Evolution - Evidence of Change

*Species change over time. The process through which these changes occur is known as **biological evolution**. Various forms of scientific evidence, including fossil records and biochemical, anatomical, embryological, and physiological similarities, allow scientists to classify organisms in order to show probable evolutionary relationships and common ancestry.*

Fossil Evidence

A great deal of Earth's history can be determined using fossils. Fossils are remnants or traces of organisms that are preserved in layers of rock. If an organism gets buried under sediment, the soft parts decay, while the hard parts (bones, teeth, etc.) undergo a change to become preserved in the sediment. This sediment eventually hardens to becomes rock.

Fossil records provide evidence for evolution, or changes in species over time. By studying the fossil record of a given species, it is possible to see the many changes that have taken place over multiple generations. These changes are called adaptations.

Paleontologists have uncovered a significant amount of information about dinosaurs by studying their fossilized remains.

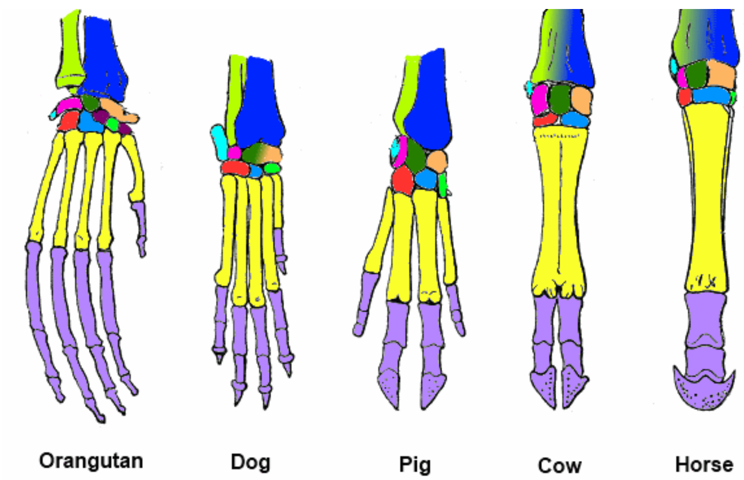
Variations in DNA sequences

One of the ways in which scientists judge whether two species are related is through **comparative biochemistry**, or the study of organisms' **DNA sequences**. Since each species has its own unique DNA sequence, it is possible to determine the relatedness of organisms by comparing their DNA. Sequences of related organisms are more similar than sequences of unrelated organisms.

Scientists have also found that classifications based on variations in DNA sequences closely match organism classifications based on comparative anatomy as well as classifications based on evidence from fossil records. So, even though **related organisms evolved from a common ancestor**, at some point, the organisms changed to form different species.

Comparative Anatomy

Much can be learned by comparing the structural similarities and differences of living things. **Homologous structures** are structures found on one species that have the same basic structure and embryonic origin as those found on another species. If homologous structures are found on two different organisms, the species are related, even if only distantly. *Organisms with homologous structures share a common ancestor*, but at some point, mutations contributed to the rise of the new species.



The forelimbs of five mammals are presented above. The bones are color-coded to allow for easy comparison among the different species.

Adapted from image courtesy of Wikipedia.

Identification of vestigial structures can also indicate a relationship between two species. **Vestigial structures** are non-functional remnants of features that were once operational in a distant ancestor. These structures help establish evolutionary pathways for modern organisms. For example, the presence of vestigial pelvic girdles and femurs in snakes and whales implies that snakes and whales descended from animals that walked on land. Because the presence of these structures were not harmful to the organisms, there was no evolutionary pressure for the structures to completely disappear.

There are a number of vestigial structures found in humans. The following list provides some of the major examples:

- **coccyx** (tailbone) - attachment site for muscles that control tail movement

- **appendix** - an organ that helped with digestion of plant material, useful for hunter-gatherer ancestors
- **wisdom teeth** - remnants of a once larger jaw or replacements for lost teeth

Comparative Embryology

Comparative embryology is the study of similarities and differences in **embryologic development** among species. To a certain extent, the evolutionary history of organisms can be seen in the development of embryos. By locating similarities in development, scientists can determine if species are related, even if only distantly.

For instance, gills are present in all vertebrate embryos at some stage in development. This common feature likely means that all vertebrates evolved from a common fish-like organism.

Physiological Similarities

The physiology of related organisms is extraordinarily similar. For example, certain organs, such as the liver, functions the same way in all mammals. This indicates that all mammals evolved from a common ancestor whose liver functioned in the same way as the livers found in current mammalian species.

Analogous & Homologous Structures

Much can be learned about the evolutionary history of an organism by comparing the structural similarities and differences of living things.

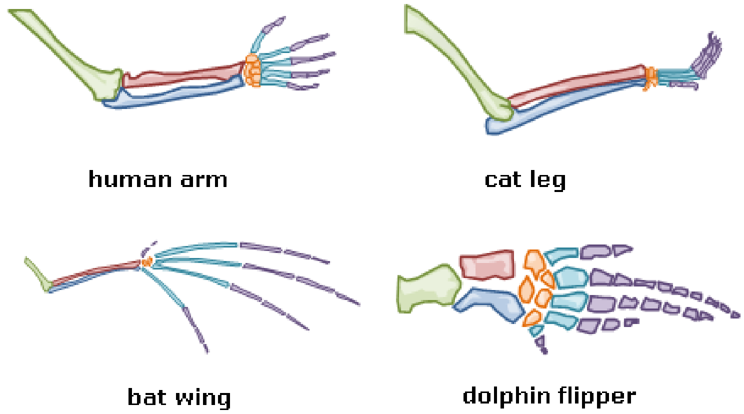
Comparative Anatomy

The study of structural differences and similarities in living things is called **comparative anatomy**. Structural similarities could be due to sharing a common ancestor, or they could be adaptations to living in similar environments.

Homologous Structures

Homologous structures are traits that were inherited from a common ancestor. The presence of homologous structures in two different organisms implies that the species are related, even if only distantly.

Homologous structures share the same origin, but may have different arrangements or functions. For example, the forelimb of humans, cats, dolphins, and bats have the same skeletal elements because these species share a common ancestor that also had these traits.



Homologous structures are represented by the same color in all represented organisms. Though they all contain the same general bones, the arrangement and function of the bones may be different because they have adapted to different lifestyles.

However, the arrangement of the bones is slightly different. Dolphins have adapted to living in water and use their forearms for swimming. Similarly, bats have adapted to flight, and humans have developed the ability to grip and adeptly control objects with their hands. Selective pressures were placed on organisms in order to survive in different types of environments. These pressures to survive in new environments led to the different adaptations of the original structures.

Analogous Structures

Sometimes, structures in different species appear to be homologous, but they are not. These structures are said to be analogous structures.

Analogous structures have the same function, but do not share a common origin. Analogous structures evolve separately in unrelated species, and their presence does not imply that the organisms descended from the same ancestor. Because analogous structures evolved separately, their structure and arrangement are also very different.

The wings of a dragonfly and the wings of an eagle both have the same function - flight. However, they are analogous structures because they evolved separately, from two different ancestors.

For example, birds have a single pair of wings that are composed mostly of muscle, bone, and feathers. Dragonflies are invertebrates, whose two pairs of wings are made mostly of integument.

Evolution - History of Life on Earth

Organisms have changed significantly since the first appearance of life on Earth.

Important Terms

- **aerobic** - living in the presence of gaseous oxygen
- **anaerobic** - living in the absence of gaseous oxygen
- **autotroph** - organism that can synthesize its own food
- **heterotroph** - organism that cannot synthesize its own food and consumes organic material

Evolutionary Timeline

- 3.8 billion years ago - first cells (anaerobic prokaryotes)
- 3.2 billion years ago - first photosynthetic bacteria (prokaryotes)
- 2 billion years ago - first eukaryotes
- 1 billion years ago - first multicellular organisms
- 570 million years ago - first arthropods
- 500 million years ago - first fish
- 475 million years ago - first land plants
- 360 million years ago - first amphibians
- 300 million years ago - first reptiles
- 225 million years ago - first mammals and dinosaurs
- 150 million years ago - first birds
- 200 thousand years ago - first humans

First Life

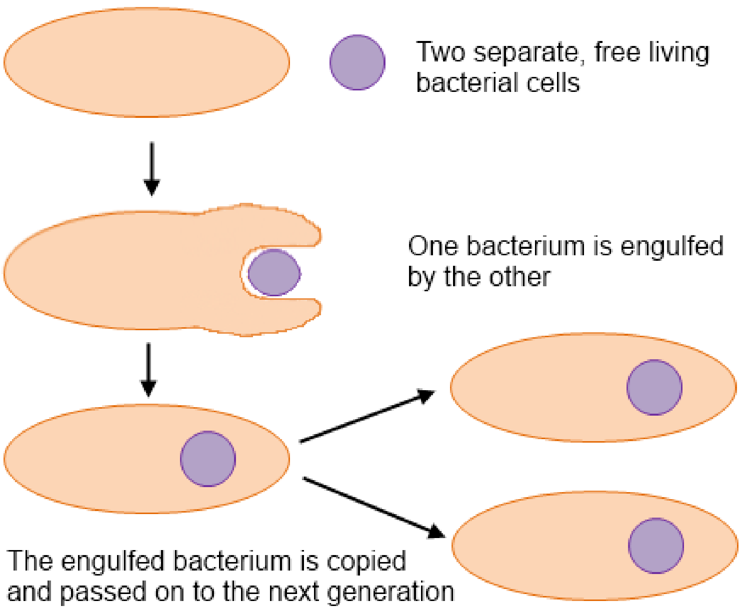
The geologic record indicates that the first life forms appeared approximately 3.8 bya and were anaerobic prokaryotes. The first cells were most likely heterotrophic, feeding on organic molecules.

Evidence of these early lifeforms can be found in structures called *stromatolites*, like the image below.

These wavy structures were created by the secretions of ancient bacteria.
Image courtesy of USGS.

Evidence of the first photosynthetic autotrophs were dated back to 3.5 - 3.1 bya. A type of cyanobacterium was able to split water molecules, releasing oxygen into the atmosphere. It was the action of these bacteria which cleared the way for the evolution of **aerobic** organisms.

Endosymbiont Theory



Championed by American biologist Lynn Margulis, the endosymbiont theory describes the evolution of eukaryotic cells from prokaryotic organisms. The theory proposes that certain eukaryotic organelles developed from prokaryotic cells engulfed by a host cell.

As the name implies, the engulfed cells developed a mutually beneficial, symbiotic relationship with each other and the host. Each part provided something the others could use. Eventually, the relationship became so interdependent that the engulfed cells and host cells could not survive independently of one another.

The host cell provided protection from predators and the environment. The chloroplast's ancestor, likely a cyanobacterium, provided the ability to synthesize complex organic molecules from simple compounds. The mitochondrion's ancestor, possibly a purple bacterium, provided more energy by possessing the ability to undergo aerobic respiration.

Evidence

Chloroplasts and mitochondria:

- have **double membranes**. The make-up of the innermost membrane for each is more similar to the plasma membrane of a prokaryote.
- have their own circular DNA, similar to prokaryotic DNA.
- are similar in size to bacteria.
- have ribosomes similar to those in bacteria.