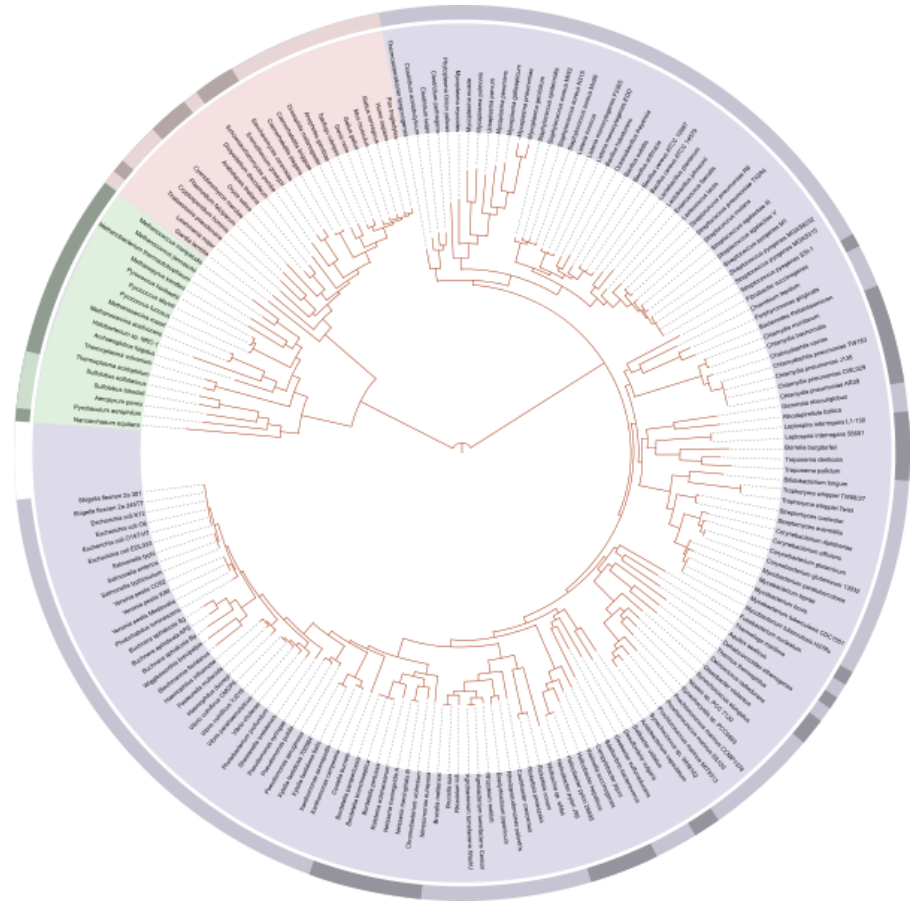


Today in Astronomy 106: biological evolution

- ❑ Structural and molecular characterization of life's diversity.
- ❑ Details of the changes in diversity through geological time.
- ❑ Theories of evolution: natural selection, or Darwin Wins.



The [Tree of Life](#). Zoom way in...

Phylogeny: characterization of life's diversity

To go with our accurate measures of time, biologists characterize the structure and, nowadays, the **genetic content** of organisms, that we may identify relationships in the progress of the evolution of species.

❑ Structural classification: Carl Linneaus, early 1700s.

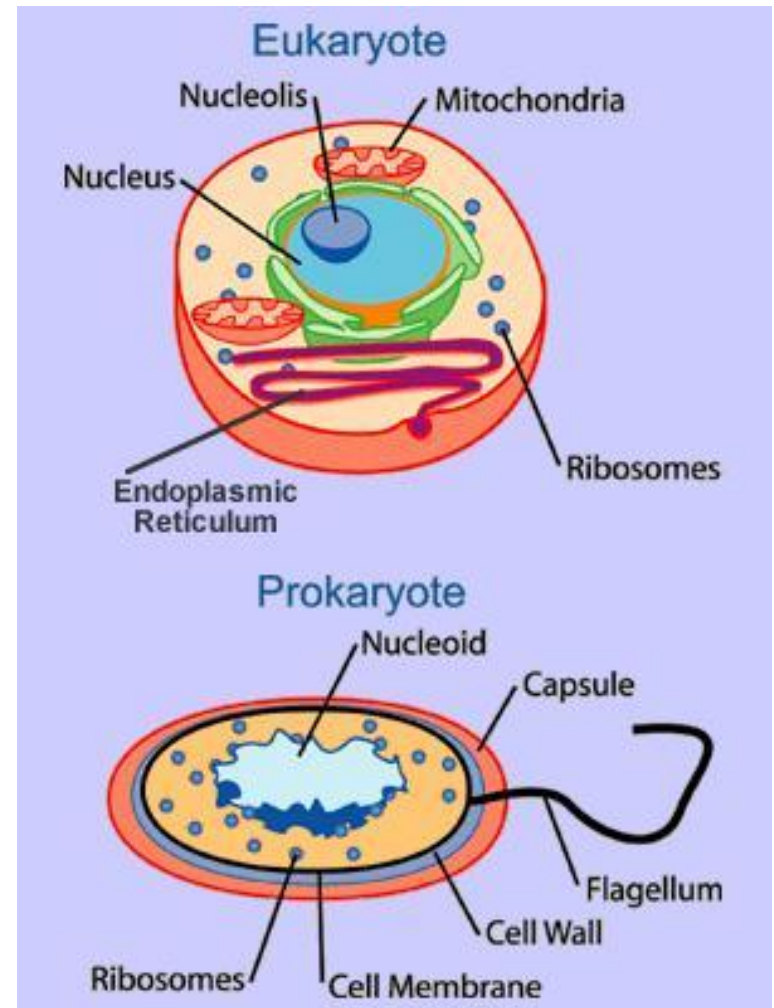
❑ Broadest classification: **domain**.

Based on distinction between cells that have organelles like nuclei, mitochondria, etc. (**eukaryotes**) and those that don't (**prokaryotes**, divided into **bacteria** and **archaea**).

- Archaea identified first among the extremophiles; later found genetically to be much different from bacteria in their ribosomal RNA.
- Still have essentially the same genetic code, though.

Phylogeny (continued)

- ❑ Evolutionary sequence
archaea-bacteria-eukaryotes
seems clear:
- complexity and diversity increase in this direction;
 - some organelles, particularly mitochondria and plastids, look for all the world like prokaryotes assimilated into the structure of eukaryotes.



Nicholas Short ([Federation of American Scientists](#))

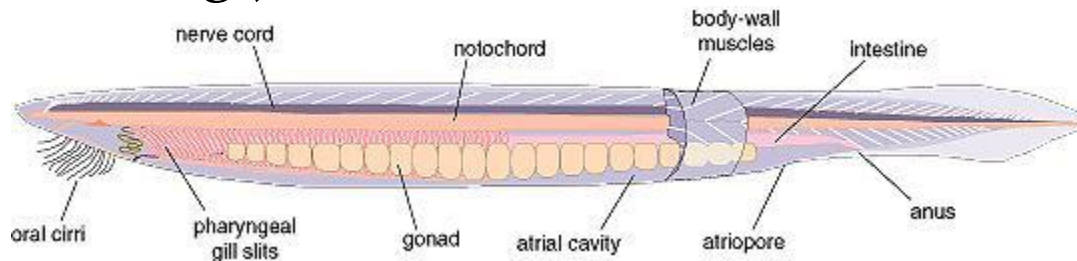
Phylogeny (continued)

- ❑ All types so far can either manufacture their own nutrients out of monomers in the environment (**autotrophs**, the forerunners of plants), or need to eat processed nutrients or other life forms (**heterotrophs**, the forerunners of animals).
- ❑ The eukaryotes are most diverse, and thus further sorted into **kingdoms**:
 - **animalia**: multicellular heterotrophs
 - **plantae**: multicellular autotrophs
 - **fungi**: multicellular symbionts
 - **protista**: unicellular eukaryotes.

(Use of Latin is traditional in phylogenetic names.)

Phylogeny (continued)

- ❑ Each kingdom is further sorted into **phyla**.
 - For example, kingdom animalia is divided into 35 different phyla.
 - You belong to phylum **chordata**, those animals with spinal cords (though not necessarily spines).
 - Plants are usually divided into 11 phyla, fungi into 6.
 - Phyla are often reclassified into higher or lower categories (e.g. slime molds, formerly a phylum of fungi).

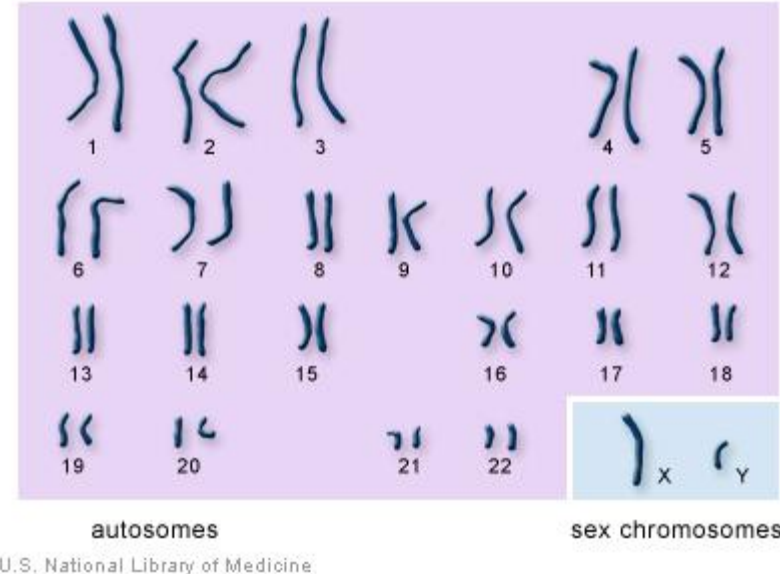


Branchiostoma lanceolata,
ancestor of the lamprey.
[Am. Scientist](#)

Phylogeny (continued)

- Within kingdoms comes an internal, genetic differentiation: **ploidy**, the number of copies of the nucleic-acid structures each cell contains.
 - Nucleic acid sequences that code proteins: **genes**.
 - Structures containing genes: **chromosomes**.
 - Lifeforms with only one copy of each chromosome: **haploids**.
 - Containing two: **diploids**.
You are a diploid.

Karyotype of a typical human cell, which contains 23 pairs of chromosomes. [NLM/NIH](http://nlm.nih.gov)



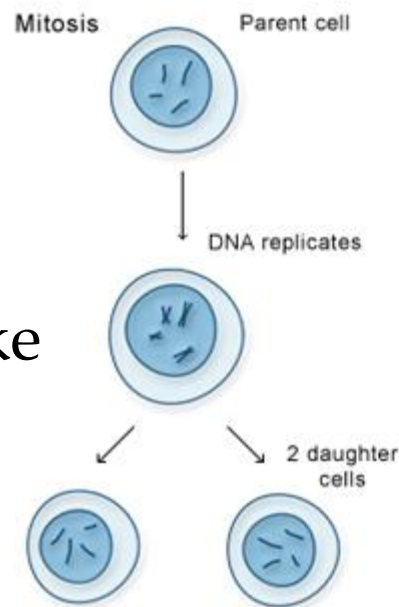
Phylogeny (con't)

❑ Importance: this leads to a non-mutation means of having reproduction lead to greater diversity of each multiploid lifeform. We call this, of course, **sexual reproduction**.

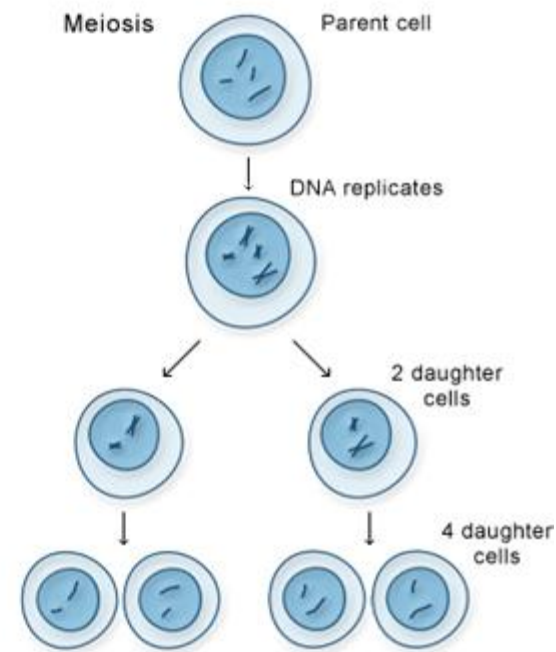
- Meiosis, which creates sperm and egg cells (or spores), essentially shuffles DNA

❑ **Asexual reproduction** with haploids is more like a copy machine

- Mitosis exactly replicates the original cell



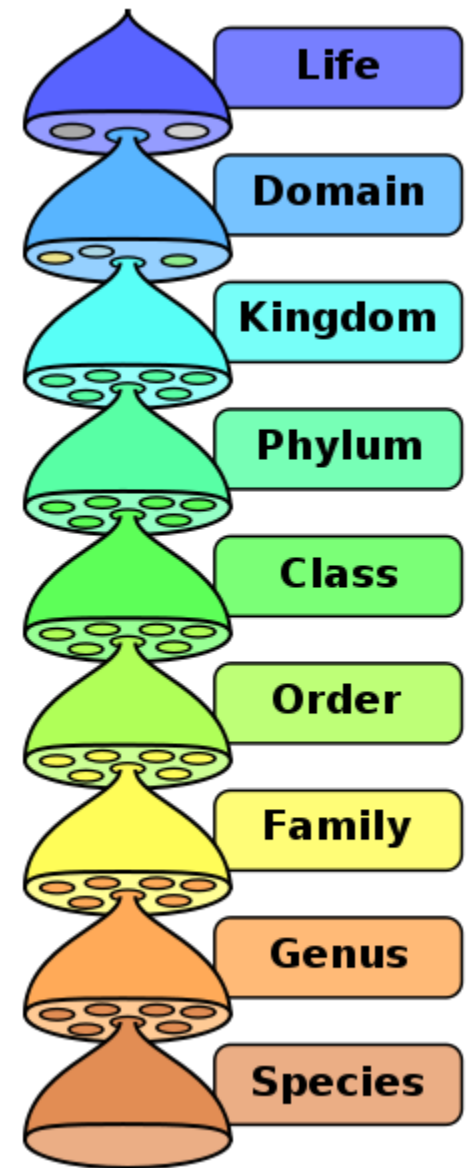
U.S. National Library of Medicine
[NML/NIH](#)



Phylogeny (continued)

- ❑ And so on, down to genus and species.
Examples:

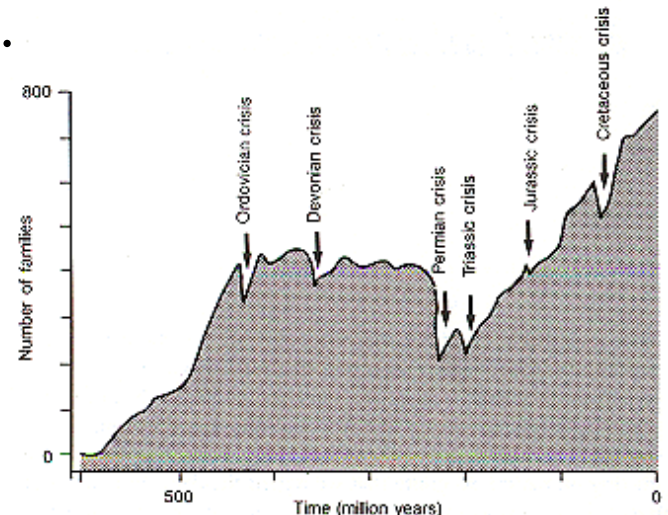
Human	Giant sequoia redwood
Eukarya	Eukarya
Animalia	Plantae
Chordata	Pinophyta
Mammalia	Pinopsida
Primatae	Pinales
Hominidae	Cupressaceae
Homo	Sequoiadendron
sapiens	giganteum



Peter Halasz, [Wikimedia Commons](#)

Categories in the fossil record

- ❑ **Kingdoms** emerge in the fossil record about 2 Gyr ago with the appearance of eukaryotes.
 - Possibly some diploids already!
 - Possibly bacteria and archaea diverged earlier if only we could sequence the RNA of 3.6 Gyr old lifeforms...
- ❑ **Phyla** emerge in the Cambrian, 550 Myr ago; most phyla still dominated by ocean dwellers.
- ❑ **Families** have been subject to booms and busts, with five major mass extinctions in the past. Example at right: families of mollusks ([Raup 1986](#)).



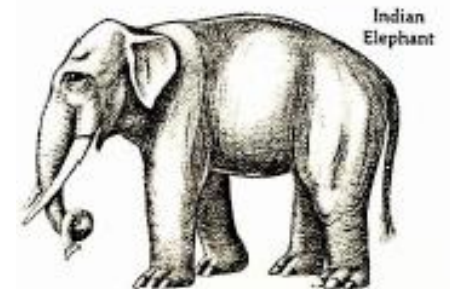
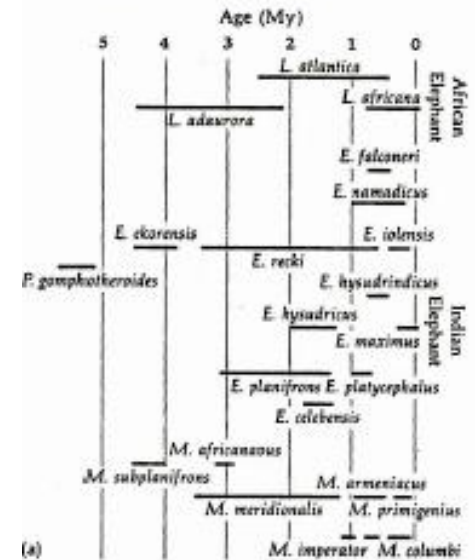
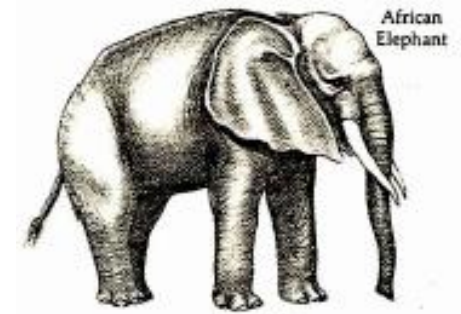
Categories in the fossil record (continued)

- The vast majority of families, and species, of organisms that have ever lived, are now extinct. (!)
- Some mass extinctions correlated with major, individual, meteoritic impacts on Earth. (!!)

❑ **Species** seem to develop suddenly, rather than gradually diverging from earlier ones (“breaks” in the fossil record).

- May be influenced by incompleteness of fossil finds and ambiguity of classification.

From Stephen Jay Gould, *Wonderful Life*.



Phylogenetics

The modern ability to determine the sequence of nucleotides in complete **genomes** has added a lot to the classification:

- ❑ Genetic complexity grows with structural complexity: bacteria have $\sim 10^3$ genes, single-cell eukaryotes 10^4 - 10^5 .
- ❑ All organisms possess a lot of non-coding, or **junk**, DNA: stretches of nucleic acid that does not lead to proteins.
 - Useful, because mutations in junk DNA do not affect the organism, allowing us to study the mutation rate separately from the fate of the species.
 - In turn, this has allowed estimates of the time scale of DNA evolution. For example, it suggests that the lineage of chimps and humans diverged 5-7 Myr ago, consistent with fossil evidence (~ 6 Myr ago).

Phylogenetics (continued)

- Number of genes does not necessarily connote complexity: e.g. human DNA has 3×10^9 base pairs, and newt DNA has about 10^{11} , mostly junk.
- Genetic similarity does not necessarily go with structural similarity.
 - Example: humans (family Hominidae) have 99.4% non-junk DNA overlap with chimpanzees (family Pongidae), apparently greater overlap than gorillas, and almost as close as Neanderthals at 99.5%.

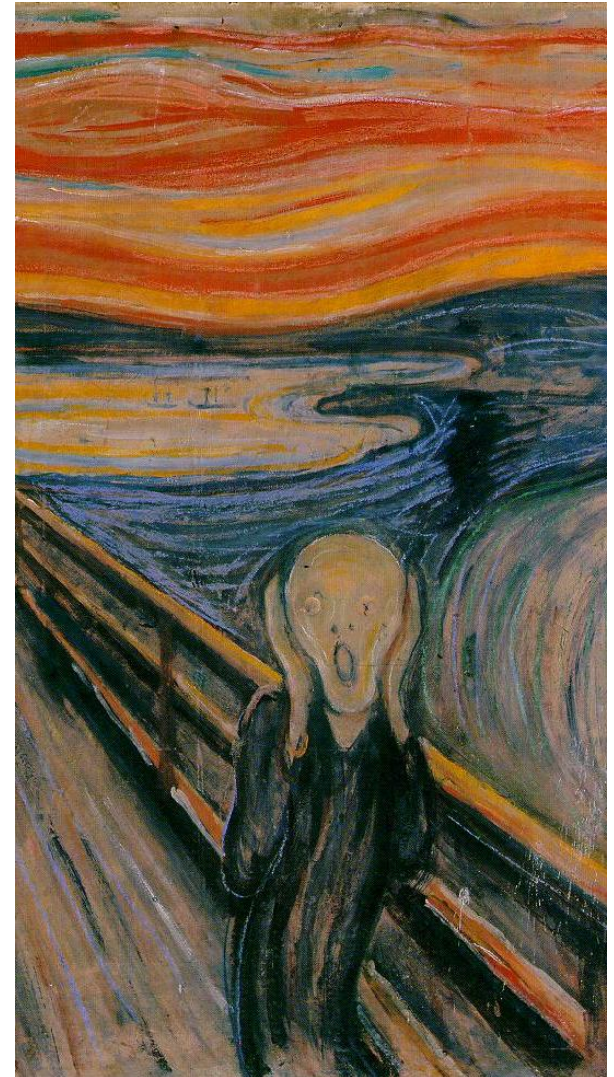
[Scientific American](#)



Mid-lecture Break

- ❑ Homework #3 is on WeBWorK; due tomorrow by midnight.
- ❑ **Exam #2** is this Friday, 10 June 2011 in a 75-minute span of your choice between 10 AM and 6 PM.
- ❑ A Practice Exam is up.
- ❑ Pre-Exam office hours tomorrow: 1-3 PM in B&L 477.

Edvard Munch, *The Scream* ([Munch Museum](http://munchmuseum.no))



Theories of biological evolution

An origin of species in evolution was first suspected in the 1700s, after Linnaean classification had become widespread.

First : **Lamarck** (France, 1744-1829): evolution by adaptation.

- ❑ Environment forces individual lifeforms to adapt.
- ❑ Individuals that succeed have adapted well to the conditions – climate, food supply, etc. -- with which they are faced.
- ❑ Beneficial adaptations are thereafter inherited: species descend from these individuals.
- ❑ Nowadays of course it's easiest to shoot this down by noting that individuals can't adapt their DNA, and that DNA governs inheritance, though other objections are not hard to come by.

Suppose you didn't know about nucleic acids and the genetic code. What are some examples that you could cite to refute Lamarck's theory of evolution?

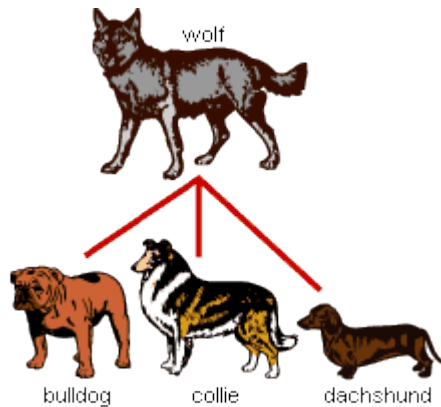


Lamarck

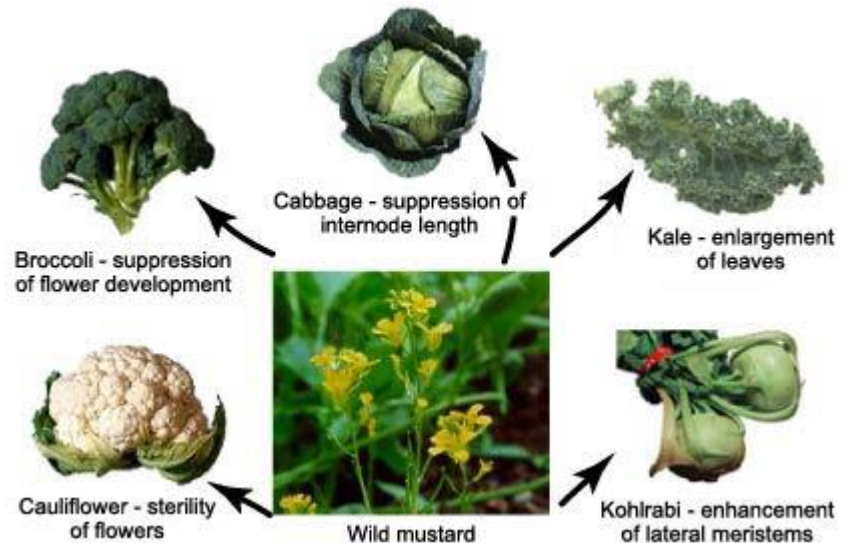
Artificial Selection

❑ At the time of Darwin, society was already familiar with the idea of artificial selection

- Human engineered breeds of dogs as different as Collies and dachshunds
- Produced a variety of edible (and delicious) crops



[UC Berkley](#)



Theories of biological evolution (continued)

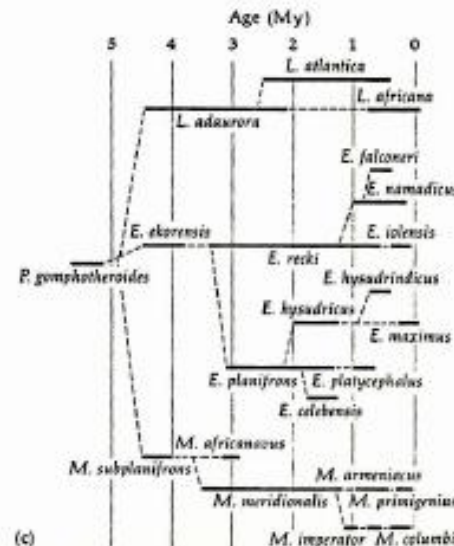
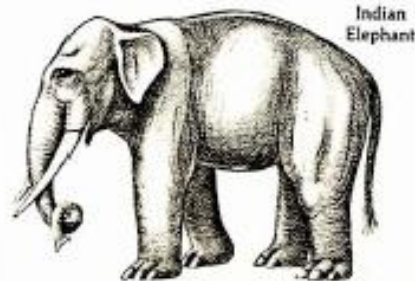
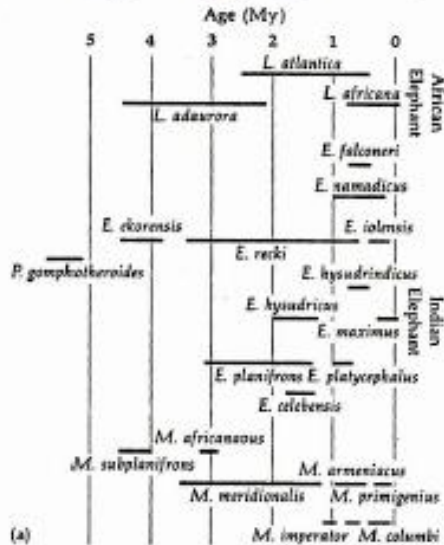
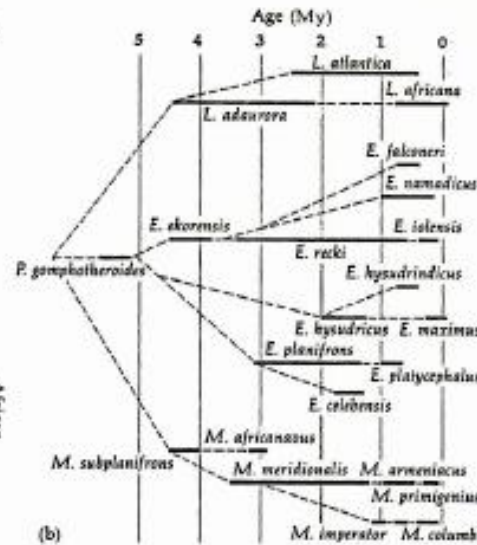
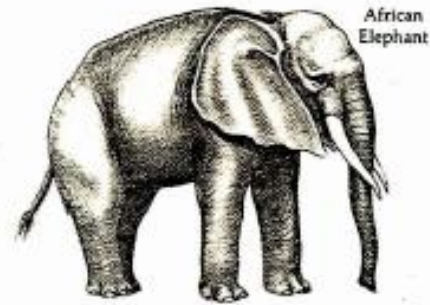
Darwin and Wallace (Britain, mid 1800s): descent with modification (evolution) driven by natural selection.

- ❑ There are random, inborn variations among lifeforms of a given type. Mutation or sexual reproduction can produce such variations.
 - Nowadays mutation is understood as DNA transcription errors, or external modification of DNA (e.g. by high-energy radiation).
- ❑ Such inborn variations can (obviously) be inherited.
- ❑ Most of these variations are neutral or harmful, but occasionally a variation is beneficial, suiting the lifeform better to its circumstances.

Theories of biological evolution (continued)

- ❑ If a beneficial variation makes it easier for a lifeform to survive or reproduce, the variation will appear in large numbers in a time short compared to the geological timescale.
 - Thus *species* evolve; individuals *develop*.
 - Small variations could produce gradual evolution and differentiation of species; more favorable variations might produce rapid takeover of the new species and an apparent break in the fossil record.
 - Which is more prevalent is still debated: gradualism *vs.* punctuated equilibrium, the latter exemplified by the theories by Stephen Jay Gould.

Theories of biological evolution (continued)



Fossil record of elephants, compared to gradualism (upper) and punctuated equilibrium (lower). From Gould, *Wonderful Life*.

Theories of biological evolution (continued)

The theory of evolution by natural selection has been very successful, and has, in particular, stood up remarkably well against the findings of molecular biology and genetics.

- ❑ Consistent with many experiments based on artificial selection (breeding), as Darwin noted.
 - ❑ Seems a natural successor to RNA World, which is the most consistent explanation of the emergence of biomolecules, and in which natural selection functions.
 - ❑ Consistent with genetics, including mutation timescales measured from junk-DNA variation.
 - ❑ Consistent with the existence of junk DNA, gene duplication in different species! Other, more “guided” theories of evolution (and creation) are not.
-

True or false: people who move to southern California and adapt to hot weather are an example of evolution.

True or false: almost all species that ever lived are now extinct.

True or false: extinction represents a failure of evolution.

True or false: A “struggle for existence” or natural catastrophe, like an asteroid impact or an ice age, is needed to cause natural selection.

True or false: evolution always selects more complex, intelligent organisms for survival.