Classification

Decide which half of your desk pair will turn around so they can't see the screen. They will need a piece of paper and a writing implement.

Those of you facing the screen will have 60 seconds to describe an image to your partner.

Your goal is to get them to draw what you see.

You are not allowed to touch the paper/guide their hand.

You may only use words to tell them what to draw.

Classification

How would you describe this image?

What is it similar to?

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

Why is the cereal aisle is one of the most complex aisles to shop in?
Products are often stocked vertically by manufacturer, with varieties blended together; healthy options alongside kid cereals, brand name alongside private label, etc.
With so much competition in-store, knowing how to best configure products on shelf is critical to driving market share and revenue. (Affinnova.com)

Organizing Life Is Complicated Too

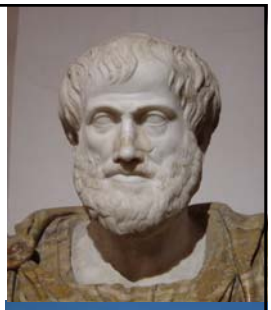
Early civilizations did not classify organisms by ancestry because it was not believed organisms evolved.

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.

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

The whale shark (*Rhincodon typus*) is a slow-moving filter feeding shark and the largest known living fish species. The largest confirmed individual had a length of 12.65 meters (41.50 ft) and a weight of more than 21.5 metric tons (47,000 lb).

Dolphins are cetacean mammals closely related to whales and porpoises. There are almost forty species of dolphin. The name is originally from the Greek delphus, "womb". The animal's name can therefore be interpreted as meaning "a 'fish' with a womb".

Mammals (class Mammalia) are a group of: endothermic amniotes distinguished from the reptiles and the birds by the possession of **hair, three middle ear bones, mammary glands in females, and a neocortex** (a region of the brain used for language and thought)**.**

The mammals include the largest animals on the planet, the whales, as well as some of the most intelligent, such as elephants, some primates and some cetaceans.

The basic body type is a four-legged land-borne animal, but some mammals are adapted for life at sea, in the air, in the trees, or on two legs.

The mammals range in size from the 30–40 mm bumblebee bat to the 33-meter (108 ft) blue whale.

Classification can also be called taxonomy

A taxon is a group or level

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

Linnaeus 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 first letter is capitalized
2. species: second name, lower case

Binomial Nomenclature:

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

Scientific names are *Italicized* (or underlined when hand written)

1. Genus: first name, first letter is capitalized

2. species: second name, lower case

Scientific names are usually in Latin because it is a universal language that all countries can use

Common names can vary from place to place and language to language but a 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.

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

The 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.

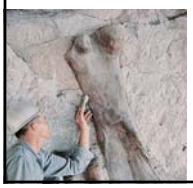
Genotype determines phenotype

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.



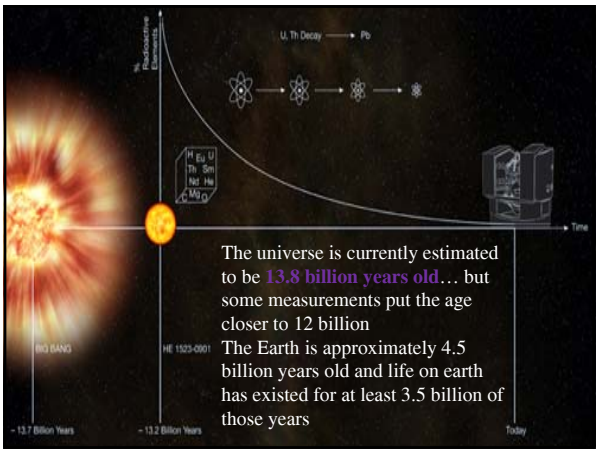
- The organic material in a dead organism usually decays rapidly, but hard parts that are rich in minerals (such as bones, teeth, shells) may remain as fossils.
- Under the right conditions minerals dissolved in groundwater seep into the tissues of dead organisms, replace its organic material, and create 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 **13.8 billion years old**… but some measurements put the age closer to 12 billion

The Earth is approximately 4.5 billion years old and life on earth has existed for at least 3.5 billion of those years

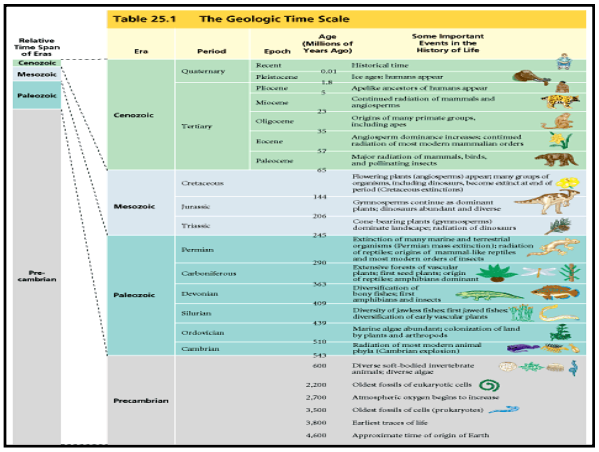


Table 25.1 The Geologic Time Scale

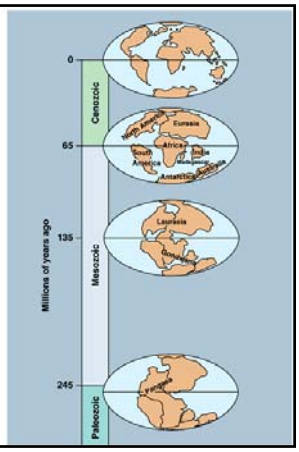
Relative Time Span of Eras	Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Cenozoic	Cenozoic	Quaternary	Recent	0.01	Historical time
			Pleistocene	1.8	Ice ages; humans appear
		Tertiary	Pliocene	5	Apelike ancestors of humans appear
			Miocene	23	Continued radiation 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	Mesozoic	Cretaceous		144	Flowering plants (angiosperms) appear; many groups of organisms, including dinosaurs, become extinct at end of period (Cretaceous extinction)
		Jurassic		206	Gymnosperms continue as dominant plants; dinosaurs abundant and diverse
		Triassic		245	Cone-bearing plants (gymnosperms) dominate landscape; radiation of dinosaurs
Paleozoic	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	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.

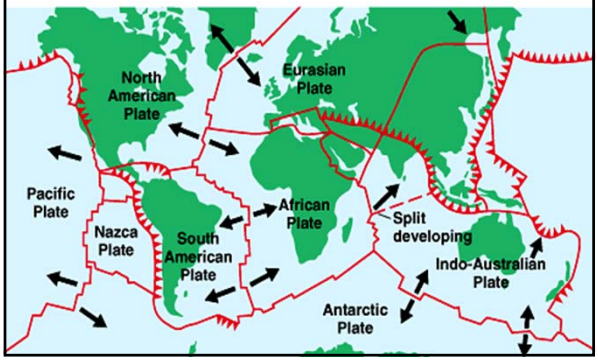
The emergence of volcanic islands such as the Galapagos opened new environments with new niches allowing for new species.

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

On a global scale, **continental drift** is the major geographic factor correlated with the distribution of life and evolutionary episodes such as mass extinctions and adaptive radiations.

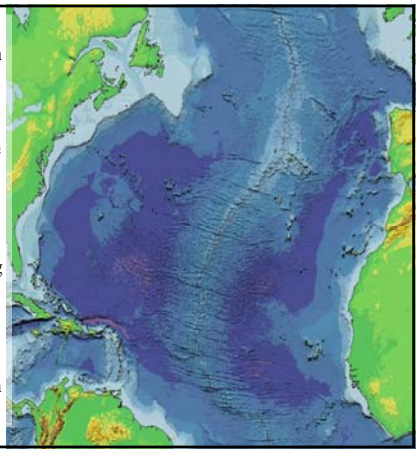


The continents drift about Earth's surface on plates of crust floating on the hot mantle.



The Mid-Atlantic Ridge is a mid-ocean ridge, a divergent tectonic plate boundary located along the floor of the Atlantic Ocean, and the longest mountain range in the world.

The rate of spreading along the Mid-Atlantic Ridge averages about 2.5 centimeters per year or 25 km in a million years.



After the break up of Pangaea each continent became a separate evolutionary area and the organisms diverged.

The great diversity of marsupial mammals in Australia is a product of 50 million years of the isolation from the 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.

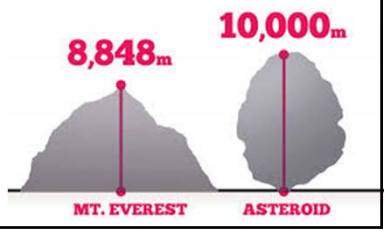
Evolutionary changes by some other species in its community impact it for the worse.

Extinction is inevitable in a changing world.

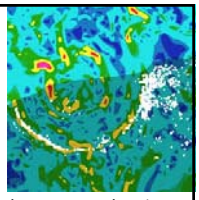
NEO Earth Close Approaches • http://neo.jpl.nasa.gov/ca/

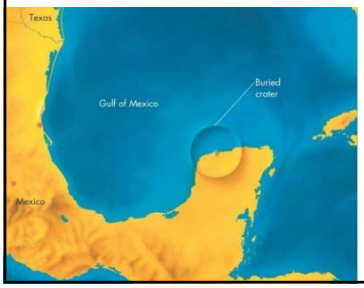
After a mass extinction there are tremendous opportunities for those that survive.

The Chicxulub Imapact 66 million years ago



The age of the rocks marked by the impact shows that this impact structure dates from roughly 66 million years ago, the end of the Cretaceous period, and the start of the Paleogene period.





The impact associated with the crater is thus implicated in the Cretaceous–Paleogene extinction event, including the worldwide extinction of non-avian dinosaurs. This conclusion is still a source of controversy.

After a mass extinction, the survivors become the breeding stock to fill the many biological roles vacated or created by the extinctions.

Survival may be due to adaptive qualities or sheer luck.

To trace phylogeny or the evolutionary history of life, biologists use evidence from paleontology, molecular data, comparative anatomy, and other approaches.

Taxonomy

Taxonomy employs a hierarchical system of classification

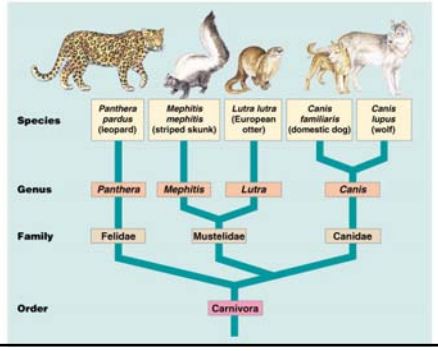
A hierarchical classification groups species into broader taxonomic categories.

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 follows our tendency to group related objects.

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



Levels of Classification

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

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

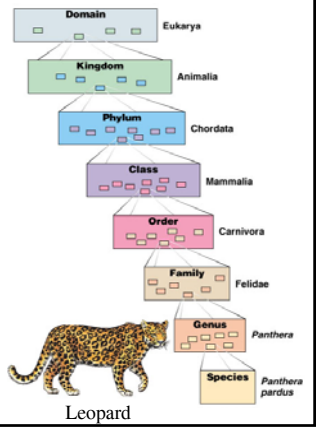
What is the sequence of the levels of classification?

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

Organisms are grouped into progressively smaller categories:

- **Domain - biggest**
- **Kingdom**
- **Phylum**
- **Class**
- **Order**
- **Family**
- **Genus**
- **Species – smallest**



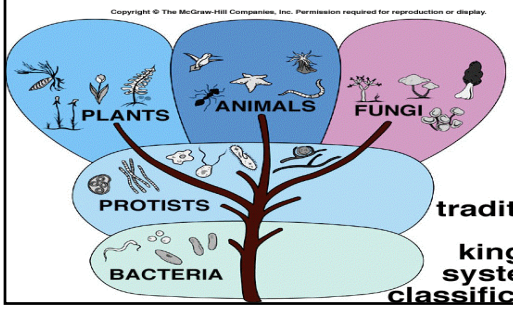
Leopard

- 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.

Classification systems are always changing

- 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 (bacteria)

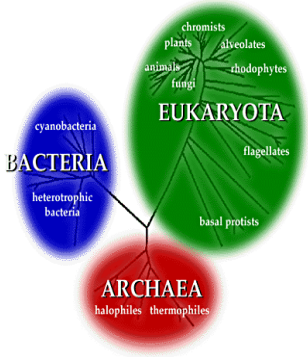


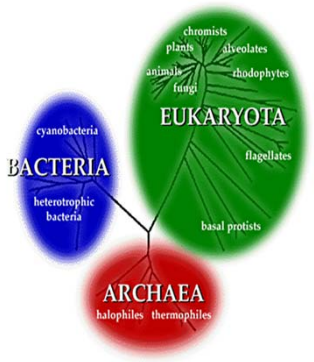
The traditional five-kingdom system of classification

- 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





The three domain system emphasizes the **separation of prokaryotes into two groups**:
the Bacteria and Archaea.

How Did Life Begin?

On the basis of differences in 16S rRNA genes, the Bacteria and Archaea along with the eukaryotes each arose separately from an ancestor often called the **last universal ancestor**.

The LUA is estimated to have lived 3.5 to 3.8 billion years ago.

The earliest evidence for life on Earth was discovered in graphite found to be biogenic in 3.7 billion-year-old metasedimentary rocks discovered in Western Greenland and in microbial mat fossils found in 3.48 billion-year-old sandstone discovered in Western Australia.

Wait… microbial mat fossils… what?

http://www.pbs.org/wgbh/nova/evolution/origins-life.html

Two kinds of Prokaryotes

- Genetic and biochemical analyses of Prokaryotes have revealed the existence of two distinct groups:
- the Archaea 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: Archaea with Bacteria and Eukaryotes			
Feature	**Eubacteria**	**Archaea**	**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

Archaea

- Archaea 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. Archaea are thought to retain features of the earliest living cells.

Hyperthermophilic Archaea
("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 because of Archaea (sometimes called Archaebacteria) converting chemical energy into organic energy

Archae don't just live in extreme environments.

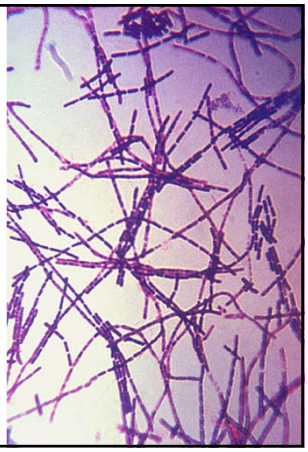
Some Archae are useful to humans

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)

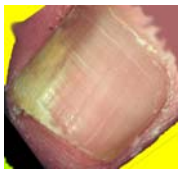
1. Kingdom Protista: mostly unicellular organisms that are plant-like, animal-like, or fungus-like

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

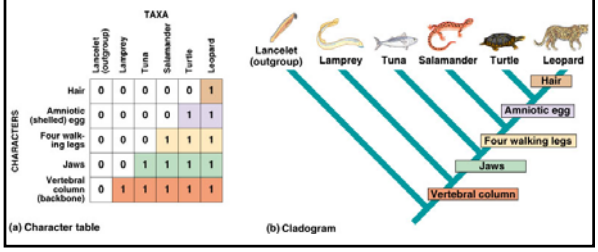
- Heterophic: herbivores, carnivores, omnivores
- Multicellular
- Mobile

Classification is Still Changing

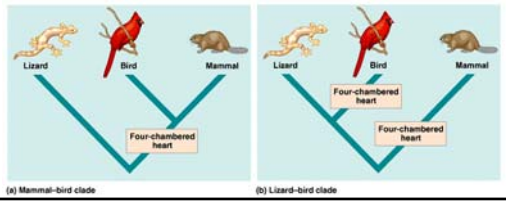
- Determining which similarities between species are relevant to grouping the species is a challenge.
- It is especially important to distinguish similarities that are based on shared ancestry or **homology** from those that are based on **convergent evolution** or **analogy**.
- These two desert plants 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.

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



- 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.



- Molecular systematics makes it possible to assess phylogenetic relationships that cannot be measured by comparative anatomy and other non-molecular methods.
  - Some groups (e.g., fungi, animals, and plants) have diverged so much that little morphological homology remains.

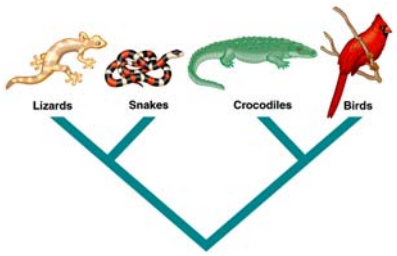
Molecular clocks may keep track of evolutionary time

- 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.

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.

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.