Darwin’s Theory of Evolution

Final Lecture Notes

**I. Introduction to Evolutionary Theory**

A. Biological Diversity

1. Many scientists have long pondered the diversity of life on Earth. How did the millions and millions of different organisms of so many shapes and sizes come to occupy so many different habitats on Earth?

2. The term “biological diversity” refers to the variety of living things that inhabit our planet.

3. Why do these organisms live where they do? How did these organisms arise? Which organisms are related to one another? What adaptations allow an organism to live in a particular place? How do organisms change over time?

4. These are the questions that are asked by evolutionary biologists.

B. What is a theory?

1. People often use the word “theory” to indicate that a thought or idea is simply an opinion, and is not supported by facts or evidence.

2. The term “theory” in a science class has a much different meaning.

3. Scientific Theory:

a) An explanation that is based on observation, experimentation, and reasoning.

b) It is supported by a large quantity of evidence.

c) It does not conflict with existing experimental results.

4. Scientists continually analyze and critique the strengths and weaknesses of theories. As new evidence is uncovered, theories are modified to reflect this new evidence.

5. Remember: A theory has been heavily tested and is supported by a large body of evidence.

C. What is evolution?

1. Evolution means “changes over time.”

2. Evolution is the process by which modern organisms have descended from ancient organisms.

3. Evolutionary theory: The collection of scientific facts, observations and hypotheses that attempt to explain the diversity of life on Earth.

4. Modern scientists define evolution as a heritable change in the characteristics within a population from one generation to the next.

D. Who “discovered” evolution?

1. Many scientists have contributed ideas and evidence that support the theory of evolution. However, the individual who contributed more to our understanding of evolution than any other was Charles Darwin.

2. This unit will explain the work of several scientists, but the focus of the unit will be on the life of Charles Darwin, and how he developed his theory of evolution.

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**II. Charles Darwin: A Brief Biography**

A. Charles Darwin was born in England on February 12, 1809, the same day as Abraham Lincoln. He was the 5th of six children. His parents were wealthy and well connected. He had a Christian upbringing, and his family was a very open-minded and freethinking family.

B. Darwin’s grandfather, Erasmus Darwin, wrote a book in 1794 called “Zoonomia” in which he discussed how one species could “transmute” into another.

C. In 1825, Charles enrolled at Edinburgh University to study medicine. He witnessed surgeries taking place without anesthesia and quickly realized that the study of medicine was not for him.

D. In 1827, Charles abandoned the study of medicine. He decided to study Divinity at Cambridge. While training to be a clergyman, he continued to pursue his love of biology and the natural world. He was an avid collector of insects and fossils. He graduated in 1831.

E. Before Darwin could take a job as a cleric, he was offered a job as a “naturalist” on a voyage around the world on the HMS *Beagle*. Over the next five years Darwin visited four continents and collected specimens of a great variety of plants, animals and fossils.

F. In 1835, the HMS *Beagle* made a 5-week stop in the Galapagos Islands.

G. 1838: Once back home in England, Darwin began to formulate his ideas on evolution. He struggled with his decisions about publishing his theories because he knew they conflicted with Christian teachings. He decided to gather more evidence before going public. Instead he published a book about his travels.

H. In 1858, more than 20 years after returning home from his voyage, Darwin received a letter from Alfred Russel Wallace. Wallace had arrived at the same conclusions about natural selection as Darwin, and intended to publish his findings. Darwin realized that he must quickly publish the work he had spent years developing.

I. In 1859, Darwin published “On the Origin of Species by Means of Natural Selection.”

J. 1869: Origin of Species was a bestseller worldwide and went into multiple editions. In the 5th edition, Darwin introduced the term “survival of the fittest.”

K. In 1871, Darwin published “The Descent of Man.”

L. Darwin died in 1882 and was buried at Westminster Abbey.

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**III. The Voyage of the HMS *Beagle***

A. In 1831, Charles Darwin completed his college studies and joined the crew of the HMS *Beagle* as a naturalist. He set sail on a 5-year trip around the world.

B. This trip would become one of the most important voyages in the history of science. On this voyage, Darwin would make observations and collect evidence that would lead him to propose his theory of evolution about the way life changes over time.

C. Whenever the *Beagle* would anchor, Darwin would go ashore and collect samples of the flora and fauna. He also collected fossils of organisms that no longer lived on Earth.

D. While at sea, Darwin spent much time reading the latest scientific books. He studied his ever-growing collections of specimens, and filled notebook after notebook with his thoughts and observations about life on Earth.

**IV. Darwin’s Observations**

A. Darwin had always been interested in nature, and he knew quite a bit about the plants and animals that lived in England. On his travels, he quickly realized that an enormous number of species lived on Earth. During a single day in a Brazilian forest, Darwin collected 68 different species of beetles.

B. Patterns of Diversity:

1. Darwin made the observation that many of the plants and animals he observed were extremely well suited to the environment in which they were living. For example, he noted that adaptations seen in desert organisms would not be seen in organisms living in a forest.

2. Adaptations: Characteristics of organisms that enhance their survival and reproduction in specific environments.

3. These observations caused Darwin to speculate and ponder upon several questions:

a) Why do organisms exhibit certain adaptations?

b) Why is there such a variety of ways of reproducing?

c) Why do organisms live where they do? Why are the grasslands on one continent inhabited by different organisms than the grasslands of a different continent? Why are there no rabbits in Australia despite the fact that they could easily live in the habitats found there?

C. Fossils:

1. Fossil: The preserved remains of ancient organisms.

2. Darwin was an avid collector of fossils. Some of the fossils resembled organisms that were still alive, while others were unlike any creature he had ever seen.

3. Studying fossils led to even more questions:

a) Why had so many species become extinct?

b) How were the species seen in fossils related to living species?

4. Darwin noted the similarities and differences among many different organisms. He became convinced that organisms had changed over time.

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D. The Galapagos Islands

1. The Galapagos Islands are a small cluster of islands located off the west coast of South America. This port of call proved to be the most influential on Darwin’s developing theory of how life on Earth changes.

2. The cluster of islands that compose the Galapagos Islands is close together, but they have very different climates. The lower islands in the group are hot, dry and nearly barren. The higher islands have greater rainfall and rich vegetation.

3. It was very clear to Darwin that the organisms found on each island had special adaptations that allowed them to survive only on that island. Adaptations that allowed for survival on one island would not be helpful at all on a different island.

4. Darwin was particularly interested in the large land tortoises of the Galapagos. He could easily tell which island a turtle lived on by the shape of its shell. The Hood Island tortoise has a long neck and a shell that is curved and open around the legs and head. This allows the tortoise to reach up high to feed upon the sparse vegetation. The Isabela Island tortoise has a dome-shaped shell and a short neck. Isabella Island has abundant vegetation that grows close to the ground. Tortoises from Pinta Island have a shell that is intermediate between the two forms.

5. It was clear to Darwin that the tortoises were adapted for their particular island, but how had these adaptations occurred?

E. The Journey Home

1. While heading home, Darwin spent most of his time studying his collections of organisms and making observations. Darwin began to wonder if animals living on different islands had once been members of the same species.

2. Darwin began to hypothesize that separate species evolved from ancestral species after becoming isolated from one another.

**V. Ideas in Darwin’s Time**

A. Darwin lived in an exciting time of scientific discovery. New discoveries were being made, and many principles and ideas previously accepted were being challenged. Darwin was affected by other scientists and their work. In turn, Darwin changed the thinking of many scientists and nonscientists.

B. However, many people found Darwin’s ideas too shocking to accept. Reasons why many people found Darwin’s work unacceptable include:

1. Many people in Darwin’s day believed that the Earth was only a few thousand years old. They believed that the Earth and all of its forms of life had been created only a few thousand years ago.

2. It was believed that since the creation of Earth and its life forms, neither the planet nor its living species had undergone any changes.

3. It was believed that rocks and major geological features had been produced suddenly by catastrophic events that humans rarely witnessed.

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C. The Earth is Ancient and Changing

1. During Darwin’s time, scientists were examining and studying the features on Earth in great detail. They began to study rock layers called strata. The data they collected suggested that the Earth was very old and had changed slowly over time.

2. Several scientists who formed important theories about the changes on Earth greatly affected and influenced Darwin.

3. These scientists began to collect evidence that showed the Earth is many millions of years old, and that the processes that changed Earth in the past are the same processes that operate in the present.

D. Georges Cuvier (1769 – 1832)

1. Cuvier was a pioneer in paleontology, the study of fossils. He collected fossilized bones and spent years reconstructing the appearance of these animals. From these fossils he collected convincing evidence that the fossilized animals were very different from any living species, and that some organisms had become extinct.

2. Cuvier discovered that deeper and older strata contain fossils that are increasingly different from living species. He noted that the older the stratum, the more ***dissimilar*** its fossils were to current life forms. He also discovered many “sudden changes” in the kinds of fossils found in one stratum compared to the next stratum.

3. Cuvier’s hypothesis was termed “catastrophism.”

4. Catastrophism: This is the principle that events in the past occurred suddenly and were caused by different mechanisms than those operating today. In other words, catastrophes in the past (such as floods or erupting volcanoes) were responsible for destroying certain species.

5. Cuvier’s work led to the acceptance of the ideas of geologic change and extinction.

E. James Hutton

1. In 1795, James Hutton published a detailed hypothesis about the geologic forces that have shaped the Earth.

2. Hutton’s hypothesis included the following ideas:

a) Layers of rock form very slowly.

b) Some rocks are moved up by forces beneath Earth’s surface to form mountains.

c) Mountains and valleys are shaped by natural forces such as rain, wind, and fluctuating temperatures.

d) These processes occur slowly over millions of years.

F. Charles Lyell (1797 – 1875)

1. Lyell’s idea was called “uniformitarianism.”

2. Principle of Uniformitarianism: The mechanisms of change are uniform over time. The same geologic forces that were active in the past are still operating today.

3. Charles Darwin was given a copy of Lyell’s book just before he set sail on the *Beagle*. By reading this book, Darwin understood much more about the geological forces acting upon the Earth.

4. This new understanding of geology affected Darwin in two ways:

a) Darwin asked himself this question: If the Earth could change slowly over time, could the living organisms on Earth also change slowly over time?

b) Darwin realized that in order for life to change over time, the Earth would have to be extremely old.

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G. Jean-Baptiste Lamarck (1744 – 1829)

1. Lamarck was one of the first scientists to propose that living organisms had changed over time.

2. In 1809, Lamarck published his hypothesis known as the “Theory of Acquired Characteristics.”

3. Theory of Acquired Characteristics: Individuals acquire traits during their lifetime as a result of their experience or behavior, and then pass these traits to their offspring.

4. In other words, if you spend your entire adult life weight lifting and building up muscle mass, your children will have big muscles, too. If you lose a finger in an accident, your children will be missing a finger, too.

5. Although Lamarck’s theory was quickly rejected, it was important for several reasons:

a) Lamarck was the first to recognize that organisms change over time.

b) He was the first to develop a hypothesis about evolution.

c) He was among the first to propose that organisms are adapted to their environment.

H. Thomas Malthus (1766 – 1834)

1. Thomas Malthus published a book in which he discussed his thoughts and ideas about human population growth. This book proved to have a great impact on Darwin’s developing theories.

2. In his book, Malthus noted that human babies were being born faster than people were dying. He reasoned that if the human population continued to grow at such a rapid rate, eventually there would not be enough space or food to support the population.

3. After Darwin read the book published by Malthus, he realized that these ideas applied even more strongly to plants and animals.

4. Darwin knew that a plant might produce thousands of seeds, but that every single seed did not result in a new plant. Only a small portion of the seeds would germinate and grow into a new plant. Further, of the seeds that did germinate and grow, only a small number of those would be successful in their own reproduction.

5. What factor or factors determine which offspring will survive and reproduce, and which will not? This key question is the foundation of Darwin’s theory of evolution.

**VI. Darwin Develops His Theory of Evolution**

A. What happened when Darwin returned home from his voyage on the *Beagle*?

1. Darwin arrived back in England in 1836. He would not publish his theories on evolution until 1859.

2. Once back in England, Darwin began to earnestly study the fossils and specimens that he had collected on his trip. He filled notebook after notebook with his ideas about the diversity of life on Earth and how it had changed (evolved) over time.

3. During his trip around the world, Darwin noticed many examples of adaptations. Adaptations are characteristics of organisms that enhance their survival and reproduction in specific environments.

4. Darwin explained that organisms become “adapted” by natural selection. According to Darwin, natural selection is a process in which individuals with certain inherited traits leave more offspring than individuals with other traits.

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5. Darwin was reluctant to publish his ideas. Apparently he was concerned about the uproar his ideas would cause. His ideas challenged fundamental scientific beliefs as well as religious beliefs.

6. Darwin continued his studies, but he shelved his manuscripts for many years. He instructed his wife to publish them in the event of his death.

B. What changed?

1. In 1858, Darwin received a letter from Alfred Russel Wallace. In his letter, Wallace summarized his thoughts on evolutionary change. Wallace had arrived at the same conclusions that Darwin had been developing for the previous 25 years.

2. Wallace intended to publish his findings. Darwin realized that he must quickly publish the work he had spent years developing.

3. Eighteen months later, in 1859, Darwin published his book, “On the Origin of Species by Means of Natural Selection.”

4. In his book, Darwin proposed a mechanism for evolution that he called natural selection. He presented evidence that evolution has been occurring for millions of years, and continues in the organisms alive today.

5. As expected, his book caused an uproar. Some felt Darwin’s arguments were brilliant, while others were bitterly opposed.

**VII. Darwin’s Theory of Evolution: Descent With Modification**

A. In his book, Darwin discusses “descent with modification.” By using this term, Darwin hypothesized that all organisms descended from a common ancestor that lived in the remote past and that species were able to change over time.

B. Darwin carefully presented his evidence for his hypothesis. For example, while in the Galapagos Islands, Darwin observed 13 different species of finches. Each species has a beak that is adapted to acquiring a very specific type of food. Darwin thought that all 13 species descended from and diverged from a common ancestral finch.

C. Darwin thought that over millions of years, the descendants of these ancestors had accumulated “modifications” or adaptations that “fit” them to a specific environment. This “descent with modification” led to the diversity of life on Earth today.

D. Artificial Selection

1. Darwin noted that plant and animal breeders were aware of the variations that existed in living organisms, and through selective breeding, they could improve their crops and livestock.

2. Selective breeding: A method of breeding that allows only those individual organisms with desired characteristics to produce the next generation.

3. Darwin noted that farmers would routinely select for breeding only the largest hogs, the fastest horses, or trees bearing the best fruit.

4. Darwin called this process artificial selection.

5. Artificial Selection: Variations exist in plants and animals. By selective breeding, humans select the variations they find to be most useful.

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**VIII. Evolution by Natural Selection**

A. Darwin's Evolutionary Theory is based on the following concepts:

1. Organisms beget like organisms. There is stability in the process of reproduction.

2. In any given population, there are chance variations among individual organisms. Some of these variations are passed to future generations.

3. The “struggle for existence”: Members of a species compete for food, water, living space, and other resources. For example, the predators that are faster, have longer claws or sharper teeth will catch more prey. Prey that are faster or better camouflaged live longer to reach reproductive maturity. Competition and certain favorable characteristics determine which organisms live to reproductive age.

4. The number of individuals that survive and reproduce in each generation is small compared to the number produced.

5. Which individuals will survive and reproduce and which will not is determined by how well suited an organism is to its environment. Darwin called the ability of an individual to survive and reproduce in its specific environment “fitness.”

6. Fitness is the result of adaptations. An adaptation is any inherited characteristic that increases an organism’s chance of survival.

7. Individuals with characteristics that are not well suited to their environment either die or leave few offspring.

8. Individuals with characteristics well suited to their environment survive and reproduce more successfully, passing these favorable traits on to future offspring. This became known as “survival of the fittest.”

B. This is the process that Darwin called “Natural Selection.”

1. Those better suited for the environment have a better chance of reproducing.

2. Natural Selection: The process in which individuals with certain favorable inherited traits leave more offspring than individuals with other traits.

3. Over time, natural selection results in changes in the inherited characteristics of a population. These changes increase the “fitness” of a species to its environment.

C. Common Descent

1. Darwin’s idea of “descent with modification” implies that all living organisms are related to one another.

2. This is the principle of “Common Descent”: The principle that all living things are derived from common ancestors.

D. The Controversy

1. Darwin’s ***“The*** ***Origin of Species”*** was truly radical for its time. It caused such a controversy because it went against two widely accepted premises:

a) The earth is only a few thousand years old (rather than billions.)

b) The earth is populated by unchanging forms of life that have been individually created (rather than the earth is populated by organisms that evolved from previous ancestors.)

2. Darwin envisioned life as evolving by a gradual accumulation of minute changes, and he postulated that natural selection operating over vast amounts of time could account for the entire diversity of life.

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E. To summarize, the main features of the Darwinian view of life:

1. Individual organisms have different traits and characteristics. These variations are heritable.

2. Organisms produce more offspring than can survive. Of those that do survive, many will never reproduce.

3. Because more organisms are produced than can survive, there is intense competition for limited resources.

4. Individuals best suited to the environment are more likely to survive and reach reproductive age. These organisms pass their heritable traits on to their offspring.

5. Organisms less suited for a particular environment often die. If they do survive, they leave less offspring.

6. This process of natural selection causes species to change over time.

7. The species that are alive today are descended with modification from ancestral species that lived in the past.

F. Important points about natural selection:

1. Individuals do not evolve. A population evolves over time.

2. Natural selection can amplify or diminish inheritable traits.

3. Environmental factors vary from place to place over time. A trait that is favored in one place may be useless, or harmful, in another place.

**IX. The Evidence for Evolution**

A. Darwin argued that life on Earth had been changing and evolving for millions of years. The following areas provide evidence for evolution.

1. The fossil record.

2. The geographic distribution of living organisms.

3. Homologous body structures.

4. Embryology.

5. Biological molecules

B. The Fossil Record

1. Fossil: A fossil is the remains or traces of an organism that died long ago.

2. Fossils provide the most powerful evidence of evolution.

3. Fossils are a record of the history of life on Earth. Many fossils have been found of organisms that are no longer living. These extinct fossils resemble organisms that are living today. The fossil evidence shows that past organisms differed from present-day organisms and that many species have become extinct. The fossil record shows when new groups appeared in Earth’s history and how they changed over time.

4. By comparing fossils from older rock layers with fossils from younger rock layers, scientists can document that life on Earth has changed over time.

5. Scientists seek to determine both the “relative age” and the “absolute age” of a fossil.

6. The relative age is the age of an object in relation to the ages of other objects. For example, when scientists study rock layers, or strata, fossils found at lower strata are deemed older than those fossils found at higher strata.

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7. Absolute age is the actual age of the fossil given in years. It is determined through radioactive dating processes. Fossils contain radioactive isotopes that have a half-life. The age of a material can be determined by measuring the amount of a particular radioactive isotope it contains.

8. What is learned from fossils?

a) Different organisms lived at different times.

b) Today’s organisms are different from those in the past.

c) Fossils found in adjacent layers are more like each other than to fossils found in deeper or higher layers.

d) By comparing fossils from around the world, scientists can determine when and where different species existed.

e) Fossils provide evidence about the environment in which the organism existed and in how the organism was adapted to that environment.

9. By observing transitional fossils, scientists can determine how organisms have changed over time. Transitional fossils have features and characteristics that are intermediate between ancient ancestors and their later descendants.

10. In 1862, the first skeleton of Archaeopteryx was found. This creature had characteristics of both reptiles and birds. It is believed that birds evolved from the reptiles. This fossil was the "missing link" between the reptiles and the birds.

C. Biogeography: The Geographic Distribution of Organisms

1. Biogeography is the study of the locations of organisms around the world. It refers to the distribution of plants and animals in the various regions of the world.

2. Darwin wondered why places geographically similar were populated by different organisms. Yet, when he looked at similar environments on those continents, he sometimes saw that different animals had similar anatomies and behaviors.

3. Darwin concluded that species now living on different continents had each descended from different ancestors. However, because some animals on each continent were living under similar ecological conditions, they were exposed to similar pressures of natural selection.

4. Because of these similar selection pressures, different animals ended up evolving with similar features.

5. How can two species that look very different from each other be more closely related than two other species that look similar to each other? Regardless of their physical appearance, two species are more closely related when they share a common ancestry.

D. Homologous Body Structures

1. Species that have common ancestors should have similar characteristics. Similarity in characteristics resulting from common ancestry is known as “homology”.

2. Homologous structures:

a) Homologous structures are body parts that are similar in structure but are different in function.

b) Example: Compare the bone structure seen in the wing of a bat, the flipper of a whale, the foreleg of a cat, and the arm of a human.

c) These animals show the same arrangement of bones from the shoulder to the tips of the digits, even though these appendages have very different functions.

d) Over time, each of these limbs has adapted in ways that enable organisms to survive in different environments.

e) What conclusion can be reached about the homologous bone structure seen in these 4 animals? They have the same forelimb bone structure because they shared a common ancestor in their distant past. Over time, different populations of descendants adapted to different environments.

3. Vestigial Organs

a) Vestigial organs are structures that seem to be “left over” from a previous ancestor and seem to serve no purpose in the living organism.

b) Vestigial structures are historical remnants of structures that had important functions in ancestors.

c) Example: The skeletons of present day whales reveal remnants of hipbones and leg bones.

d) Example: The human tailbone, or coccyx, is made up of four fused vertebrae that resemble the bones in an animal’s tail.

e) Vestigial structures in living organisms show a relationship to organisms that lived in the past.

E. Embryology

1. Embryology is the study of embryos and their development.

2. Many embryos of organisms of different species look very similar in their early stages of development.

3. For example: All vertebrate (fish, amphibian, reptile, bird and mammal) embryos have structures called pharyngeal gill slits in their throat regions and a postanal tail at some point during their development. Although these embryos are very alike at early stages of development, these similarities fade as development proceeds.

4. One explanation for these similarities in embryological development is that these organisms shared a common ancestor.

F. Biological Molecules

1. Scientists also observe similarities among organisms at the molecular level.

2. All species of life have the same basic genetic machinery of DNA and RNA.

3. All types of green plants have similar types of chlorophylls.

**X. Evolution in Action**

A. Darwin believed evolution to be such a slow process that it could never be observed directly. However, the effects of human civilization have produced such extremely strong ***selection pressures*** on some organisms that it has been possible to observe not only the results but also the actual process of evolution by natural selection.

B. Example of evolution in progress: The Peppered Moth

1. The peppered moth is commonly found in Britain.

2. These moths were usually found on lichen covered trees and rocks. Against this background, the light coloring of the moth made them practically invisible, concealing them from predatory birds.

3. In 1845 one black moth of this species was captured living in an industrial section.

4. With increasing industrialization of the period, the pollution killed the lichens. The trees and rocks became black from heavy pollution from the burning of coal.

5. More and more black moths were found, until they made up 98% of the moth population.

6. The black color was the result of a rare mutation. The black moths had always been present, but in very small numbers. They were usually eaten by birds because their black color stood out against the light lichens. Since they were not living to reproduce, they were not passing down the black allele.

7. As the smog turned the trees black, the black moths had a better chance of survival, and began to live to reproduce. Thus the black allele was passed down with greater frequency because now the white moths were being eaten.

8. In the 1950's strong pollution controls were implemented. Less pollution brought a return of the light colored lichen. The number of white colored moths increased as a result.

9. Neither the black moths nor the white moths are superior. It is simply a matter of which trait is favored by the environment at a given time.

C. Example of evolution in progress: The Evolution of Insecticide Resistant Insects

 Whenever a new insecticide is used, the results are usually the same. The first spraying of the new insecticide may kill 99% of the insects it is intended to kill. Subsequent sprayings will be less and less effective. The relatively few survivors of the first spraying are insects with alleles that somehow enable them to withstand the poison. The poison kills most members of the target population, but leaves the most resistant members to reproduce. The survivors pass these favorable traits on to their offspring. In each generation, the proportion of insecticide resistant individuals increases. The population has adapted to a change in the environment.

**XI. Patterns of Evolution**

A. There are several ways that species can change to adapt to their environments. The pattern and speed of evolution depends on the changing requirements of the environment. This is called ***selection pressure***.

B. The large-scale evolutionary patterns and processes that have occurred over large periods of time are the result of the following processes:

1. Extinctions

2. Adaptive radiation

3. Convergent evolution

4. Divergent evolution

5. Coevolution

6. Punctuated equilibrium

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C. Extinctions

1. More than 99% of all species that have ever lived are now extinct.

2. Reasons for extinctions include:

a) Species have to compete for similar resources and often one species is better at acquiring the resource than a competitor. The competitor is driven to extinction.

b) The environment changes and some species adapt while others perish.

c) Gradual extinctions occur due to natural selection.

d) Occasionally extinctions are not caused by ordinary natural selection, but by catastrophic events in Earth’s history. Mass extinctions wipe out entire ecosystems. During a mass extinction, species become extinct due to the environmental collapse that is occurring around them, rather than the inability to compete for resources.

e) Example: At the end of the Cretaceous Period, it is hypothesized that a huge asteroid impacted with the Earth. A huge amount of dust and water vapor was thrown into the atmosphere, causing dramatic climate change. The large-scale mass extinction that followed was not caused by natural selection, but by a complete change in environment.

3. There have been many mass extinctions in Earth’s history.

4. ***This is important!*** What effects have mass extinctions had on life on Earth? With each disappearance of so many species, many habitats and niches were opened and left unoccupied. This provides the ecological opportunity for those organisms that survived the mass extinction to move into these habitats and niches.

D. Adaptive Radiation

1. Adaptive radiation is the sudden appearance of many new species when organisms move into unoccupied habitats and niches.

2. Adaptive radiations have occurred many times in Earth’s history. Examples include:

a) The evolution of the first amphibians as they were the first vertebrates to colonize the landmasses.

b) The arrival of the dinosaurs.

c) The explosion of new mammal species that occurred when the dinosaurs became extinct.

E. Convergent Evolution

1. Convergent evolution: The process by which different species evolve similar traits.

2. Closely related organisms share characteristics because of common descent. Distantly related organisms can come to resemble one another because of convergent evolution. These organisms face similar environmental demands and will often develop similar structures to meet the demands of the environment.

3. In convergent evolution, organisms that are very distantly related come to resemble each other because they live in similar environments. An example is a shark and a dolphin. These two organisms resemble one another even though they are very distantly related. They were exposed to the same environment, subjected to the same selection pressures and had to solve “evolutionary problems” in the same way.

4. Since the shark and dolphin adapted to similar environments in similar ways, they developed analogous structures. There is very little structural similarity between the fin of the shark and the flipper of the dolphin. The dolphin has a skeleton made of bone, and the shark has no bones, only cartilage. These structures are analogous since they have the same function but no structural similarity. They evolved in this way in response to the selection pressure that was placed on them.

5. Even penguins, which are birds, show a similar body type as sharks and dolphins. Here we have an example of fish, mammals, and birds developing similar structural characteristics to meet the demands of the environment in which they live.

F. Divergent Evolution

1. In divergent evolution, closely related species become more and more dissimilar.

2. The descendants of a single ancestor diversify into species that each fit different parts of the environment.

3. Example:

a) Assume that a small number of lizards are introduced on an island.

b) The lizards show variations in body types.

c) Lizards with thin bodies, short legs and large toe pads survive at a higher rate by living in trees.

d) Lizards with longer legs and tails survive better in the grass.

e) Eventually, each group may become a separate species.

G. Coevolution

1. Coevolution: The process by which two species evolve in response to changes in each other.

2. In coevolution, an evolutionary change in one organism may also be followed by a corresponding change in another organism.

3. Example: Insects have been feeding on plants since insects evolved. In response, many plants developed toxins or poisons to prevent insects from feeding on them. Natural selection favored any insect that could withstand the effects of the toxin. Those insects then survived and produced a population of offspring who could also withstand the effect of the toxin or poison. This is coevolution since one species evolved in response to another species.

H. Punctuated Equilibrium

1. Darwin was convinced that evolution was a very slow process that occurred over a very long time. In many cases, the fossil record confirms that some species did evolve very slowly over time. This idea was known as ***gradualism***.

2. Most of the time, species are in a state of equilibrium, meaning they are not changing very much. However, every now and then, something happens to upset this equilibrium. When this equilibrium is upset, changes in organisms can occur rapidly.

3. The equilibrium can be upset when:

a) Small populations become isolated from the main population.

b) A small group of organisms migrates to a new area.

c) Mass extinctions open up new ecological niches.

4. Punctuated equilibrium is a term used to describe a pattern of long, stable periods interrupted by brief periods of more rapid change.

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