Tracing Evolutionary History

Introduction

Piecing together the details of the life of extinct forms, like the duck-billed dinosaur, involve integrating knowledge about many prehistoric aspects such as **geology**, **climate**, and **fossils**, as well as **knowledge about comparable present day species**.

Fossils are particularly important. Sometimes, as in case described, a particularly important fossil deposit can provide special insight into how ancient life forms behave and otherwise lived.

1. Tracks of hadrosaurs indicate they lived in large herds on outwash plains.
2. Details of the skull anatomy show large ears and unusual beaks, suggesting these animals were quite vocal.
3. Fossilized nests, egg fragments, and young show hadrosaur parents remained with their nests and cared for their young.

The fossil record chronicles macroevolution

•**Macroevolution**, the main events in the evolutionary history of life on Earth, is determined by comparing the fossil records in strata representing various ages, from various parts of the Earth's surface.

•The geological timeline is a standardized, hierarchical system of age categories.

•The oldest fossils are of microorganisms from ≈3.5 billions years ago during the early **Precambrian era**.

•Late Precambrian fossils show that animal life had diversified by ≈610 million years ago (mya).

•Early Paleozoic (≈570mya) rocks bear fossils that gave rise to modern organisms, as well as fossils of extinct lineages.

•By ≈400 mya, during the middle **Paleozoic** ("ancient animals") era, life had moved out of water and onto dry land.

•The **Mesozoic** ("middle animal") era began ≈248 mya and is the age of dinosaurs and cone-bearing plants. During this era the first mammals, birds, and angiosperms appeared.

•The **Cenozoic** ("recent animal") era began ≈65 mya and is the age of mammals and flowering plants.

•Homo sapiens arose during the **Pleistocene epoch** (≈100,000-200,000 years ago).

The actual ages of rocks and fossils mark geological time

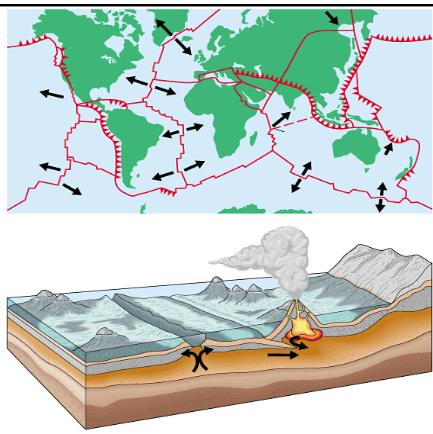
•The records of fossils in rock strata chronicles the relative ages of life.

•The actual ages of fossils can be obtained by radioactive dating. Radioactive isotope "decay" at a known rate relative to other isotopes. For instance half of the amount of ^{14}C decays to ^{12}C in 5600 years. Measuring the relative amounts of the two isotopes in a sample (and comparing this ratio to the ratio known to have been in the original organism, that is, the ratio of ^{14}C to ^{12}C in the atmosphere) gives the actual age of the sample, with an error factor of about 10%. Elements with longer half lives are used to date older fossils.

Continental Drift has played a major role in macroevolution

•In 1912 **Wegener** proposed continental drift as the mechanism that accounts for the similarities of coastal outlines of present-day continents. The proposal was not accepted because geologists knew of no method that would cause the continents to move.

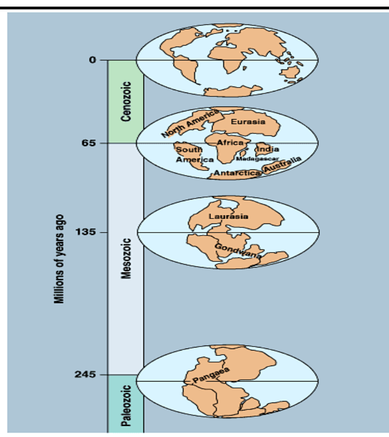
•Continents are above-water parts of crustal plates that "float" on the fluid mantle. New crust is formed along ocean ridges, and old crust is destroyed at the leading margins of the plates.



•About 250 mya, the present continents were united as a single supercontinent called Pangea. This must have made weather patterns and climate much different than they are now.

•About 180 mya (early Mesozoic), Pangea began to break apart, first forming northern (Laurasia) and southern (Gondwana) landmasses. This process was completed ≈135 mya.

•Relative distribution of present-day life forms and their fossilized ancestors are explained by the known courses of continental drift.



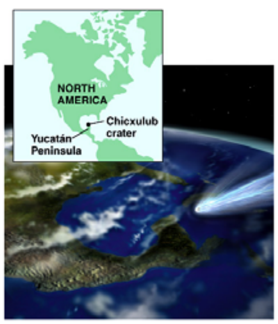
•Continental drift is an ongoing process. For example ongoing collision in the Himalayan region is creating forces that are splitting the Indo-Australian plate, resulting in Australia moving independent of India.

Tectonic trauma imperils local life

- The forces responsible for the movement of the Earth's crust are called plate tectonics.
- Earthquakes are the result of the movement of crustal plates.
- Volcanic eruptions occur along plate margins or mid-ocean ridges and can build mountains or islands, such as the Galapagos, and can pose a threat to local populations.

Mass extinctions were followed by diversification of life forms

- At the end of the Cretaceous period (≈65mya), many lineages of terrestrial plants and animals, and about half the marine animals , became extinct.
- Particularly noteworthy was the demise of the dinosaurs (within a span of less than ≈10 million years), which had dominated the land and air for ≈150 million years during the Mesozoic.
- Several, not necessarily mutually exclusive, explanations have been proposed to account for this change: an asteroid impact in what is now the Caribbean sea; slow changes in climate due to continental drift ; and massive volcanic activity in India during the late Cretaceous that contributed to cooling.



- During the last 600 million years there have been **six mass extinction events**. During these events the extinction rate was nearly six times the average rate.
- Another major extinction occurred at the end of the Permian period coinciding with the formation of Pangea. At this time, over 90% of all species of marine animals went extinct.
- Mass extinctions events are followed by huge increases in diversity as surviving organisms (apparently) exploit new environmental opportunities.

Key adaptations may allow species to survive and proliferate after mass extinctions

- Each of the six periods of mass extinction in the past 600 million years has been followed by an "explosion" in evolution of certain groups of organisms.
- Chance can play a role; an organism just happens to "make it" in the right place. Key adaptations also play a role in allowing species to survive a mass extinction event.
- An **exaptation** is a feature that evolved in one context and was later adapted for another function.

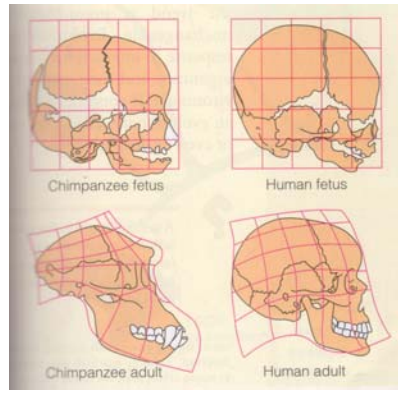
i.e.- leaves on a pineapple that form a rainwater catch-basin.

- Changes in how organisms develop, which may involve only a few regulatory genes, can also lead to adult features that are very different and that may offer advantages in certain environments.

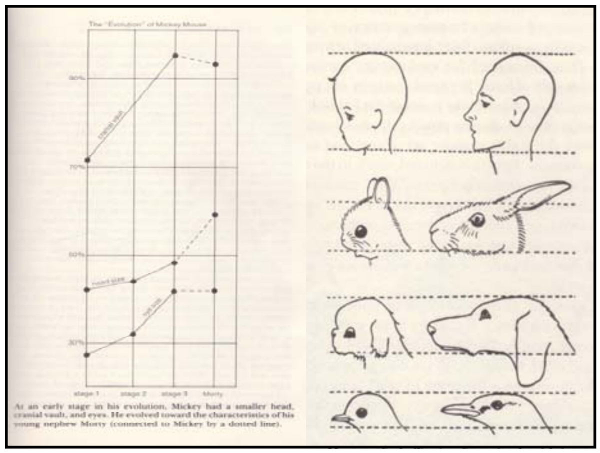
Delayed maturity was a key novelty in human evolution

•**Paedomorphosis** is retention of juvenile body features in the adult.

•Paedomorphosis has been important in the evolution of humans and chimpanzees from a common ancestor. The large, paedomorphic human skull and the long period of time as a nonreproductive child provide the human with both space for a larger brain and time to learn from adults.

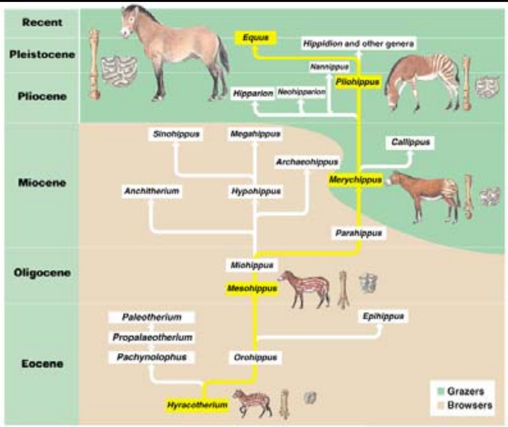


•Evolutionary biologist **Stephen Jay Gould** contends that youthful characteristics in children elicit parental affection and care. He uses Mickey Mouse's early evolution as a cartoon character to illustrate this.



What accounts for evolutionary trends

•Evolutionary trends show gradual, one-directional changes in morphology over long periods of evolutionary time, such as the increase in brain complexity among human ancestors and the increase in size and modification of the limbs seen in the lineage that gave rise to modern horses.



•Unequal survival of new species can explain the apparent trend.

•Unequal speciation with equal survival of all new species can also explain the data. Current debate exists over the relative importance over each of these mechanisms.

•Evolutionary trends are not preordained or unchangeable. Such trends can stop or reverse.

Phylogenic trees symbolize evolutionary history

•**Phylogeny** is the evolutionary history of a group of organisms.

•**Phylogenetic trees** represent the most likely phylogeny of a group. The phylogeny of the Galapagos finches is based on body structures, especially beak structure, and field studies of reproductive isolation and feeding behavior.

•Each branch axis represents the evolution of subsequent groups based on some important feature.

•Organisms on branches close to the base of the tree are more primitive (in the sense of having appeared earlier in time), showing more ancestral features than organisms on later branches.

Systematics classify organisms by phylogeny

•Reconstructing phylogenies, assigning scientific names, and classifying the names are all aspects of the biological science of **systematics**.

•Common names can be ambiguous because there are so many species and because different people use different names for the same species.

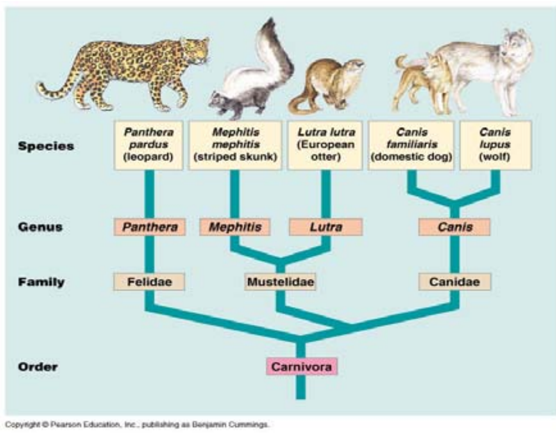
•Linnaeus devised the binomial form for a species' scientific name (genus name plus specific name –for example *Felis catus*, the domestic cat) and a hierarchical system of progressively broader categories.

NOTE: The species name is always italicized or underlined.

•Ideally the species taxon is based on a real group in nature (biological species), but all the other, larger taxa are determined according to systematists' understanding of relationships between and among species.

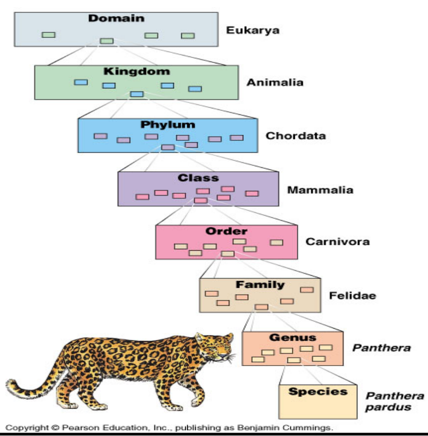
•Although identifying species often requires judgment calls, classifying species in higher taxa always does.

•It has always been a goal of taxonomists to have there taxonomic systems reflect the evolutionary relationship and phylogeny of whatever group is in the system.



•Systematics reflects the hierarchical nature of biology. The major levels of classification, from most to least inclusive, from a lesser degree of relationship to a greater degree of relationship, are Domain, Kingdom, Phylum, Class, Order, Genus, and Species.

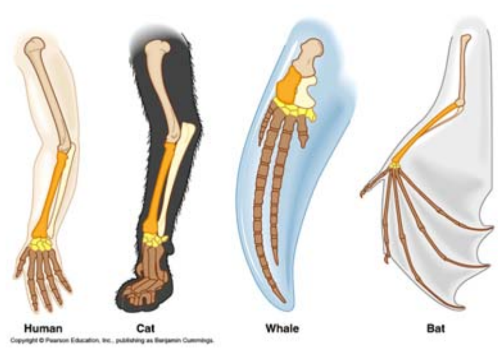
Note: A good mnemonic for this hierarchy is "**D**ear **K**ing **P**hillip **C**ome **O**ut **F**or **G**oodness' **S**ake."



Homology indicates common ancestry, but analogy doesn't

•**Homologous structures** may function differently, such as the wing of a bird, and the flipper of a whale, but they exhibit fundamental similarities-in this example, the bone supporting these appendages.

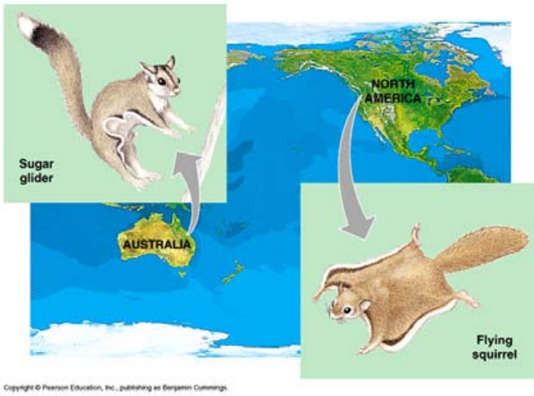
•The greater the number of homologies between two species, the more closely related they likely are.



•**Analogous structures** may look and function the same, but they do not exhibit the fundamental similarities that reflect common ancestry. Instead, they more likely reflect the results of convergent evolution.

•**Convergent evolution** is a process by which different evolutionary lineages evolve similarities as a result of similar selective pressures.

NOTE: A good example of convergent evolution of as a result of common selective pressures in a common environment is the evolution of torpedo-shaped bodies in sharks (a fish), penguins (a bird), and dolphins (a mammal).



Otocillo
SW North America

Allauidia
Madagascar

Molecular biology is a powerful tool in systematics

•Bears and raccoons have long been recognized as closely related mammals base on morphology, but such relationships can be clarified by analyzing DNA and proteins. The data suggests that lesser pandas are more closely related to raccoons than to bears.

•Comparing the amino acid sequence in human **cytochrome c** and that of other animals:

-humans differ from chimpanzees by 0 amino acids.

-from rhesus monkeys 1 amino acid.

-from dogs 13 amino acids.

-from rattlesnakes by 20.

-from tuna by 31.

•In addition to protein sequence analysis, molecular methods used in phylogenetic analysis include:

***DNA-DNA hybridization**

***DNA sequence analysis**

***Ribosomal RNA (rRNA) sequence analysis**

Systematists attempt to make classification consistent with phylogeny

•**Cladistic** analysis is concerned only with the order of branching in phylogenetic lineages. Each branch on a cladogram represents the most recent ancestor common to all taxa beyond that point. All the taxa above a branch share one or more homologous features. The end result of this analysis should be **clades** (groupings) consisting of monophyletic taxa.

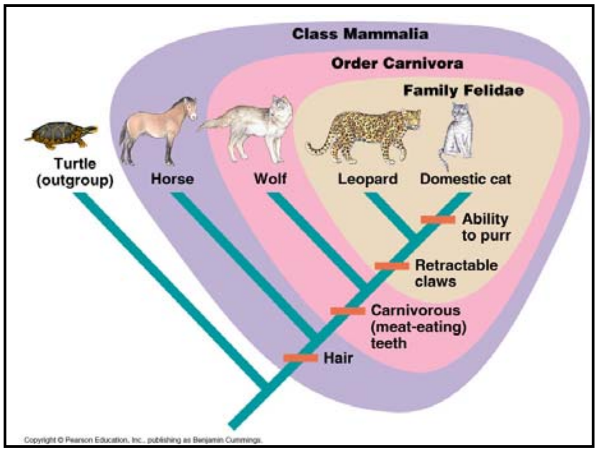
•Homologous characters unique to each lineage are called shared derived characteristics (**synapomorphies**).

•The comparison of an ingroup with an outgroup aids in determination of whether a character is primitive or derived.

•The ingroup consists of the taxa being analyzed. The outgroup, though having a known relationship to the ingroup, is not a member of the ingroup. Characters shared by the **ingroup and outgroup** are considered primitive characters; character unique to the **ingroup** are considered derived characters.

•Derived characters are used to identify the branch points of a **cladogram**.

i.e.- hair and mammary glands are derived characters that distinguish the mammalian lineage.



•Cladistics is particularly suited for analysis of the similarities and differences of molecular data, which may be done entirely objectively and parsimoniously.

***Parsimony** seeks the simplest explanation of observed data

•Cladistic analysis has demonstrated that <u>*birds are a lineage of dinosaurs more closely related to crocodiles than lizard and snakes*</u>.

•In contrast **classical evolutionary taxonomy** also takes into account the *apparent degree of divergence of taxa*. Unlike cladistic analysis, <u>classical analysis places the crocodiles with lizards and snakes and places birds in a separate taxon</u>.

Arranging life into kingdoms is a work in progress

•Linnaeus used a two-kingdom system to categorize life at the most inclusive level of classification.

•In 1969, Whitaker proposed a five-kingdom system: **Monera** (prokaryotes), **Protista** (unicellular eukaryotes). **Plantae** (multicellular eukaryotes, photosynthetic autotrophs with cell walls), **Fungi** (eukaryotic decomposers with cell walls), and **Animalia** (multicelluair eukaryotes without cell walls, heterotrophs) .

NOTE: The multicellular protists are highly variable in the degree to which their cells are cooperative/specialized. A sequence can be set up that reflects hypothesized intermediates from unicelluarity to true multicellularity.

•The protista is a polyphyletic group that will be split into several kingdoms.

Many biologists now use a three-domain classification system

1. **Bacteria** (also called Eubacteria; prokaryotes)
2. **Archea** (also called Arhceabacteria; prokaryotes)
3. **Eukarya** (Eukaryotes)