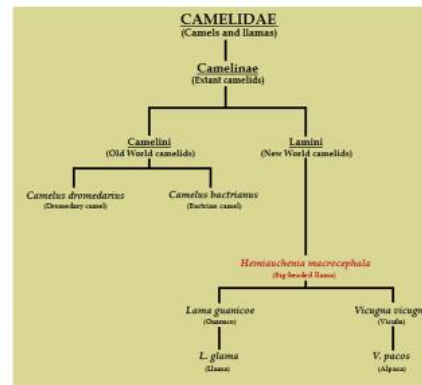
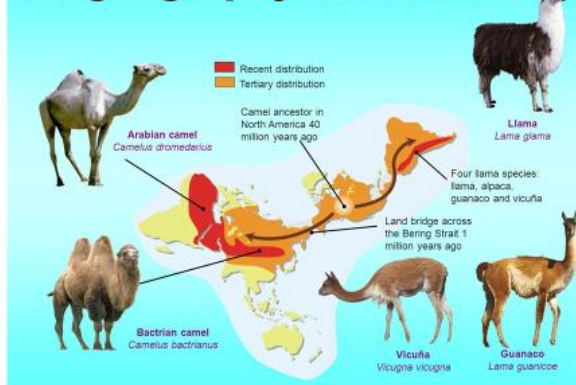
a) *Ensatina* ring species



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Biogeography of Camelidae: Dispersal

Biogeography-Camel Family

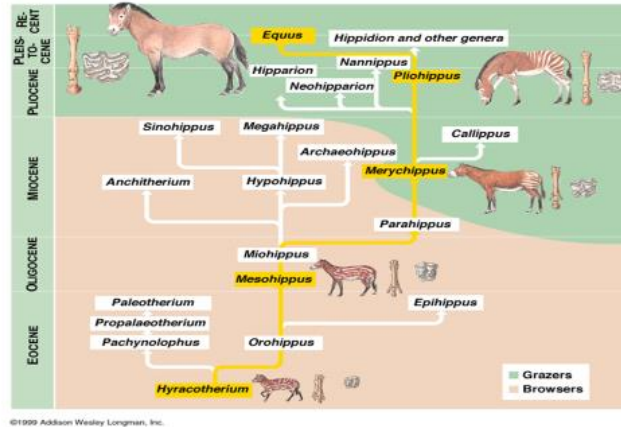


<https://www.youtube.com/watch?v=IJNoAE0UH2Y>

Evolutionary Trends

Evolutionary trends are not

- Interaction between organisms and their current environment

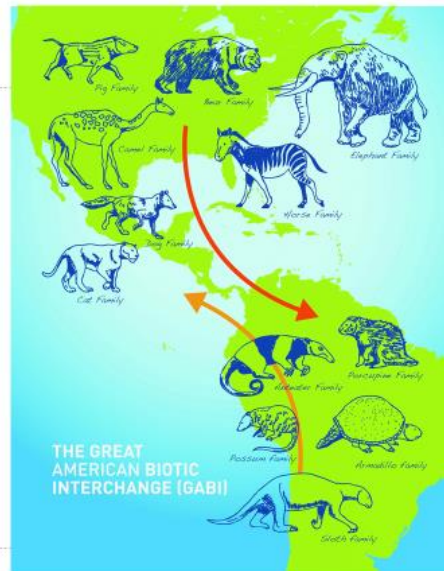


Biotic Interchange

Biotic interchange: when barrier between previously separated biotas breaks down, resulting in drastic changes to biodiversity

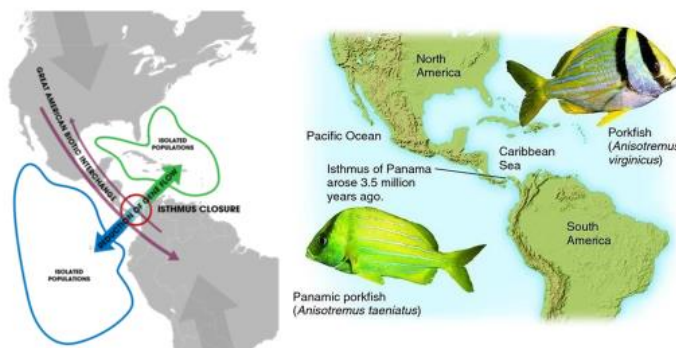
Great American Biotic Interchange

- Isthmus of Panama connected North and South America
 - Heading south: Bear, Cat, Camel, Horse, Elephant, Dog and Pig families
 - Heading north: Anteater, Porcupine, Armadillo, Sloth, and Possum families



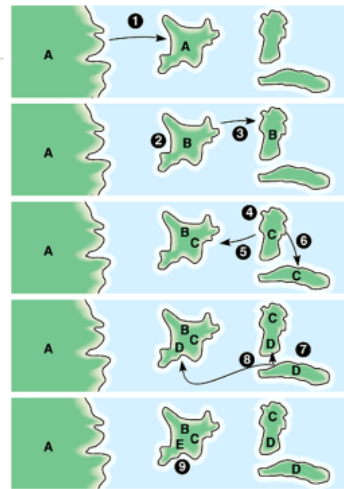
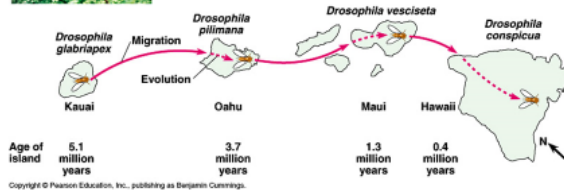
Biogeography: Vicariance

- Connection of North and South America at the Panama isthmus led to the vicariance of the pork fish populations.



Allopatric Speciation

- Common in island chains (archipelagos)
- Ex. *Drosophila* on Hawaiian Islands

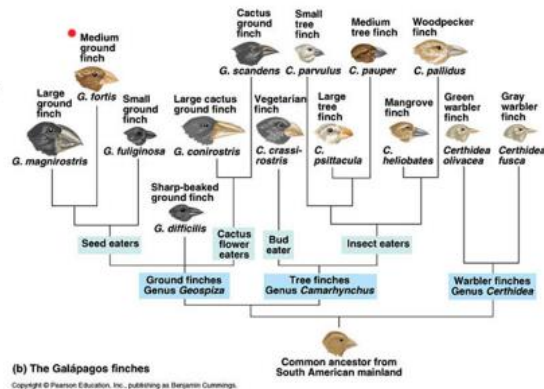


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Adaptive Radiation

Adaptive radiation: process in which organisms _____, especially when exposed to a new environment with different challenges, new resources, and available niches

- After mass extinction events
 - Cambrian explosion
 - Mammal diversification after Cretaceous mass extinction 65 Mya
- Archipelagos
 - Galapagos finches
 - Hawaiian silverswords



Speciation Without Separation

- speciation:** Speciation without geographic separation
- Ecological niche:** The _____ of a species within its ecosystem.
 - Includes the interaction with all other organisms

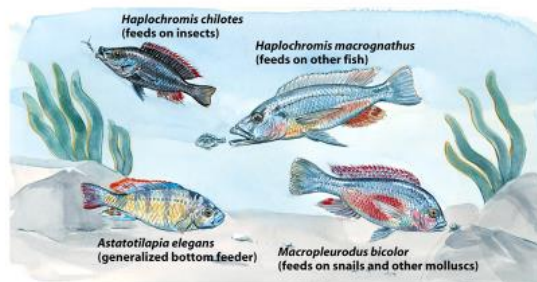
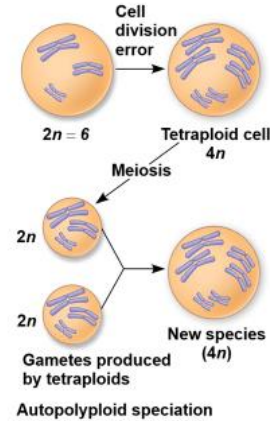
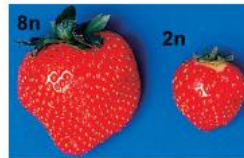
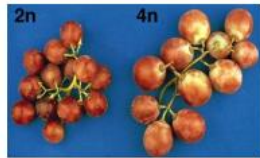


Figure 18-10 Discover Biology 3e
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Ployploidy

Ployploidy: a _____ of a set of chromosomes that results from an accident during cell division

- Common in plants due to self pollination (asexual reproduction)
- Leads to instantaneous speciation
- Can lead to larger crop sizes
 - Large apples, pears and grapes are tetraploid
 - Large strawberries are octoploid

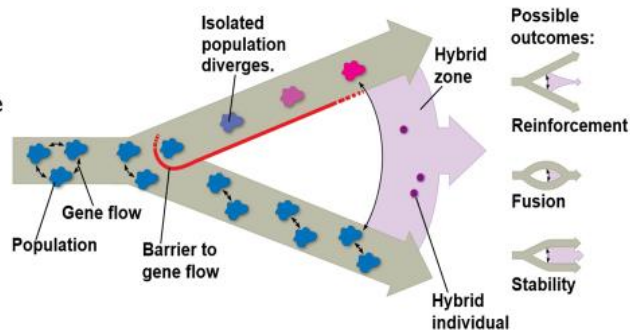


Hybrid Zones

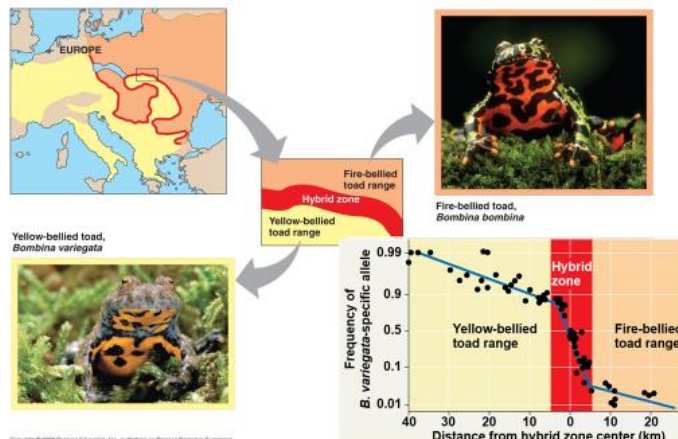
Regions where two different species meet and mate

Three possible outcomes:

- Reinforcement:** reproductive barriers are strengthened
 - Hybrids diminish
- Fusion:** reproductive barriers are weakened
 - Two species fuse into one
- Stability:** Hybrid individuals persist



Hybrid Zones

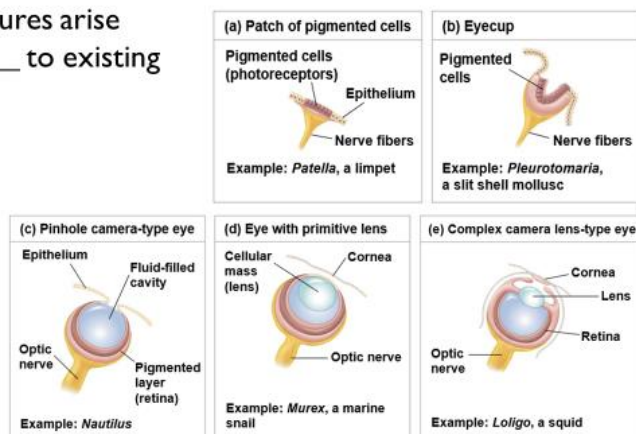


How do evolutionary changes arise?

- ▶ Evolutionary novelties
- ▶ Exaptations
- ▶ Evolution of genes that control development (“Evo-Devo”)
 - ▶ Changes in spatial pattern
 - ▶ Changes in rate and timing of development

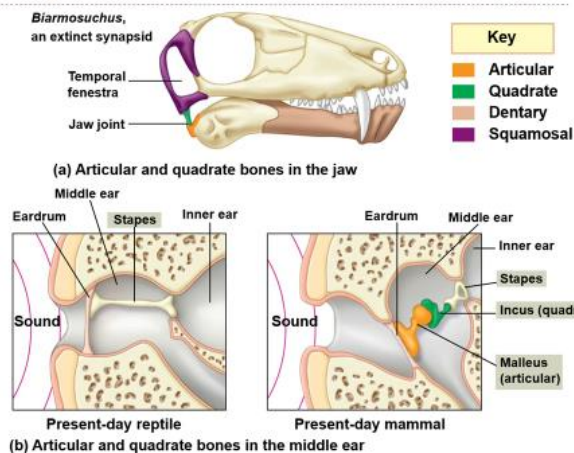
Evolutionary Novelties

- ▶ Novel and complex structures arise from _____ to existing structures



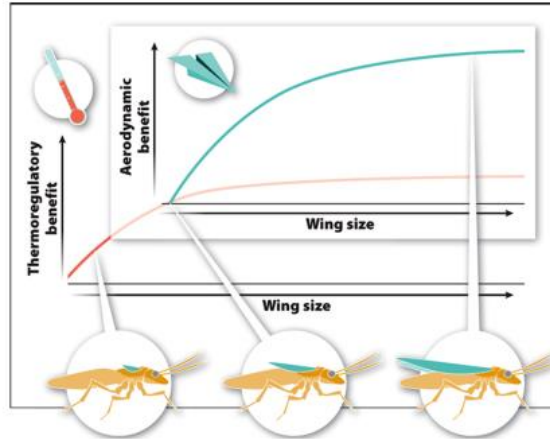
Exaptation

- ▶ Structures that evolved for one function but become _____ for another function.
- ▶ Inner ear bones in mammals
- ▶ Feathers in birds



Exaptation

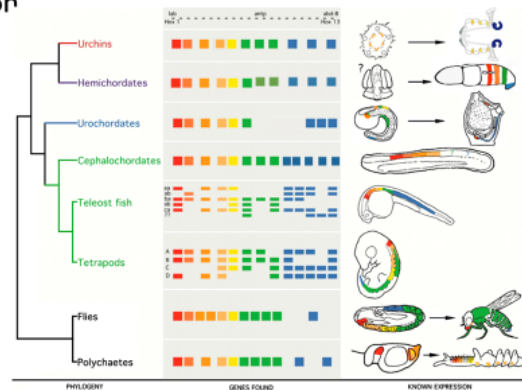
1. Tiny wing nubs provide a thermoregulatory benefit, which leads to the selection for greater nub size.
2. At an intermediate size wing nubs provide an aerodynamic benefit
3. Greater wing size is selected for due to aerodynamic benefit



Evolutionary Development (Evo-Devo)

Study of the evolution and modification of development processes (ontogeny) of various organisms

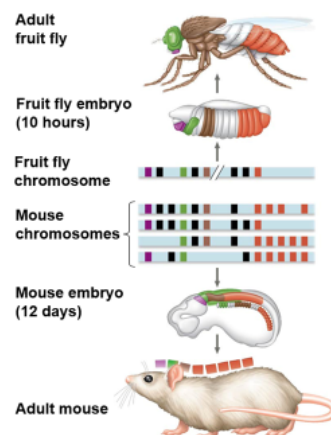
- ▶ **Homeobox genes:** 180 base pair DNA sequence that codes for a section of the protein that controls gene regulation
- ▶ “Tool kit”



Evolutionary Development (Evo-Devo)

_____ : type of homeobox gene that determines body plan in animal embryos

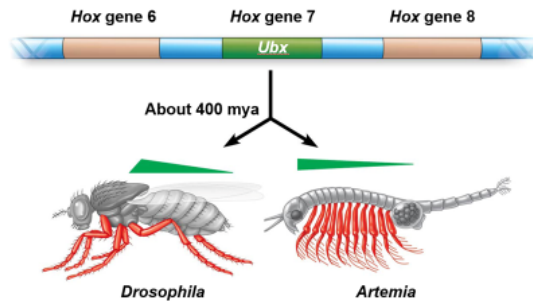
- ▶ Nearly identical in all animals



Evolutionary Development (Evo-Devo)

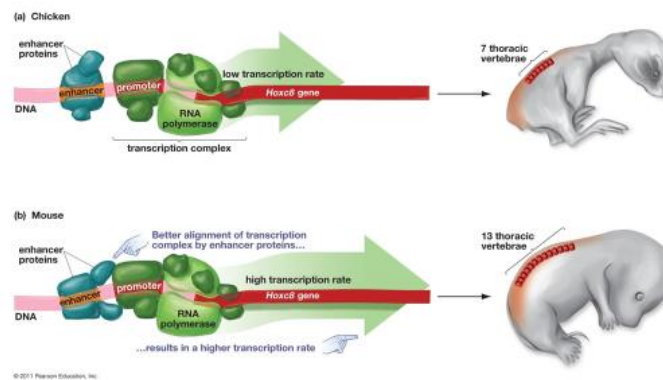
Change in gene expression

- ▶ Alteration of developmental gene can cause significant morphological changes
 - ▶ Insects from crustacean-like ancestor



Gene Expression: Promoters and Enhancers

- ▶ Transcription factors (enhancer and promoter proteins) can increase or decrease the rate of transcription, which can increase or decrease gene expression.
 - ▶ Greater expression of *Hoxc8* gene results in more thoracic vertebrae in mice compared to chickens



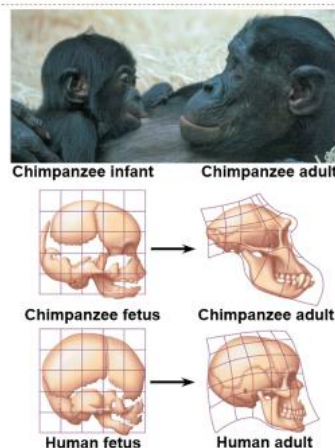
Evolutionary Development (Evo-Devo)

Heterochrony: evolutionary change in the _____ of developmental events

- ▶ “Different time”

Examples:

- ▶ Growth rate of skull bones in human and chimpanzee infants
- ▶ Growth of phalanges in bats
- ▶ Decreased growth rate in pelvic bone of whales



Evolutionary Development (Evo-Devo)

Paedeomorphosis: when an organism reaches sexual maturity while retaining _____ characteristics

- ▶ Mexican salamander
- ▶ Birds?

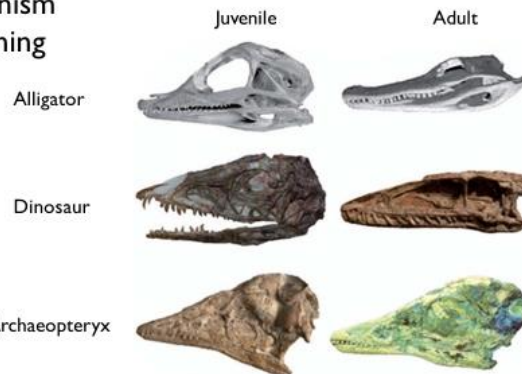
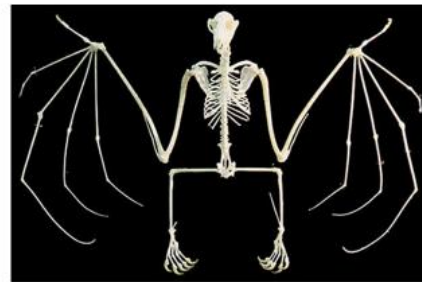
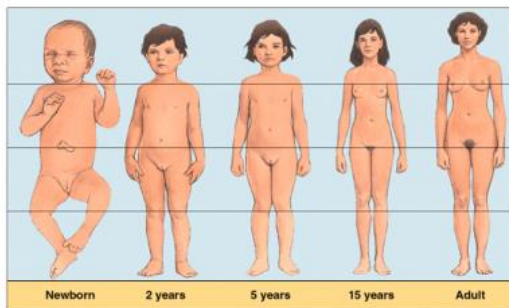


Image modified from Bhullar et al. 2012. Nature, Vol. 487 Issue 7406, p223-226

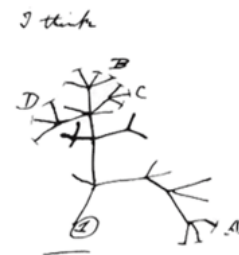
Evolutionary Development (Evo-Devo)

Allometric growth: a change in the rate of growth of some body parts relative to other body parts



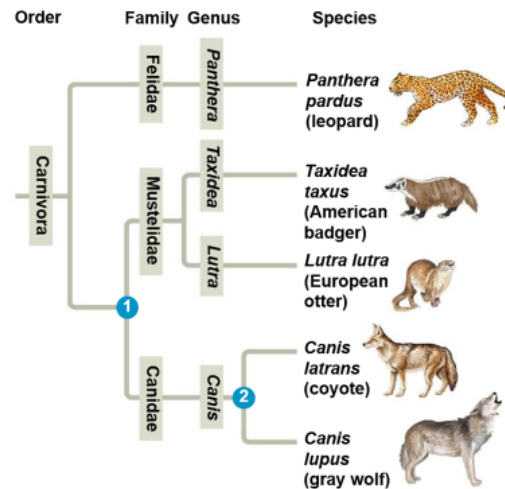
Organizing Evolutionary Relationships

- ▶ **Phylogeny:** the evolutionary history of a species
- ▶ **Phylogenetic tree:** hypothesis about evolutionary relationships where branch length often represents amount of evolutionary change or time
- ▶ **Cladistics:** an analytical approach to classification that groups organisms based on shared characteristics
- ▶ **Cladogram:** a phylogenetic tree formed using cladistics methods, which only infers the relationship between organisms based on shared traits



Phylogenetic trees can be used to depict taxonomic classification and evolutionary relationships

- 1 = Last common ancestor between Mustelidae and Canidae
- 2 = Last common ancestor between coyotes and gray wolves

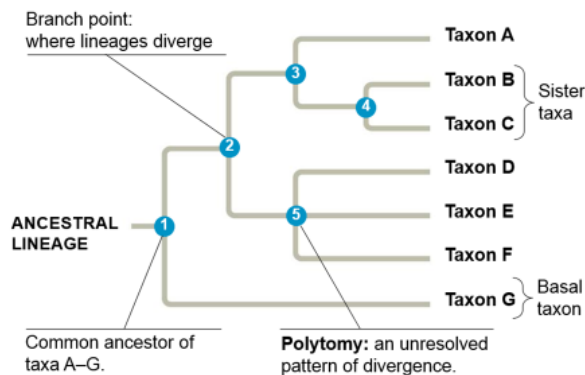


Understanding a Phylogenetic Tree

_____: organisms that share an immediate common ancestor

_____: lineage that diverged early in the phylogenetic history

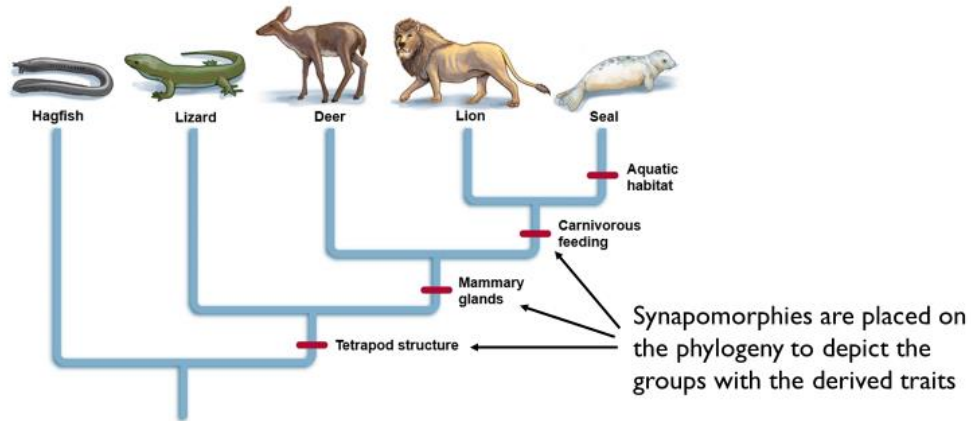
- ▶ Patterns of descent, **not** phenotypic similarity
- ▶ Branching does not always signify age of particular species
- ▶ Taxon did not evolve from sister taxon



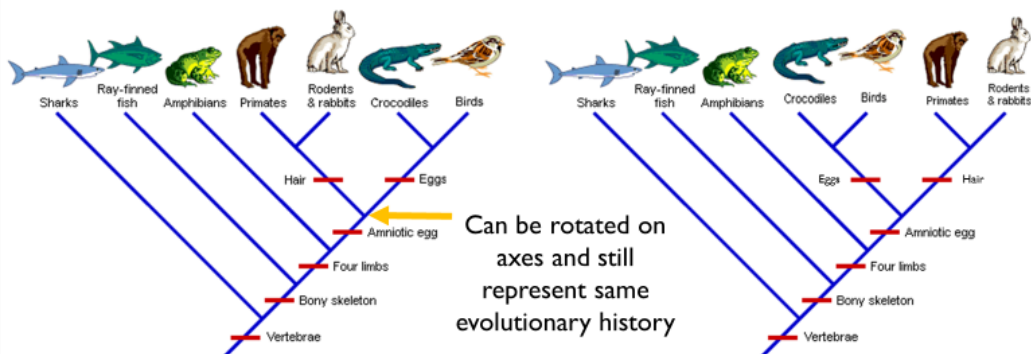
Phylogeny Terms

- ▶ **Ancestral trait:** a characteristic that existed in an ancestor
 - ▶ **Symplesiomorphy:** an ancestral trait shared by two or more taxa
- ▶ **Derived trait:** a characteristic that is a modified form of an ancestral trait
 - ▶ _____: a shared, derived characteristic
 - ▶ Used to _____
- ▶ **Clade:** a group of species used in cladograms and phylogenetic trees, which contains one ancestor and _____
 - ▶ _____
- ▶ **Outgroup:** a taxa that diverged before all other taxa in the phylogenetic tree, which is used for reference

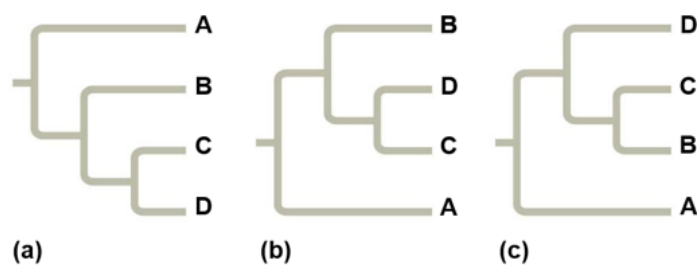
Interpreting Phylogenetic Trees



Interpreting Phylogenetic Trees

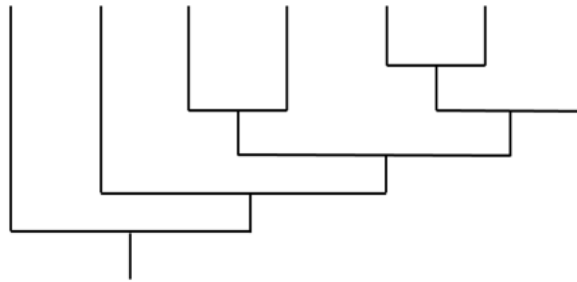


Interpreting Phylogenetic Trees



Check Your Understanding

Write the names of the listed organisms in the correct location in the phylogeny below. Place the synapomorphies in the correct location on the phylogeny.



Species list

Bat
Wolf
Coyote
Bear
Eagle
Beaver
Mouse

Adaptations

Feathers
Backbone
Mammary glands
Carnassial teeth (flesh eating teeth)
Continuously growing incisors

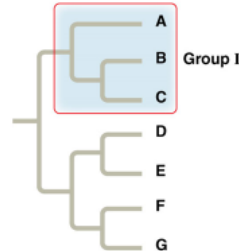
Phylogenetic Groupings

Monophyletic – Clade that includes ancestor and ____ of its descendants.

Paraphyletic – Grouping that includes ancestor and ____, but not all, of it's descendants.

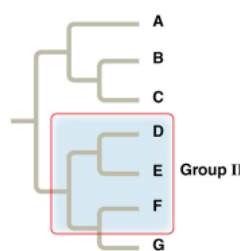
Polyphyletic – Grouping that lacks a most recent ____.

(a) Monophyletic group (clade)

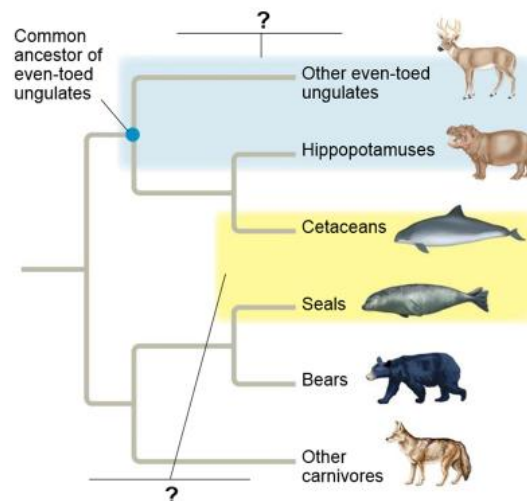
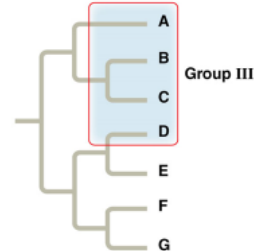


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(b) Paraphyletic group

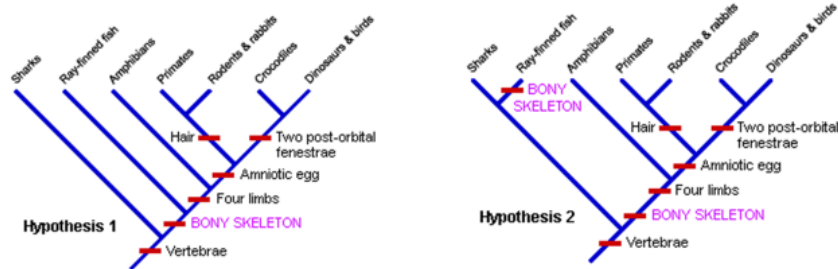


(c) Polyphyletic group



Constructing a Phylogeny

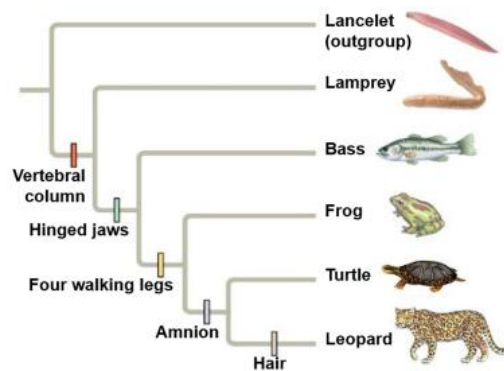
- ▶ **Maximum Parsimony:** adopting the simplest explanation that is consistent with the facts.
- ▶ Tree which requires the _____ or the number of times a derived trait appears within the phylogenetic tree



Cladistics and Cladograms

CHARACTERS	TAXA					
	Lancelet (outgroup)	Lamprey	Bass	Frog	Turtle	Leopard
Vertebral column (backbone)	0	1	1	1	1	1
Hinged jaws	0	0	1	1	1	1
Four walking legs	0	0	0	1	1	1
Amnion	0	0	0	0	1	1
Hair	0	0	0	0	0	1

(a) Character table



(b) Phylogenetic tree

Constructing a Cladogram

Characters	Taxa					
	Millipede	Body Louse	Beetle	Assassin Bug	Bee	Ant
Wings	0	0	1	1	1	1
3 body regions	0	1	1	1	1	1
Social	0	0	0	0	1	1
Complete Metamorphosis	0	0	1	0	1	1
Mobile Head	0	0	0	0	1	1
Flattened Body	0	1	0	0	0	0

Constructing a Cladogram

Construct a cladogram using the character table on the previous slide.

