Evolution: Evidence and Theory

1: Evidence of Evolution

- Evolution: the change in the characteristics of a species over time
  - Today's species descended from more ancient forms of life by structural and physiological modifications.

Evidence from Fossils

- Fossil: the remains or traces of a once-living organism
- Fossils are found most commonly in layers of sedimentary rock.
  - This type of rock begins to form when water and wind form layers of sand and silt.
  - These actions can bury remains of an organism so quickly that bacteria and other decomposers are sealed off, preventing decomposition.
  - After time, the sedimentary layers become rock.
- The most common fossils found in sedimentary rock are from the hardest parts of organisms (shells, bones, teeth, woody stems, etc.)
- Sometimes minerals replace the original remains, often molecule by molecule. Such replacement preserves the microscopic structure of the organism.
- Other means of fossil formation: insects trapped in resin, woolly mammoth frozen in Arctic ice, etc.
- Other types of fossils:
  - Imprint: a type of fossil in which a thick film of carbon remains after the organism has decayed
  - Mold: a type of fossil formed from an impression of the shape or tracks of an organism
  - Cast: a type of fossil formed when sediments fill in the cavity left by a decomposed organism

Dating Fossils

- The relative age of fossils is determined from their position in sedimentary rock.
- The absolute age of a fossil is determined by radioactive dating.
  - Radioactive isotopes have unstable nuclei that break down, or decay, and form other elements. These isotopes decay at a constant rate.
  - Half-Life: the period of time that it takes for one-half of the radioactive material to decay
    - Example: The half-life of carbon-14 is 5,730 years.
  - The ratio of carbon-12 (most common, stable isotope of carbon) and carbon-14 in the atmosphere is assumed to be constant over time.
  - Organisms take up the two isotopes of carbon in about the same ratio that the isotopes are found in the atmosphere.
    - After an organism dies, the amount of carbon-14 will decrease as it changes into nitrogen-14. However, carbon-12 does not decay.
    - By comparing the ratio of carbon-14 to carbon-12 in a fossil with the ratio of these isotopes in the atmosphere, scientists can date fossils that are up to 50,000 years old.
  - Scientists use other isotopes (i.e. potassium-40 and uranium-238) to date older fossils.

The Fossil Record

- By dating fossils and examining geologic data, scientists have been able to put together a time scale for the history of life on earth. (see book)

- Fossil evidence indicates that over time organisms of increasing complexity appeared on the earth.

Evidence From Living Organisms

Evidence of Common Ancestry

- If species change over time, then scientists should be able to cite examples showing that a group of living species may have come from a common ancestor.
- Example: All Hawaiian honeycreepers have similarities in skeletal and muscle structure that indicate they are closely related. However, each of the Hawaiian honeycreeper species has a bill specialized for eating certain foods.

Homologous Structures

- Homologous Structures: structures that are embryologically similar
- "Living organisms evolved through gradual modification of earlier forms- descent from a common ancestor" (Darwin).

Vestigial Organs

- Vestigial Organ: a functionless structure that may be homologous to useful structures in other species
  - Examples: human tailbone, pelvic and limb bones of snakes, eyes of cave-dwelling salamanders, etc.
- Organisms having vestigial structures probably share a common ancestry with organisms in which the homologous structure is functional.

Biochemistry

- Biochemistry reveals similarities between organisms of different species.
  - Examples: cytochrome c, blood proteins, etc.
- This evidence implies that some species share a more recent common ancestor than other species do. From such evidence scientists have inferred the evolutionary relationships between different species of organisms.

Embryological Development

- The embryos of certain species develop almost identically, especially in the early stages.
- These similarities can be considered evidence that the organisms probably descended from a common ancestor.

2: Darwin's Theory of Evolution

Evolutionary Theory Before Darwin

- The first systematic presentation of evolution was put forth by the French scientist Jean Lamarck in 1809.
  - Lamarck described a mechanism known as "the inheritance of acquired characteristics."
  - Lamarck presented no experimental evidence or observation and his theory fell out of scientific favor.

Darwin's Background

- In 1831 Charles Robert Darwin (1809-1882) was chosen for the position of naturalist on the ship the HMS *Beagle*. The voyage around the world began in England.

The Voyage of the *Beagle*

- The *Beagle* was chartered for a five-year mapping and collecting expedition to South America and the South Pacific.
- Darwin's job as the ship's naturalist was to collect specimens, make observations, and keep careful records of anything he observed that he thought significant.

Darwin in England

- When Darwin returned to England in October 1836, his collections from the voyage were praised by the scientific community.
- Darwin sent his bird collections from the Galápagos Islands to an ornithologist.
  - He reported that Darwin had collected 13 similar but separate species of finches. Each finch species had a distinctive bill specialized for a particular food source.
- The similarities of the finches led Darwin to infer that the finches shared a common ancestor. The similarities between the fossil mammals Darwin also collected and modern mammals led him to believe that species change over time.
- Darwin observed that fossils of similar relative ages are more closely related than those of widely different relative ages.

Evolution by Natural Selection

- Darwin stated:
  - variation exists among individuals of a species.
  - scarcity of resources in a growing population would lead to competition between individuals of the same species because all use the same limited resources.
  - such competition would lead to the death of some individuals, while others would survive.
- Darwin concluded that individuals having advantageous variations are more likely to survive and reproduce than those without the advantageous variations (fitness).
- Natural Selection: process by which organisms with favorable variations survive and reproduce at a higher rate
- Adaptation: an inherited variation that increases an organism's chance of survival in a particular environment
- Over many generations, an adaptation could spread throughout the entire species.
  - In this way, according to Darwin, evolution by natural selection would occur.

The Origin of Species

- Darwin's book *The Origin of Species by Means of Natural Selection* was published in 1859.

3: Patterns of Evolution

- Divergent Evolution: the process of two or more related species becoming more and more dissimilar
  - Examples: Galápagos finches, brown bear/polar bear
  - Adaptive Radiation: an evolutionary pattern in which many species evolve from a single ancestral species
    - Adaptive radiation most commonly occurs when a species of organisms successfully invades an isolated region where few competing species exist. If new habitats are available, new species will evolve.
- Convergent Evolution: the process by which unrelated species become more similar as they adapt to the same kind of environment
  - Examples: dolphins/sharks/whales/porpoises

- Coevolution: the joint change of two or more species in close interaction
  - Examples: predators & prey, parasites & hosts, plant-eating animals & plants

Divergent evolution, convergent evolution, and coevolution are different ways organisms adapt to the environment. These are examples of how the diversity of life on earth is due to the ever-changing interaction between a species and its environment.