Classification

Classification

How would you describe this image?

What is it similar to?

Classification

Classification is the process by which biologists group and categorize organisms by common characteristics

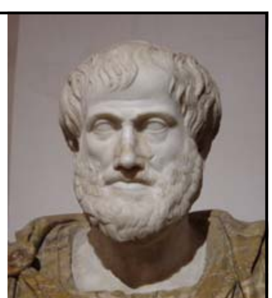
Early civilizations did not classify organisms by ancestry because it was not believed organisms evolved.

Instead things were classified as being male or female, dangerous to eat or safe, easy to catch and eat etc.

Aristotle created a classification system that was divided into two groups-
plants and animals.

He then divided the plants further by their size

Animals were divided by where they lived-
air, water, or land.



Aristotle had the right idea in that he grouped organisms by shared characteristics…. However he started down the wrong path when he decided to do so using their environment. However just because an organism lives in the same area it doesn't mean that they are related.

According to Aristotle which of these 3 animals would be classified more closely?

Classification can also be called taxonomy
A taxon is a group or level

Modern classification has its root in the work of **Carolus Linnaeus** who was the first to publish a system for grouping species according to shared physical (phenotypic) characteristics.

He gave each organism a unique two part name

This naming system is called **Binomial Nomenclature**

Many of his **Scientific Names** are still used today

Binomial Nomenclature:

Binomial nomenclature: A two part name that is unique to every type of organism

Names are *Italicized* (or underlined when hand written)
1. Genus: first name and is capitalized
2. species: second name, lower case and descriptive

All scientific names are in latin because it is a universal language that all countries can use

While common names can vary from place to place and language to language their scientific name is universal.

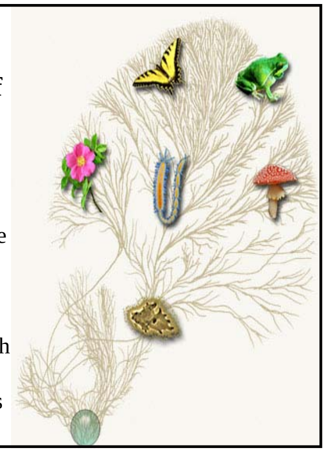
Examples of Names

Common name	Genus and species
1. Humans	1. *Homo sapiens*
2. Housefly	2. *Musca domesticus*
3. White Oak tree	3. *Quercus alboa*
4. Red Oak tree	4. *Quercus rubra*

Linnaeus' system was based mostly on the physical appearance of organisms.

These phenotypic groupings have since been revised to improve consistency with the Darwinian principle of common descent.

Molecular systematics, which uses DNA sequences, has driven many recent revisions in the phylogenetic tree.

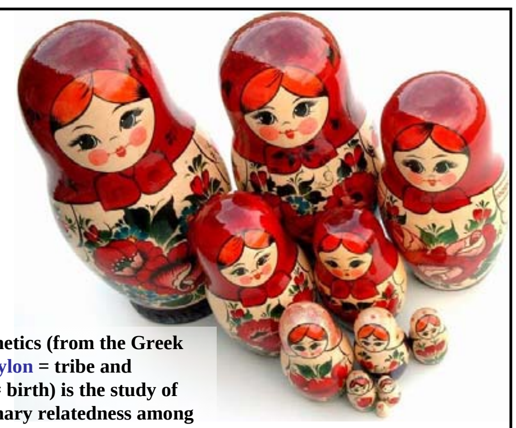


Evolutionary biology is focused on increasing our understanding of how selection pressures lead to new species.

A major goal of evolutionary biologists is to reconstruct the history of life on earth.

How did the first living things give rise to all of the other life forms on the planet?

This evolutionary history of a species or group of related species is called phylogeny.



Phylogenetics (from the Greek word phylon = tribe and genesis = birth) is the study of evolutionary relatedness among various groups of organisms.

Genotype determines phenotype

Organisms generally inherit genes in two ways:

1. Parent to offspring (vertical gene transfer)
2. When genes jump between unrelated organisms a common phenomenon in prokaryotes. (remember bacterial transformation)

If we can determine the order that a particular gene appears in a particular species we can determine their order and place in the family tree.

- **The fossil record is slanted toward species that existed for a long time, were abundant and widespread, and had hard shells or skeletons.**
- The **fossil record** is ordered by the layers that appear within sedimentary rocks.
  - These rocks record the passing of geological time.

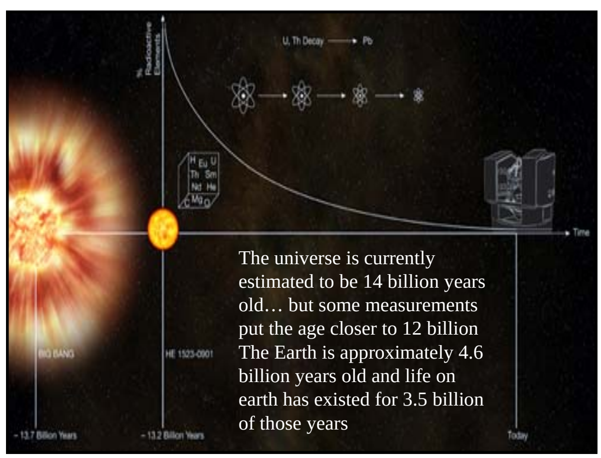
- The organic material in a dead organism usually decays rapidly, but hard parts that are rich in minerals (such as bones, teeth, shells) may remain as fossils.
- Under the right conditions minerals dissolved in groundwater seep into the tissues of dead organisms, replace its organic material, and create a cast in the shape of the organism.

Petrified Wood

- A substantial number of species that have lived have probably left no fossils
- Most fossils that formed have probably been destroyed
- Only a fraction of existing fossils have been discovered.

By comparing different sites, geologists have established a geologic time scale with a consistent sequence of historical periods.

- The order of fossils in rocks provides relative ages, but not *absolute* ages, (who died first but not the actual time when the organism died).



The universe is currently estimated to be 14 billion years old… but some measurements put the age closer to 12 billion The Earth is approximately 4.6 billion years old and life on earth has existed for 3.5 billion of those years

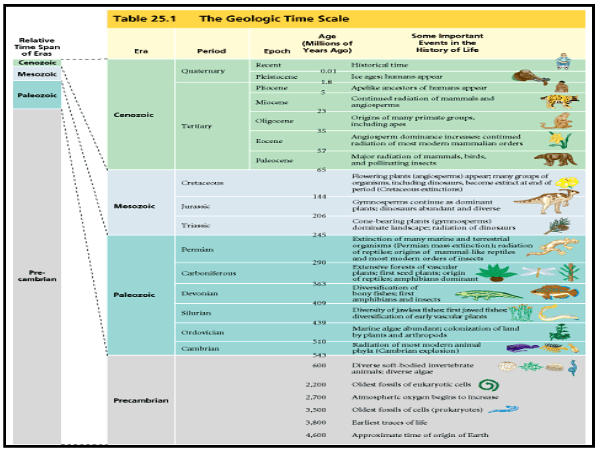


Table 25.1 The Geologic Time Scale

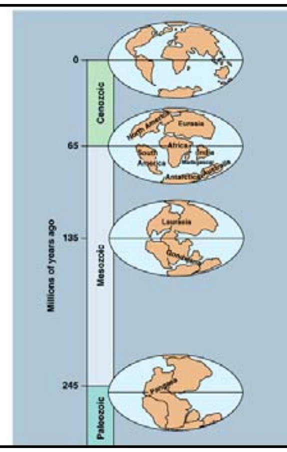
Relative Time Span of Eras	Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Cenozoic	Cenozoic	Quaternary	Recent	0.01	Historical time
Mesozoic			Pleistocene	1.8	Ice ages; humans appear
Paleozoic		Tertiary	Pliocene	5	Apelike ancestors of humans appear
Pre-cambrian			Miocene	23	Continued radiation of mammals and angiosperms
			Oligocene	35	Origins of many primate groups, including apes
			Eocene	57	Angiosperm dominance increases; continued radiation of most modern mammalian orders
			Paleocene	65	Major radiation of mammals, birds, and pollinating insects
	Mesozoic	Cretaceous		144	Flowering plants (angiosperms) appear; many groups of organisms, including dinosaurs, become extinct at end of period (Cretaceous extinctions)
		Jurassic		206	Gymnosperms continue as dominant plants; dinosaurs abundant and diverse
		Triassic		245	Cone-bearing plants (gymnosperms) dominate landscape; radiation of dinosaurs
	Paleozoic	Permian		290	Extinction of many marine and terrestrial organisms (Permian mass extinction); radiation of reptiles; origins of mammal-like reptiles and most modern orders of insects
		Carboniferous		363	Extensive forests of vascular plants; first seed plants; origin of reptiles; amphibians dominant
		Devonian		409	Diversification of bony fishes; first amphibians and insects
		Silurian		439	Diversity of jawless fishes; first jawed fishes; diversification of early vascular plants
		Ordovician		510	Marine algae abundant; colonization of land by plants and arthropods
		Cambrian		543	Radiation of most modern animal phyla (Cambrian explosion)
	Precambrian			600	Diverse soft-bodied invertebrate animals; diverse algae
				2,200	Oldest fossils of eukaryotic cells
				2,700	Atmospheric oxygen begins to increase
				3,500	Oldest fossils of cells (prokaryotes)
				3,800	Earliest traces of life
				4,600	Approximate time of origin of Earth

The history of Earth helps explain the current geographic distribution of species.

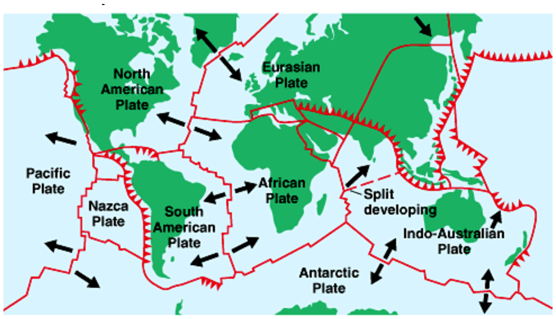
- For example, the emergence of volcanic islands such as the Galapagos opens new environments for founders that reach the outposts, and adaptive radiation fills many of the available niches with new species.
- On a global scale, continental drift is the major geographic factor correlated with the spatial distribution of life and evolutionary episodes such as mass extinctions and adaptive radiations.

- About 250 million years ago, all the land masses were joined into one supercontinent, **Pangaea**, with dramatic impacts on life on land and the sea.
  - Species that had evolved in isolation now competed.
  - The total amount of shoreline was reduced and shallow seas were drained.
  - The interior of the continent was drier and the weather more severe.
  - The formation of Pangaea surely had tremendous environmental impacts that reshaped biological diversity by causing extinctions and providing new opportunities for taxonomic groups that survived the crisis.

- A major shock to life on Earth was initiated about 180 million years ago, as Pangaea began to break up into separate continents.



- The continents drift about Earth's surface on plates of crust floating on the hot



(a) Major plates

- **Each continent became a separate evolutionary area and organisms in different biogeographic realms diverged.**
  - For example, paleontologists have discovered matching fossils of Triassic reptiles in West Africa and Brazil, which were contiguous during the Mesozoic era.
  - The great diversity of marsupial mammals in Australia is a product of 50 million years of the isolation of Australia from other continents.

The fossil record shows us that the vast majority of organisms have gone extinct.

A species may become extinct because:

- Its habitat has been destroyed.
- Its environment has changed in an unfavorable direction.
- Evolutionary changes by some other species in its community impact it for the worse.
- As an example, the evolution by some Cambrian animals of hard body parts, such as jaws and shells, may have made some organisms lacking hard parts more vulnerable to predation and thereby more prone to extinction.

Extinction is inevitable in a changing world.

- While the emphasis of mass extinctions is on the loss of species, there are tremendous opportunities for those that survive.
- Survival may be due to adaptive qualities or sheer luck.
- After a mass extinction, the survivors become the stock for new radiations to fill the many biological roles vacated or created by the extinctions.

- **To trace phylogeny or the evolutionary history of life, biologists use evidence from paleontology, molecular data, comparative anatomy, and other approaches.**
  - Tracing phylogeny is one of the main goals of **systematics**, the study of biological diversity in an evolutionary context this includes taxonomy, which is the naming and classification of species.

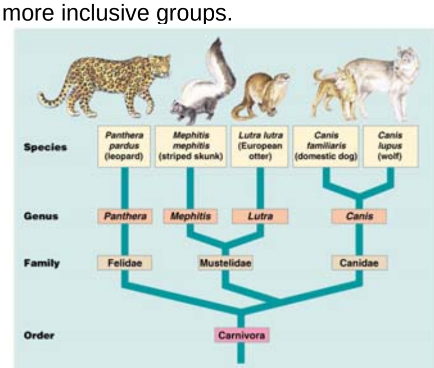
Taxonomy employs a hierarchical system of classification

- The Linnean system, first formally proposed by Linneaus in *Systema naturae* in the 18th century, has two main characteristics.
  - Each species has a two-part name.
  - Species are organized in levels that become broader and broader groups of organisms.

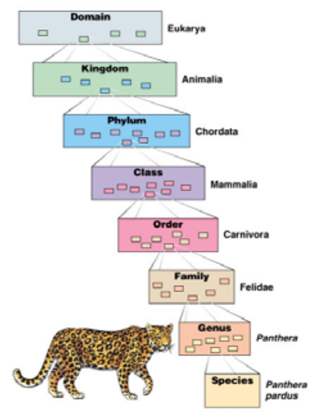
- Under the binomial system, each species is assigned a two-part latinized name, a **binomial**.
  - The first part, the **genus**, is the closest group to which a species belongs.
  - The second part refers to one **species** within each genus.
  - The first letter of the genus is capitalized and both names are *italicized* and latinized.
  - For example, Linnaeus assigned to humans the scientific name *Homo sapiens*, which means “wise man,” perhaps in a show of optimism.

- A **hierarchical classification** groups species into broader taxonomic categories.
- Species that appear to be closely related are grouped into the same genus.
  - For example, the leopard, *Panthera pardus*, belongs to a genus that includes the African lion (*Panthera leo*) and the tiger (*Panthera tigris*).
  - Biology’s taxonomic scheme formalizes our tendency to group related objects.

- Phylogenetic trees reflect the hierarchical classification of taxonomic groups nested within more inclusive groups.



- Organisms are grouped into progressively smaller categories:
- **Domain - biggest**
- **Kingdom**
- **Phylum**
- **Class**
- **Order**
- **Family**
- **Genus**
- **Species – smallest**



- Each taxonomic level is more comprehensive than the previous one.
  - As an example, all species of cats are mammals, but not all mammals are cats.
- The named taxonomic unit at any level is called a **taxon**.
  - Example: *Pinus* is a taxon at the genus level, the generic name for various species of pine trees.
  - Mammalia, a taxon at the class level, includes all the many orders of mammals.

Levels of Classification

- Domain
- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- species

•Did
•King
•Phillip
•Come
•Over
•From
•Great
•Spain?

What is the sequence of the levels of classification?

The more closely related species share more levels of classification

From Domain down to species, each level has a new set of criteria that each organism must share

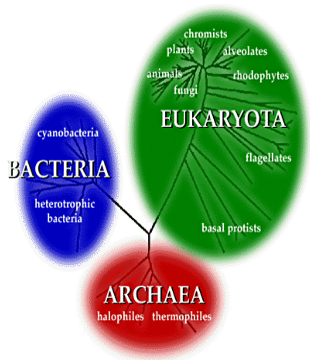
Classification systems are always changing

- As new information is discovered organisms are moved around to different groups.
- Sometimes a new discovery is soooo different that it needs its own category.
- As new categories are created sometimes the old ones don't make much sense anymore
- In the mid 1990's a new level was added to the older classification system.

- The old 5 Kingdom system was started before we knew about the different kinds of prokaryotes.
- So they used to be lumped together in a kingdom called Monera
- In the mid 1990's it was discovered that there were two kinds of prokaryotes (based upon their chemistry)
- Two new kingdoms were created for the Archae and Bacteria
- Then it was learned that the Archae and Bacteria were so different from each other that we needed a better way to show that difference so a new higher level was added called DOMAIN.

The 3 Domain System

- Archae: oldest group of prokaryotic microbes
- Bacteria: evolved from Archae
- Eukaryota: cells with a membrane enclosed nucleus
- Animals, Plants, Fungi, and Protists



Two kinds of Prokaryotes

- Genetic and biochemical analyses of Prokaryotes have revealed the existence of two distinct groups:
- the Archae and bacteria
- Theses two groups of prokaryotes are very distantly related in evolutionary terms.
- Why didn't why know that there were different kinds of prokaryotes?

Comparing the Three Domains

Comparing the 3 Domains: Archea with Bacteria and Eukaryotes			
Feature	**Eubacteria**	**Archae**	**Eukaryotes**
Type of Cell	Prokaryotic	Prokaryotic	Eukaryotic
Cell wall contains peptidoglycan?	Yes	No	No
Type of chemical linkage between polar heads and fatty acid tails in membrane lipids	Ester-linked	Ether-linked	Ester-linked
DNA-directed RNA polymerase (transcribes DNA into messenger RNA)	Single type	Several	Three
Initial amino acid in polypeptide at translation	Formylmethionine	Methionine	Methionine

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Archae

- Archaebacteria occur in a wide range of habitats, but are associated particularly with extreme environments, such as hot springs and salt lakes. Some of these bacteria have changed little since their ancestral forms first appeared on
- Earth over three billion years ago. Archaebacteria are thought to retain features of the earliest living cells.

Hyperthermophilic Archae (“extremely heat-loving”)

- Found typically in and around hot springs or volcanic flows, where temperatures can exceed 100°C and there are high concentrations of sulfuric acid.
- Most are strict anaerobes, and live on organic or inorganic compounds. Some, such as the aerobe
- Sulfolobus, chemically reduce sulfur to hydrogen sulfide.
- Pyrodictium- Live in undersea volcanic vents that emit water (not steam) at temperatures over 100°C.
- Cells of Pyrodictium grow best at 105°C, and are attached to a mass of filaments composed of protein subunits, that anchor the bacteria to the substrate.

Hydrothermal vent communities exist beacuse of Archae (sometimes called Archaebacteria) converting chemical energy into organic energy

Archae don’t just live in extreme environments.

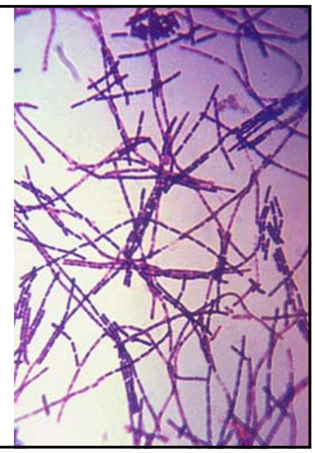
Some Archae are useful to humans

For example, methanogenic archaea live in anoxic sediments in marshes and are used in sewage treatment facilities.

Another archaean, *Methanobrevibacter smithii*, lives and generates methane in the human colon. (This allows the guys on the show Jackass to light their farts on fire)

Domain Bacteria

Bacteria are unicellular microorganisms. They are typically a few micrometers long and have many shapes including spheres, rods, and spirals.
Bacteria are found in every habitat on Earth, growing in soil, hot springs, radioactive waste, seawater, and deep in the earth's crust.
Some bacteria can even survive in the extreme cold and vacuum of outer space.
There are typically 40 million bacterial cells in a gram of soil



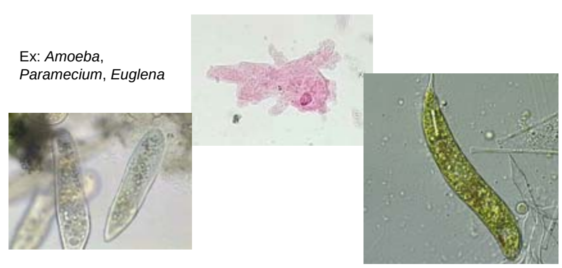
Stromatolites: calcareous mounds formed by cyanobacteria (in the domain bacteria). These mounds may be billions of years old

Domain Eukarya

- All are eukaryotic (cells have a nucleus)

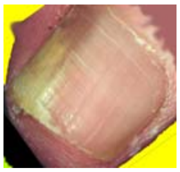
1. Kingdom Protista: mostly unicellular organisms that are plant-like, animal-like, or fungus-like

Ex: *Amoeba*, *Paramecium*, *Euglena*



Domain Eukarya continued

2. Kingdom Fungi: all types of fungus (mushrooms)
- Heterotrophic: mostly decomposers but may also be parasites
- Cell wall (chitin and cellulose)
- multicellular



Domain Eukarya continued..

3. Kingdom Plantae: land based plants, trees, grasses, moss, and shrubs
- Cell wall (cellulose)
- Photosynthetic
- multicellular



Domain Eukarya continued..

4. Kingdom Animalia: divided into vertebrates and invertebrates
- Heterophic: herbivores, carnivores, omnivores
- Multicellular
- Mobile



Classification is Still Changing

- Determining which similarities between species are relevant to grouping the species is a challenge.
- It is especially important to distinguish similarities that are based on shared ancestry or **homology** from those that are based on **convergent evolution** or **analogy**.
- These two desert plants are not closely related but owe their resemblance to analogous adaptations.


- As a general rule, the more homologous parts that two species share, the more closely related they are.
  - Adaptation can obscure homology and convergence can create misleading analogies.
- Also, the more complex two structures are, the less likely that they evolved independently.
- For example, the skulls of a human and chimpanzee are composed not of a single bone, but a fusion of multiple bones that match almost perfectly.
  - It is highly improbable that such complex structures matching in so many details could have separate origins.

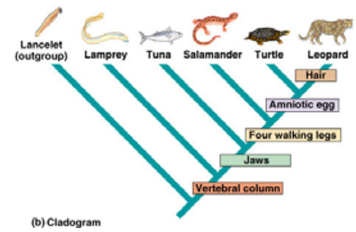
- For example, the forelimbs of bats and birds are analogous adaptations for flight because the fossil record shows that both evolved independently from the walking forelimbs of different ancestors.
  - Their common specializations for flight are convergent, not indications of recent common ancestry.
- The presence of forelimbs in both birds and bats is homologous, though at a higher level of the cladogram, at the level of tetrapods.
- The question of homology versus analogy often depends on the level of the clade that is being examined.

- Analyzing the taxonomic distribution of homologies enables us to identify the sequence in which derived characters evolved during vertebrate phylogeny.

TAXA

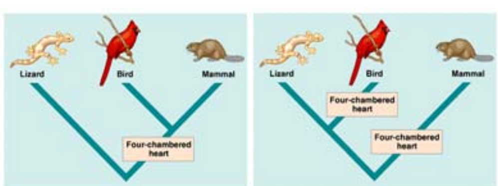
CHARACTERS	Lancelet (outgroup)	Lamprey	Tuna	Salamander	Turtle	Leopard
Hair	0	0	0	0	0	1
Amniotic (shelled) egg	0	0	0	0	1	1
Four walking legs	0	0	0	1	1	1
Jaws	0	0	1	1	1	1
Vertebral column (backbone)	0	1	1	1	1	1

(a) Character table



(b) Cladogram

- For example, based on the number of heart chambers alone, birds and mammals, both with four chambers, appear to be more closely related to each other than lizards with three chambers.
- But abundant evidence indicated that birds and mammals evolved from *different* reptilian ancestors.



(a) Mammal-bird clade (b) Lizard-bird clade

- Molecular systematics makes it possible to assess phylogenetic relationships that cannot be measured by comparative anatomy and other non-molecular methods.
  - This includes groups that are too closely related to have accumulated much morphological divergence.
  - At the other extreme, some groups (e.g., fungi, animals, and plants) have diverged so much that little morphological homology remains.

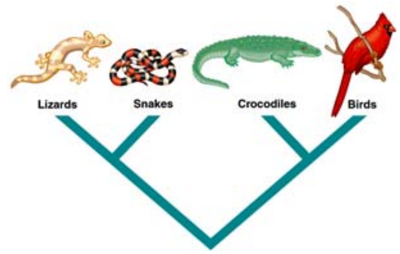
Molecular clocks may keep track of evolutionary time

- The timing of evolutionary events has rested primarily on the fossil record.
- Recently, **molecular clocks** have been applied to place the origin of taxonomic groups in time.
  - Molecular clocks are based on the observation that some regions of genomes evolve at constant rates.
  - For these regions, the number of nucleotide and amino acid substitutions between two lineages is proportional to the time that has elapsed since they branched.

- For example, the homologous proteins of bats and dolphins are much more alike than are those of sharks and tuna.
  - This is consistent with the fossil evidence that sharks and tuna have been on separate evolutionary paths much longer than bats and dolphins.
  - In this case, molecular divergence has kept better track of time than have changes in morphology.

- In other cases, molecular data present a different picture than other approaches.
  - For example, fossil evidence dates the origin of the orders of mammals at about 60 million years ago, but molecular clock analyses place their origin to 100 million years ago.
  - In one camp are those who place more weight in the fossil evidence and express doubts about the reliability of the molecular clocks.
  - In the other camp are those who argue that paleontologists have not yet documented an earlier origin for most mammalian orders because the fossil record is incomplete.

- For example, the fossil record, comparative anatomy, and molecular comparisons all concur that crocodiles are more closely related to birds than to lizards and snakes.



Can we ever construct a tree of life that shows the interrelatedness of the three domains, with one common ancestor for all life?

Many biologists have argued that based on phylogenetic methodology and data from several genes that there is a single common ancestor.

Other biologists have countered that the true universal tree of life may be more complicated. Lateral gene transfer, where individuals exchange genes between one another, occurs frequently between Bacteria.

This transfer of genes between bacterial species by the action of viruses and by conjugation (cell-to-cell contact in which DNA is copied and transferred to a recipient cell) adds a complication to genetic research into the true ancestor of all living things.

Lateral gene transfer, if restricted to very similar organisms, would not pose a problem for constructing a universal tree of life. However, there is evidence that genes have been exchanged between very distant organisms. Eukarya acquired mitochondrial and chloroplast DNA from Bacteria. Genes can also be shared between Archaea and Bacteria.

Twenty-four percent of the genome of the bacterium *Thermotoga maritima* contains archaen DNA. Similarly, the archaean *Archaeoglobus fulgidus* has numerous bacterial genes. Some scientists believe that a more diverse community of primitive cells gave rise to the three domains and that the notion of a single universal ancestor might be replaced. W. Ford Doolittle has suggested that lateral gene transfer among early organisms has generated a "tree of life," which more closely resembles a shrub with untreelike links (shared genes) connecting the branches.