MS Evolution

Corliss Karasov, (CorlissK)
Sarah Johnson, (SarahJ)
CK12 Editor

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

AUTHORS
Corliss Karasov, (CorlissK)
Sarah Johnson, (SarahJ)
CK12 Editor

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook**®, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform**®.

Printed: August 6, 2012

flexbook
next generation textbooks

CHAPTER 1 MS Evolution

CHAPTER OUTLINE

1.1 Evolution by Natural Selection

1.2 Evidence of Evolution

1.3 Macroevolution

1.4 History of Life on Earth

1.5 References

Does this frog look a little scary? It looks that way on purpose. This frog is a poisonous dart frog. They live in Central and South America. Why do you think the frog is so brightly colored? Why do you think the frog is poisonous? Why does the frog only live in warmer climates? There are also many different types of poisonous dart frogs. Some are red, some blue, some yellow. So why is there such a great diversity of poisonous dart frogs?

Scientists who study evolution are concerned with these types of questions, but they ask them about all of the species on the planet. Why are there millions of different types of species? Why are some small, some large, some furry, and some covered in feathers? These questions will be explored as we learn about the theory of evolution.

1.1 Evolution by Natural Selection

Lesson Objectives

- Explain how evolution is the change of an inherited trait in a population over many generations.
- Explain how evolution is caused by the process of natural selection.
- Describe how both Darwin and Wallace developed the theory of evolution by natural selection at the same time.

Check Your Understanding

- What does the word "inherit" mean?
- Why do offspring have some of the same traits as their parents?

Vocabulary

acquired trait A feature that an organism gets during its lifetime in response to the environment (not from genes); not passed on to future generations through gene

adaptation A beneficial trait that helps an organism survive in its environment.

artificial selection Occurs when humans select which plants or animals to breed to pass specific traits on to the next generation.

evolution The process in which something passes to a different stage, such as a living organism turning into a more advanced or mature organism; the change of the inherited traits of a group of organisms over many generations.

Galápagos Islands A group of islands in the Pacific Ocean off South America; known for unusual animal life. Many scientists, including Charles Darwin, made many discoveries that led to and support the theory of evolution by natural selection, while studying the plants and animals on these islands.

inherited traits Features that are passed from one generation to the next.

natural selection Causes beneficial heritable traits to become more common in a population, and unfavorable heritable traits become less common.

trait A feature or characteristic of an organism; for example, your height, hair color, and eye shape are physical traits.

Darwin's Observations and The Theory of Evolution

Do you ever wonder why some birds are big like ostriches and some birds are small like robins? Or why a lion has a mane while a leopard has spots? In the 19th century, an English natural scientist named Charles Darwin (**Figure** 1.1) was also fascinated by the diversity of living things on earth.

He set out to answer the following questions:

- Why are organisms different?
- Why are organisms similar?
- Why are there so many different types of organisms?

To answer his questions, he developed what we now call "the theory of evolution by natural selection." This theory is one of the most important theories in the field of life science. In everyday English, "evolution" simply means "change". In biology, **evolution** is the process that explains why species change over time. Darwin spent over 20 years traveling around the world and making observations before he fully developed his theory.

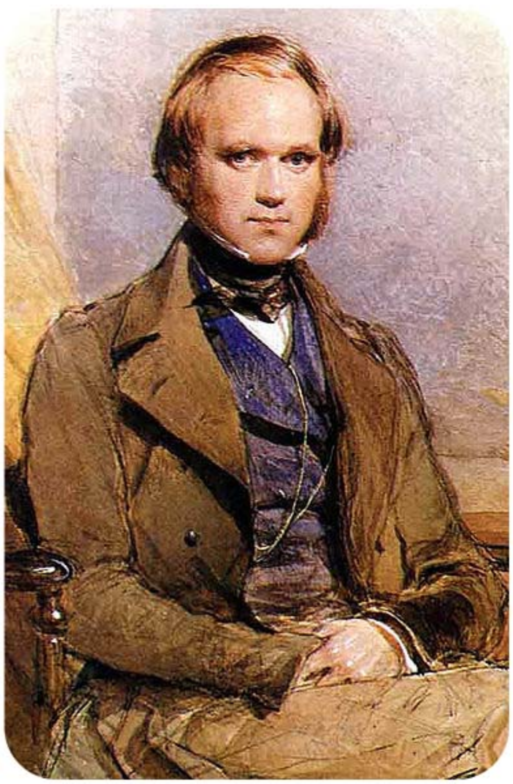


FIGURE 1.1
Charles Darwin was one of the most influential scientists who has ever lived. Darwin introduced the world to the theory of evolution by natural selection, which laid the foundation for how we understand the living world today.

Voyage of the HMS Beagle

In 1859, Charles Darwin published his book, *On the Origin of Species by Means of Natural Selection.* His book describes the observations and evidence that he collected over 20 years of research, beginning with a five-year voyage around the world on a British research ship, the *HMS Beagle*. During the voyage (**Figure** 1.2), Darwin made observations about plants and animals around the world. He also collected specimens to study when he returned to England.

Each time the Beagle stopped at a port, Darwin went on land to explore and look at the local plants, animals, and fossils. One of the most important things Darwin did was keep a diary. He took detailed notes and made drawings.

FIGURE 1.2
Charles Darwin's famous five year voyage was aboard the HMS Beagle from 1831-1836.

The Galápagos Islands

While the crew of the *HMS Beagle* mapped the coastline of South America, they traveled to a group of islands called the Galápagos. The Galápagos are a group of 16 volcanic islands near the equator, about 600 miles from the west coast of South America. Darwin spent months on foot exploring the islands. The specimens he collected from the Galápagos and sent back to England greatly influenced his ideas of evolution (**Figure** 1.3).

On the Galapagos, Darwin observed that the same kind of animal differed from one island to another. For example, the iguanas (large lizards) differed between islands (**Figure** 1.4). The members of one iguana species spent most of their time in the ocean, swimming and diving underwater for seaweed, while those of another iguana species lived on land and ate cactus. Darwin wondered why there were two species of iguana on the same set of islands that were so different from one another. What do you think?

Giant Tortoises

Darwin also observed giant tortoises on the Galápagos (**Figure** 1.5). These tortoises were so large that two people could ride on them. Darwin noticed that different tortoise species lived on islands with different environments. He realized that the tortoises had traits that allowed them to live in their particular environments. For example, tortoises that ate plants near the ground had rounded shells and shorter necks. Tortoises on islands with tall shrubs had longer necks and shells that bent upwards, allowing them to stretch their necks (**Figure** 1.6). Darwin began to hypothesize that organisms developed traits over time because of differences in their environments.

FIGURE 1.3
The Galápagos Islands are a group of 16 volcanic islands 600 miles off the west coast of South America. The islands are famous for their many species found nowhere else.

FIGURE 1.4
The Galápagos iguanas are among the signature animals of the Galápagos Islands. Here both a land iguana and a marine iguana are shown.

FIGURE 1.5
The name "Galápagos" means "giant tortoise." When Darwin arrived on the Galápagos Islands, he was amazed by the size and variety of shapes of these animals. The giant tortoise is a unique animal found only in the Galápagos Islands. There are only about 200 tortoises remaining on these islands.

Darwin's Finches

The most studied animals on the Galápagos are finches, a type of bird (**Figure** 1.7). When Darwin first observed finches on the islands, he did not even realize they were all finches. But when he studied them further, he realized

FIGURE 1.6
This tortoise is able to reach leaves high in shrubs with its long neck and curved shell.

they were related to each other. Each island had its own distinct species of finch. The birds on different islands had many similarities, but their beaks differed in size and shape.

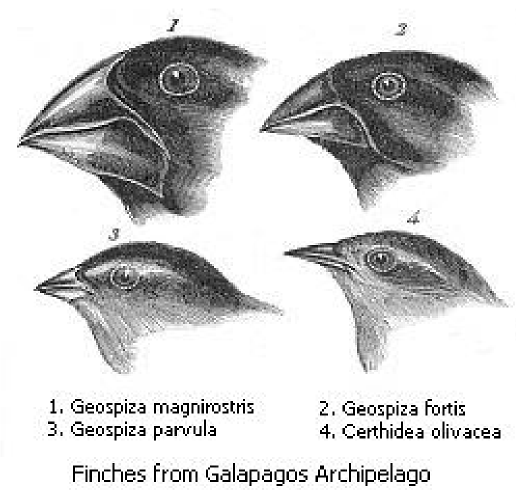


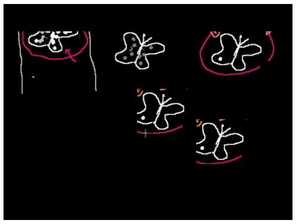
FIGURE 1.7
Four of Darwin's finch species from the Galápagos Islands. The birds came from the same finch ancestor. They evolved as they adapted to different food resources on different islands. The first bird uses its large beak to crack open and eat large seeds. Bird #3 is able to pull small seeds out of small spaces.

In his diary, Darwin pointed out how each animal is well-suited for its particular environment. The shapes of the finch beaks on each island were well-matched with the seeds available on that island, but not the seeds on other islands. For example, a larger and stronger beak was needed to break open large seeds on one island and a small beak was needed to eat the small seeds on a different island.

For a video of naturalist Sir David Attenborough on Charles Darwin and evolution, see http://www.youtube.com/watch?v=uz7U4k522Pg (4:27).

MEDIA
Click image to the left for more content.

An overview of evolution can be seen at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/0/G cjgWov7mTM (17:39).



MEDIA

Click image to the left for more content.

Darwin's ideas can be summarized in the *Natural Selection and the Owl Butterfly* video: http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/3/dR_BFmDMRaI (13:29).

MEDIA

Click image to the left for more content.

Influences on Darwin

When Darwin returned to England five years later, he did not rush to announce his discoveries. Unlike other naturalists before him, Darwin did not want to present any ideas unless he had strong evidence supporting them. Instead, once Darwin returned to England, he spent over twenty years examining specimens, talking with other scientists and collecting more information before he presented his theories.

Some of Darwin's ideas conflicted with widely held beliefs, including those from religious leaders, such as:

- All organisms never change and never go extinct.
- The world is only about 6,000 years old.

These beliefs delayed Darwin in presenting his findings. How did Darwin come up with his theories? Charles Darwin was influenced by the ideas of several people. Before the voyage of the *Beagle*, Jean-Baptiste Lamarck proposed the idea that evolution occurs. However, Darwin differed with Lamarck on several key points. Lamarck proposed that traits acquired during one's lifetime could be passed to the next generation. Darwin did not agree with this. The findings of Charles Lyell, a well-known geologist, also influenced Darwin. Lyell taught Darwin about geology, paleontology and the changing Earth. Lyell's findings suggested the Earth must be much older than 6,000 years.

After the Voyage of the *Beagle*, another naturalist, Alfred Wallace (**Figure** 1.8), developed a similar theory of evolution by natural selection. Wallace toured South America and made similar observations to Darwin's. Darwin and Wallace presented their theories and evidence in public together. Due to the large number of observations and conclusions he made, Darwin is mostly credited and associated with this theory.

Natural Selection and Adaptation

The theory of evolution by natural selection means that the inherited traits of a population change over time through a process called natural selection. **Inherited traits** are features that are passed from one generation to the next. For

FIGURE 1.8
Alfred Wallace developed a similar theory of evolution by natural selection.

example, your eye color is an inherited trait (you inherited it from your parents). Inherited traits are different from **acquired traits,** or traits that organisms develop over a lifetime, such as strong muscles from working out (**Figure** 1.9).

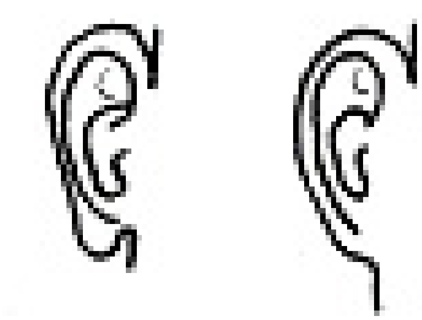


FIGURE 1.9
Human earlobes may be free or attached. You inherited the particular shape of your earlobes from your parents. Inherited traits are influenced by genes, which are passed on to offspring and future generations. Your summer tan is not passed on to your offspring. Natural selection only operates on traits like earlobe shape that have a genetic basis, not on traits like a summer tan that are acquired.

Natural selection explains how organisms in a population develop traits that allow them to survive and reproduce. These traits will most likely be passed on to their offspring. Evolution occurs by natural selection. Take the giant tortoises on the Galápagos as an example. If a short-necked tortoise lives on an island with fruit located at a high level, will the short-necked tortoise survive? No, it will not, because it will not be able to reach the food it needs to survive. If all of the short necked tortoises die, and the long-necked tortoises survive, then over time only the long-necked trait will be passed down to offspring. All of the tortoises with long-necks will be "naturally selected" to survive.

Every plant and animal depends on its traits to survive. Survival may include getting food, building homes, and attracting mates. Traits that allow a plant, animal, or bacteria to survive and reproduce in its environments are called **adaptations.**

Natural selection occurs when:

a. There is some variation in the inherited traits of organisms within a species.
b. Some of these traits will give individuals an advantage over others in surviving and reproducing.
c. These individuals will be likely to have more offspring.

Imagine how in winter, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Natural selection suggests that white fur is a beneficial trait that improves the chance that a rabbit will survive, reproduce and pass the trait of white fur on to its offspring (**Figure** 1.10). Over time, dark fur rabbits will become uncommon. Rabbits will adapt to have white fur.

FIGURE 1.10
In winter, the fur of Arctic hares turns white. The camouflage may make it more difficult for fox and other predators to locate hares against the white snow.

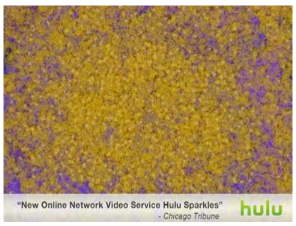
Why so many species?

Scientists estimate that there are between 5 million and 100 million species on the planet. But why are there so many? As environments change over time, organisms must constantly adapt to those environments. Diversity of species increases the chance that at least some organisms adapt and survive any major changes in the environment. For example, if a natural disaster kills all of the large organisms on the planet, then the small organisms will continue to survive.

Lesson Summary

- Evolution is a change in species over multiple generations.
- Natural selection is how evolution occurs when organisms develop traits that allow them to survive, reproduce, and pass on their traits to their offspring.
- Adaptations are the result of natural selection.
- Charles Darwin is credited with developing the theory of evolution by natural selection.

The Simpsons - Homer Evolution can be viewed at http://www.youtube.com/watch?v=faRlFsYmkeY (1:30).



MEDIA

Click image to the left for more content.

Review Questions

Recall

1. Define biological evolution.

2. What was the name of the ship that Darwin traveled on?

3. What is the name of the islands where Darwin studied evolution?

4. Who proposed a theory of evolution by natural selection that was similar to Darwin's theory?

Apply Concepts

5. How is evolution the result of natural selection?

6. What is an example of an adaptation?

7. What is the difference between an inherited trait and an acquired trait?

8. A giraffe's long neck allows the giraffe to eat leaves from high in the tree. This is an example of an _____________.

Critical Thinking

9. If a species of finch lives on an island with small seeds that fall easily into cracks between rocks, what kind of beak traits will be selected for over time?

Further Reading / Supplemental Links

- Stein, Sara, The Evolution Book, Workman, N.Y., 1986.

- Yeh, Jennifer, Modern Synthesis, (From Animal Sciences).
- Darwin, Charles, Origin of the Species, Broadview Press (Sixth Edition), 1859.
- Ridley, Matt, The Red Queen: Sex and the Evolution of Human Nature, Perennial Books, 2003.
- Ridley, Matt, Genome, Harper Collins, 2000.
- Sagan, Carl, Cosmos, Edicions Universitat Barcelona, 2006.
- Carroll, Sean B., The Making of the Fittest: DNA and the Ultimate Forensic Record of Evolution, Norton, 2006.
- Dawkins, Richard, The Blind Watchmaker, W.W. Norton & Company, 1996.
- Dawkins, Richard, The Selfish Gene, Oxford University Press, 1989.
- Diamond, Jared, The Third Chimpanzee: The Evolution and Future of the Human Animal, HarperCollins, 2006.
- Mayr, Ernst, What Evolution Is, Basic Books, 2001.
- Zimmer, Carl, Smithsonian Intimate Guide to Human Origins, Smithsonian Press, 2008.

Charles Darwin and the Tree of Life

Part 1: http://www.youtube.com/watch?v=cQJ4wIHPQHI

MEDIA

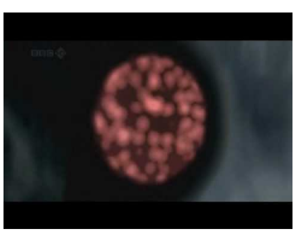
Click image to the left for more content.

Part 4: http://www.youtube.com/watch?v=81cCx9OtvpA&feature=related

MEDIA

Click image to the left for more content.

Part 5: http://www.youtube.com/watch?v=3d2VBNPEITU&feature=fvwrel



MEDIA

Click image to the left for more content.

Points to Consider

- What kind of evidence supports the theory of evolution by natural selection?
- How does genetics provide a basis for Darwin's original observations?

1.2 Evidence of Evolution

Lesson Objectives

- Explain how the scientific theory of biological evolution is based on physical evidence and experiments.
- Discuss the significance of the fossil record as evidence for evolution.
- Compare vestigial structures and embryos as a biological basis for evolution.
- Explain the genetic basis for evolution.

Check Your Understanding

- Where did Charles Darwin collect evidence of evolution and what kinds of evidence did he find?
- What is natural selection?
- What kinds of traits change through evolution?

Vocabulary

embryology The study of how organisms develop.

fossil The preserved remains or traces of animals, plants, and other organisms from the distant past; examples include bones, teeth, impressions, and leaves.

fossil record Fossils and the order in which fossils appear; provides important records of how species have evolved, divided and gone extinct.

genome All of the genes in an organism.

paleontologists Scientists who study fossils to learn about life in the past.

radiometric dating A method to determine the age of rocks and fossils in each layer of rock; measures the decay rate of radioactive materials in each rock layer.

vestigial structure Body part that, through evolution, has lost its use, such as a whale's pelvic bones.

The Fossil Record

Fossils are preserved parts of animals, plants, and other organisms from the distant past. Examples of fossils include bones, teeth, and impressions. By studying fossils, evidence for evolution is revealed.

Paleontologists are scientists who study fossils to learn about life in the past. Paleontologists compare the features of species from different periods in history. With this information, they try to understand how species have evolved over millions of years (**Figure** 1.11).

Until recently, fossils were the main source of evidence for evolution (**Figure** 1.12 and **Figure** 1.13).

- The location of each fossil in layers of rock provides clues to the age of the species and how species evolved in the past.
- In the past, organisms were spread out differently across the planet. Fossils also allow us to understand how earthquakes, volcanoes, shifting seas, and other movements of the continents affect where organisms once lived and how they adapted to their changing environments.

Rock Layers and the Age of Fossils

There are many layers of rock in the Earth's surface. These layers provide evidence for when organisms lived on Earth, how species evolved, and how some species have gone extinct. The fossils and the order in which fossils appear is called the **fossil record**.

Geologists use a method called **radiometric dating** to determine the age of rocks and fossils in each layer of rock. This technique measures the how fast the radioactive materials in each rock layer are broken down (**Figure** 1.14).

Radiometric dating has been used to determine that the oldest known rocks on Earth are between 4 and 5 billion years old. The oldest fossils are between 3 and 4 billion years old. Remember that during Darwin's time, people believed the earth was just about 6,000 years old. The fossil record proves that Earth is much older than people once thought.

Vestigial Structures

Millions of species of organism are alive today. Even though two different species may not look similar, they may have similar internal structures that suggest they have a "common ancestor," or organism that they both evolved from a long time ago.

Some of the most interesting kinds of evidence for evolution are body parts that have lost their use through evolution (**Figure** 1.15). For example, most birds need their wings to fly. But the wings of an ostrich have lost their original use. Structures that have lost their use through evolution are called **vestigial structures**. They provide evidence for evolution because they suggest that an organism changed from using the structure to not using the structure, or using it for a different purpose. Penguins do not use their wings to fly in the air; however they do use them to "fly" in the water. The theory of evolution suggests that penguins evolved to use their wings for a different purpose. A whale's pelvic bones, which were once attached to legs, are also vestigial structures (**Figure** 1.16).

Similar Embryos

Some of the oldest evidence of evolution comes from **embryology**, the study of how organisms develop. An embryo is an animal or plant in its earliest stages of development, before it is born or hatched. Centuries ago, people recognized that the embryos of many different species have similar appearances (**Figure ??**). The embryos of some species are even difficult to tell apart. Many of these animals do not differ much in appearance until they develop further.

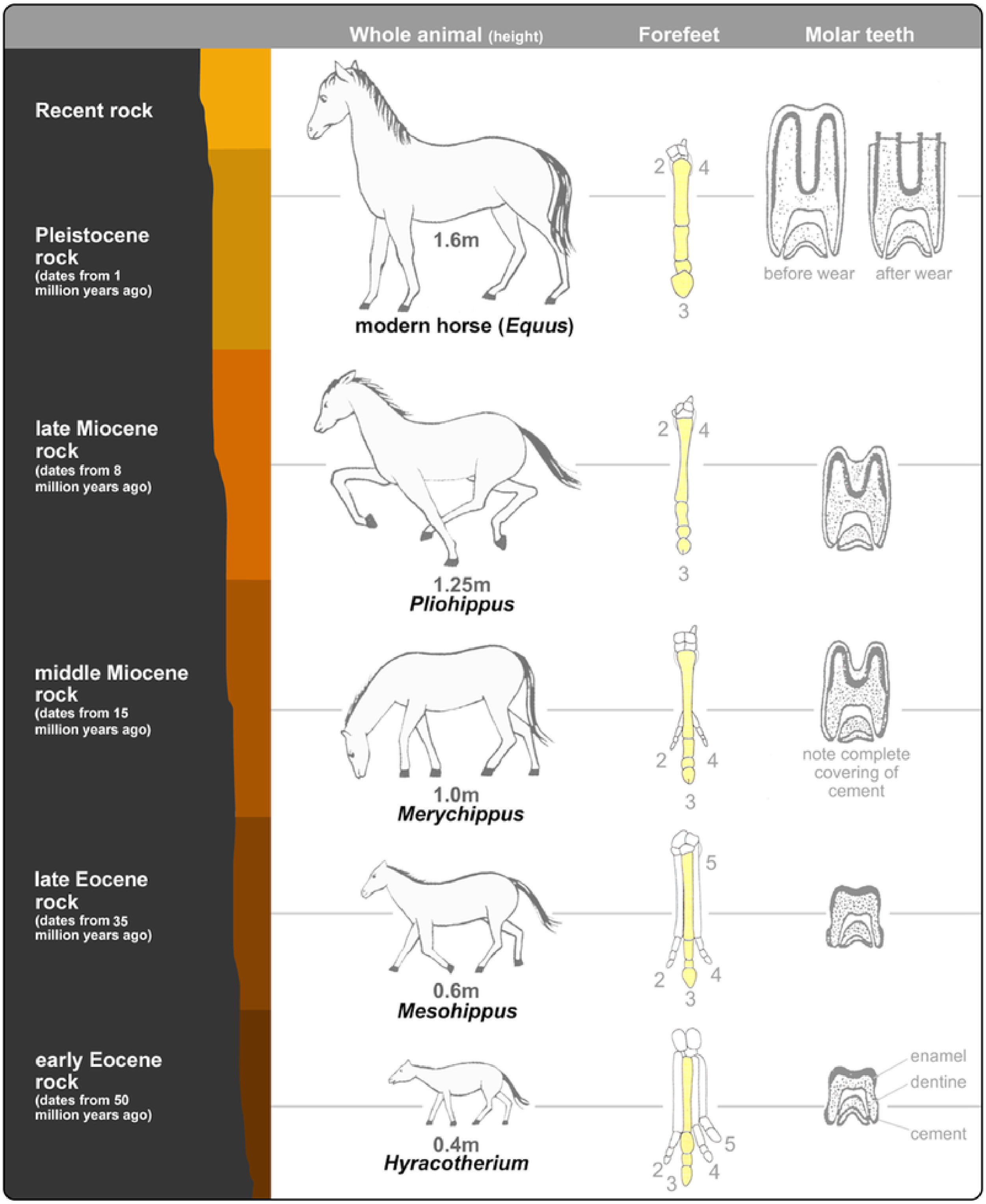


FIGURE 1.11

Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones in this process. Notice the 57 million year evolution of the horse leg bones and teeth. Especially obvious is the transformation of the leg bones from having four distinct digits to that of today's horse.

FIGURE 1.12
A fossil is the remains of a plant or animal that existed some time in the distant past. Fossils, such as this one, were found in rocks or soil that formed long ago.

FIGURE 1.13
About 40 to 60 million years ago this mosquito and fly were trapped in a gooey substance, called resin, that comes from trees. The fossils in the movie *Jurassic Park* were trapped in resin.

Many traits of one type of animal appear in the embryo of another type of animal. For example, fish embryos and human embryos both have gill slits. In fish they develop into gills, but in humans they disappear before birth (**Figure** 1.18).

The similarities between embryos suggests that these animals are related and have common ancestors. For example, humans did NOT evolve from chimpanzees. But the similarities between the embryos of both species suggest that we have an ancestor in common with chimpanzees. As our common ancestor evolved, humans and chimpanzees went down different evolutionary paths and developed different traits.

FIGURE 1.14
This device, called a spectrophotometer, can be used to measure the level of radioactive decay of certain elements in rocks and fossils to determine their age.

FIGURE 1.15
Mole rats live under ground where they do not need eyes to find their way around. This mole's eyes are covered by skin. Body parts that do not serve their original function are vestigial structures.

Similar Molecules

Arguably, some of the best evidence of evolution comes from examining the molecules and DNA found in all organisms (**Figure** 1.19).

In the 1940's, scientists studying molecules and DNA confirmed conclusions about evolution drawn from other forms of evidence. **Molecular clocks** are used to determine how closely two species are related by calculating the number of differences between the species' DNA sequences or amino acid sequences. These clocks are sometimes called gene clocks or evolutionary clocks. The fewer the differences, the less time since the species split from each other and began to evolve into different species. For example, a chicken and a gorilla will have more differences between their DNA and amino acid sequences then a gorilla and an orangutan. This provides additional evidence that the gorilla and orangutan are more closely related than the gorilla and the chicken.

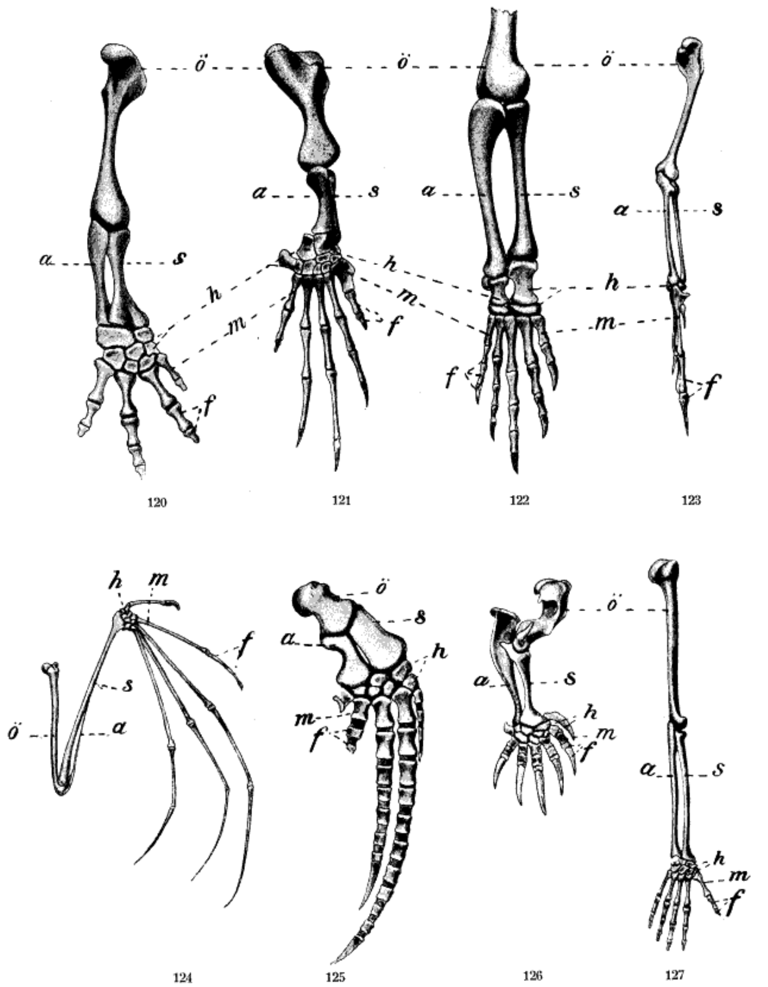


FIGURE 1.16
The bones in your arms and hands have the same bone pattern as those in the wings, legs, and feet of the animals pictured above. The bone structures clockwise from top left are: salamander, turtle, crocodile, bird, human, mole, whale, bat. How have the bones adapted for different uses in each animal?

Similar Genetics

The study of genetics has revealed the record of evolution left in the genomes of all organisms (**Figure** 1.20). It also provides new information about the relationships among species and how evolution occurs.

Genetic evidence for evolution includes:

a. The same biochemical building blocks – such as amino acids and nucleotides - are responsible for life in all organisms, from bacteria to plants and animals.
b. DNA and RNA determine the development of all organisms.
c. The similarities and differences between the genomes reveal patterns of evolution.

Lesson Summary

- Fossils provide evidence of how different organisms exist as environmental conditions change over time.
- Radiometric dating has been used to determine that the oldest known rocks on Earth are between 4-5 billion years old. The oldest fossils are between 3-4 billion years old.
- Vestigial structures indicate that two species have a common ancestor.

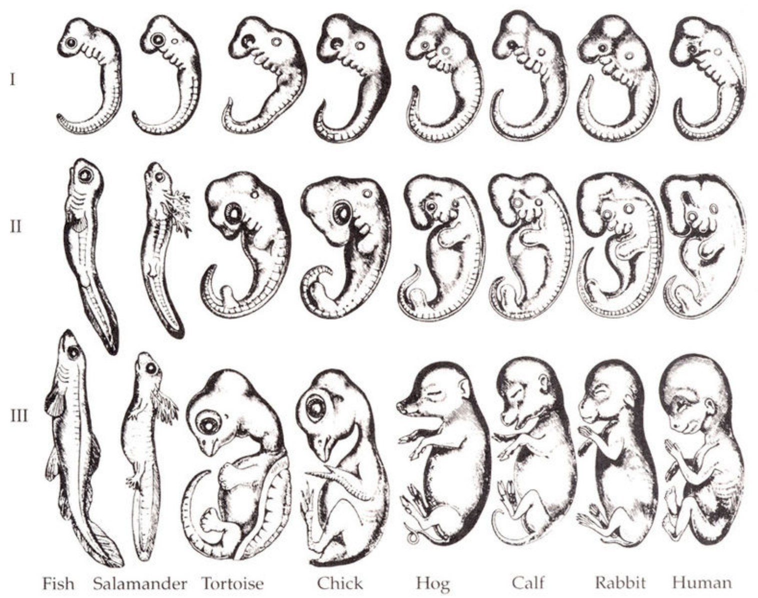


FIGURE 1.17

Vertebrate Embryos. Embryos of different vertebrates look much more similar than the adult organisms do.

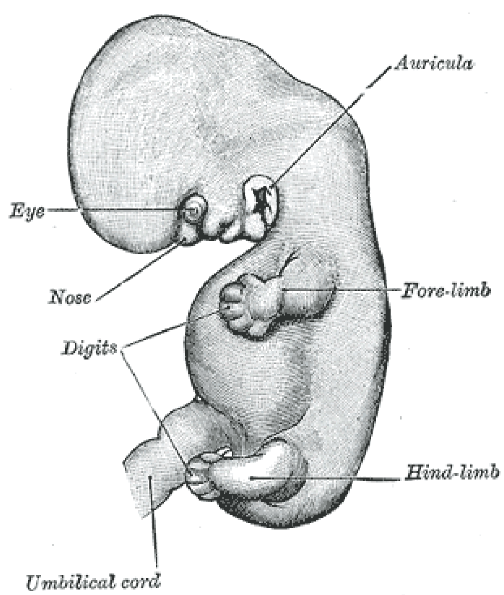


FIGURE 1.18

This is an illustration of a six week old human embryo by Henry Gray. Notice the similarities between this embryo and those of the other animals in **Figure** .

- The similarities between embryos suggests that animals are related and have common ancestors.
- The same biochemical building blocks – such as amino acids and nucleotides - are responsible for life in all organisms, from bacteria to plants and animals.
- The similarities and differences between the genomes reveal patterns of evolution.

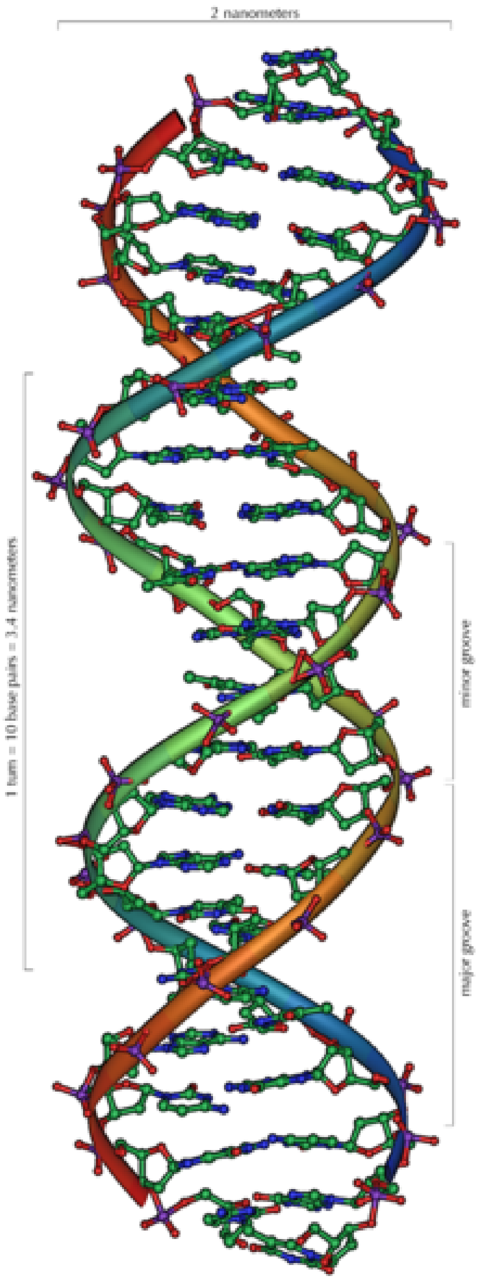


FIGURE 1.19
Almost all organisms are made from DNA with the same building blocks. The genomes (all of the genes in an organism) of all mammals are almost identical.

Review Questions

Recall

1. What are the different kinds of evidence of evolution? How do geologists determine the age of rocks and fossils?
2. What is a vestigial structure?
3. What is an embryo?
4. What is a molecular clock?

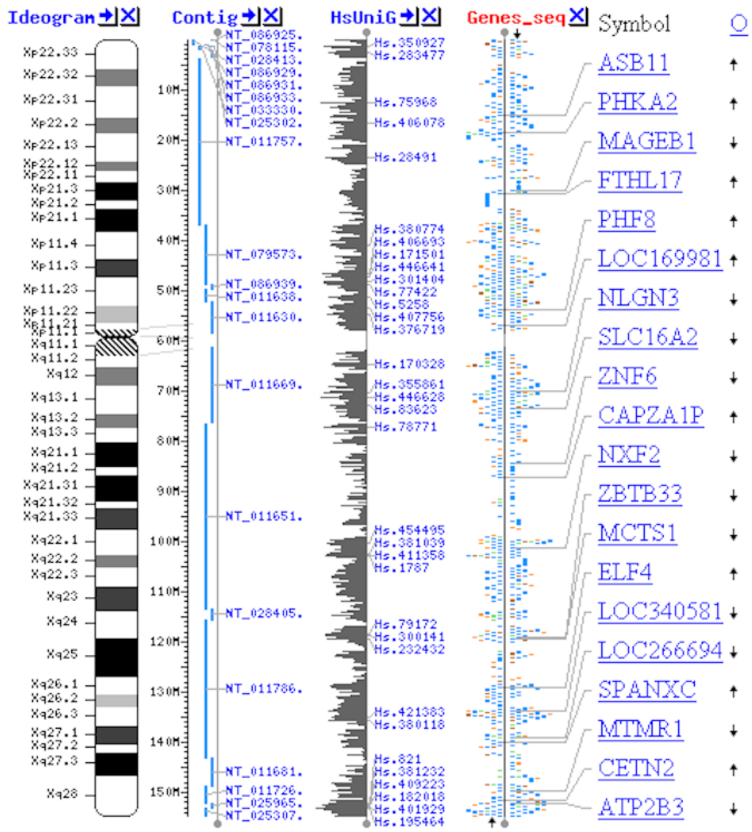


FIGURE 1.20

This is a map of the genes on just one of the 46 human chromosomes. Similarities and differences between the genomes (the genetic makeup) of different organisms reveal the relationships between the species. The human and chimpanzee genomes are almost identical- there is only a difference of 1.2% between the two genomes.

Apply Concepts

5. What is an example of a vestigial structure?

6. How do the embryos of different species support the theory of evolution?

7. How do similarities between molecules support the theory of evolution?

Critical Thinking

8. If a type of bird in California is 80% genetically similar to a bird in Nevada, do you think they evolved from a common ancestor? Why or why not?

9. How does one recent scientific advancement support a part of Darwin's Theory of Evolution by Natural Selection?

Further Reading / Supplemental Links

- Stein, Sara, The Evolution Book, Workman, N.Y., 1986.
- Yeh, Jennifer, Modern Synthesis, (From Animal Sciences).
- Darwin, Charles, Origin of the Species, Broadview Press (Sixth Edition), 1859 .
- Ridley, Matt, The Red Queen: Sex and the Evolution of Human Nature. Perennial Books, 2003.
- Ridley, Matt, Genome, Harper Collins, 2000.
- Sagan, Carl, Cosmos, Edicions Universitat Barcelona, 2006.

- Carroll, Sean B., The Making of the Fittest: DNA and the Ultimate Forensic Record of Evolution, Norton, 2006.
- Dawkins, Richard, The Blind Watchmaker, W.W. Norton & Company, 1996.
- Dawkins, Richard, The Selfish Gene, Oxford University Press, 1989.
- Diamond, Jared, The Third Chimpanzee: The Evolution and Future of the Human Animal, HarperCollins, 2006.
- Mayr, Ernst, What Evolution Is, Basic Books, 2001.
- Zimmer, Carl, Smithsonian Intimate Guide to Human Origins, Smithsonian Press, 2008.
- http://en.wikipedia.org/

Points to Consider

- How do you think new species evolve?
- How long do you think it takes for a new species to evolve?

1.3 Macroevolution

Lesson Objectives

- Compare and contrast microevolution and macroevolution.
- Define speciation as the formation of new species.
- Explain the ways that speciation can occur.

Check Your Understanding

- Why can't an individual person evolve? Why can only groups evolve over many generations?
- What causes a species or a population to evolve?

Vocabulary

allopatric speciation Speciation that occurs when groups from the same species are geographically isolated physically for long periods.

behavioral isolation The separation of a population from the rest of its species due to some behavioral barrier, such as having different mating seasons.

evolutionary tree Diagram used to represent the relationships between different species and their common ancestors.

geographic isolation The separation of a population from the rest of its species due to some physical barrier, such as a mountain range, an ocean, or great distance.

macroevolution Big evolutionary changes that result in new species.

microevolution Small changes in inherited traits; does not lead to the creation of a new species.

population A group of organisms belonging to the same species, that live in the same area, and interact with one another.

reproductive isolation Allopatric and sympatric speciation; isolation due to geography or behavior, resulting in the inability to reproduce.

speciation The creation of a new species; either by natural or artificial selection.

sympatric speciation Speciation that occurs when groups from the same species stop interbreeding, because of something other than physical separation, such as behavior.

Microevolution and Macroevolution

A species is a group of organisms that have similar characteristics and can mate with one another to produce offspring. The offspring of two members of the same species must also be able to reproduce. So, how are new species created? Through the process of evolution.

A **population** is a group of organisms of the same species that live in the same area (**Figure** 1.21). But does evolution happen as small changes build up in a population of organisms over time and gradually lead to a new species? Or is it possible that drastic environmental changes rapidly give rise to new species? Or can both small and large changes cause evolution to occur?

FIGURE 1.21
This school of fish are considered a species because they are able to mate with one another. But they are considered a population because they live in the same part of the ocean.

Microevolution

You already know that evolution is the change in species over time. Most evolutionary changes are small and do not lead to the creation of a new species. When organisms change in small ways over time, the process is called **microevolution**.

An example of microevolution is the evolution of mosquitoes that cannot be killed by pesticides, called pesticide-resistant mosquitoes. Imagine that you have a pesticide that kills most of the mosquitoes in your state. As a result, the only remaining mosquitoes are the pesticide-resistant mosquitoes. When these mosquitoes reproduce the next year, they produce more mosquitoes with the pesticide-resistant trait.

This is an example of microevolution because the number of mosquitoes with this trait changed. However, this evolutionary change did not create a new species of mosquito because the pesticide-resistant mosquitoes can still reproduce with other non-pesticide-resistant mosquitoes.

Macroevolution

Macroevolution refers to much bigger evolutionary changes that result in new species. Macroevolution may happen:

a. When microevolution occurs for a long period of time and leads to the creation of a new species.

b. As a result of a major environmental change, such as a volcanic eruption, earthquake, or asteroid hitting Earth, which changes the environment so much that natural selection leads to large changes in the traits of a species.

After thousands of years of isolation from each other, Darwin's finch populations have experienced both microevolution and macroevolution. These finch populations cannot breed with other finch populations when they are brought together. Since they do not breed together, they are classified as separate species.

Evolution Acts on the Phenotype

Natural selection acts on the phenotype - the traits or characteristics - of an individual, not on the underlying genotype. For many traits, the homozygous genotype, *AA* for example, has the same phenotype as the heterozygous *Aa* genotype. If both an *AA* and *Aa* individual have the same phenotype, the environment cannot distinguish between them. So natural selection cannot choose a homozygous individual over a heterozygous individual. The recessive *a* allele will be maintained in the population through heterozygous *Aa* individuals. Thus, the mating of two heterozygous individuals can produce homozygous recessive (*aa*) individuals.

Carriers

Since natural selection acts on the phenotype, if an allele causes death in a homozygous individual, *aa* for example, it will not cause death in a heterozygous *Aa* individual. These heterozygous *Aa* individuals will then act as **carriers** of the *a* allele, meaning that the "a" allele could be passed down to offspring. This allele is said to be kept in the population's gene pool. The **gene pool** is the complete set of alleles within a population.

Tay-Sachs disease is an autosomal recessive genetic disorder. It is caused by the homozygous recessive genotype, *rr*.

Affected individuals usually die from complications of the disease in early childhood. If the parents are each heterozygous (Rr) for the Tay-Sachs, they will not die, but they will be carriers. If you create a Punnett Square, what are the chances of a child inheriting the disorder? This deadly allele is kept in the gene pool even though it does not help humans adapt to their environment. This happens because evolution acts on the phenotype, not the genotype (**Figure** 1.22).

Hardy-Weinberg Equilibrium

The Hardy-Weinberg model states that a population will remain at **genetic equilibrium**, with no evolution, as long as five conditions are met:

a. No change in the DNA sequence
b. No migration (moving into or out of a population)
c. A very large population size
d. Random mating
e. No natural selection

These five conditions rarely occur in nature. When one of the conditions exists, then evolution can occur. The Hardy-Weinberg model is a mathematical formula used to predict allele frequencies in a population at genetic equilibrium.

A video explanation of the Hardy-Weinberg model can be viewed at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/14/4Kbruik_LOo (14:57).

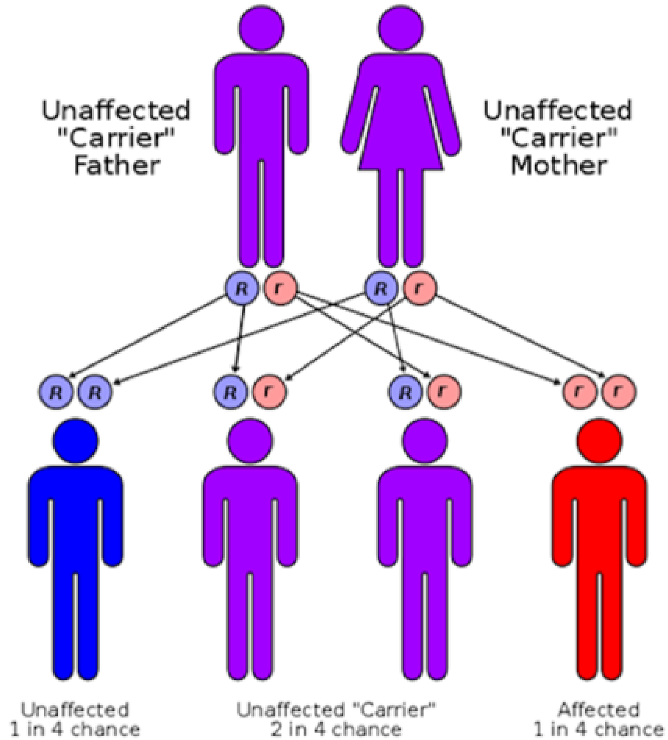
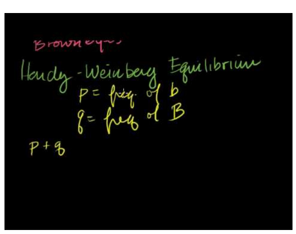


FIGURE 1.22
Tay-Sachs disease is inherited in the autosomal recessive pattern. Each parent is an unaffected carrier of the lethal allele.



MEDIA
Click image to the left for more content.

The Origin of Species

The creation of a new species is called **speciation**. Most new species develop naturally, but humans have also artificially created new breeds and species for thousands of years. Natural selection causes beneficial heritable traits to become more common in a population, and unfavorable heritable traits to become less common. For example, a giraffe's neck is beneficial because it allows the giraffe to reach leaves high in trees. Natural selection caused this beneficial trait to become more common than short necks.

As new changes in the DNA sequence are constantly being generated in a population's gene pool, some of these changes will be beneficial and result in traits that allow adaptation and survival. Natural selection causes evolution of a species as these beneficial traits become more common within a population.

Artificial Selection

Artificial selection occurs when humans select which plants or animals to breed to pass specific traits on to the next generation. For example, a farmer may choose to breed only cows that produce the best milk and not breed cows that produce less milk . Humans have also artificially bred dogs to create new breeds (**Figure** 1.23).

FIGURE 1.23
Artificial Selection: Humans used artificial selection to create these different breeds. Both dog breeds are descended from the same wolves, and their genes are almost identical. Yet there is at least one difference between their genes that determine size.

Reproductive Isolation

There are two main ways that speciation happens naturally. Both processes create new species by isolating populations of the same species from each other. Organisms can be geographically isolated or isolated by a behavior. Over a long period of time, usually thousands of years, each of the isolated populations evolves in a different direction.

How do you think scientists test whether two populations are separate species? They bring species from two populations back together again. If the two populations do not mate and produce fertile offspring, they are separate species.

Geographic Isolation

Allopatric speciation happens when groups from the same species are geographically isolated for long periods. Imagine all the ways that plants or animals could be isolated from each other:

- A mountain range.
- A canyon.

- Rivers, streams, or an ocean.
- A desert.

Here are two examples of allopatric speciation:

- Darwin observed thirteen distinct finch species on the Galápagos Islands that had evolved from the same ancestor. Different finch populations lived on separate islands with different environments. They evolved to best adapt to those particular environments. Later, scientists were able to determine which finches had evolved into distinct species by bringing members of each population together. The birds that could not mate were separate species.

- When the Grand Canyon in Arizona formed, two populations of one squirrel species were separated by the giant canyon, shown in **Figure** 1.24 and **Figure** 1.25. After thousands of years of isolation from each other, the squirrel populations on the northern wall of the canyon looked and behaved differently from those on the southern wall. North rim squirrels have white tails and black bellies. Squirrels on the south rim have white bellies and dark tails. They cannot mate with each other, so they are different species.

FIGURE 1.24
Abert squirrel on the southern rim of the Grand Canyon.

Isolation without Physical Separation

Sympatric speciation happens when groups from the same species stop mating because of something other than physical separation, such as behavior. The separation may be caused by different mating seasons, for example. Sympatric speciation is more difficult to identify.

Here are two examples of sympatric speciation:

- Some scientists suspect that two groups of orcas (killer whales) live in the same part of the Pacific Ocean part of the year, but do not mate. The two groups hunt different prey species, eat different foods, sing different songs, and have different social interactions (**Figure** 1.26).

- Two groups of Galápagos finch species lived in the same space, but each had their own distinct mating signals. Members of each group selected mates according to different beak structures and bird calls. The behavioral differences kept the groups separated until they formed different species.

FIGURE 1.25
Kaibab squirrel found on northern rim of the Grand Canyon.

FIGURE 1.26
Scientists that two types of orca whales live in the same part of the Pacific Ocean for part of the year, but do not mate.

Rates of Evolution

How fast is evolution? How long did it take for the giraffe to develop a long neck? How long did it take for the Galápagos finches to evolve? How long did it take for whales to evolve from land mammals? These and other questions about the rate of evolution are difficult to answer.

The rate of evolution depends on how much an organism's genotype changes over a period of time. Evolution is usually so gradual that we do not see the change for many, many generations.

Not all organisms evolve at the same rate. Humans took millions of years to evolve from a mammal that is now extinct. It is very difficult to observe evolution in humans. However, there are organisms that are evolving so fast that you can observe evolution! A human takes about 22 years to go through one generation. But some bacteria go through over a thousand generations in less than two months. Since bacteria go through many generations in a few days, we can actually trace their evolution as it is happening.

Evolutionary Trees

Charles Darwin came up with the idea of an evolutionary tree to represent the relationships between different species and their common ancestors (**Figure** 1.27). The base of the tree represents the ancient ancestors of all life. The separation into large branches shows where these original species evolved into different populations.

The branches keep splitting into smaller and smaller branches as species continue to evolve into more and more species. Some species are represented by short twigs spurting out of the tree, then stopping. These are species that went extinct before evolving into new species. Other "Trees of Life" have been created by other scientists (**Figure** 1.28).

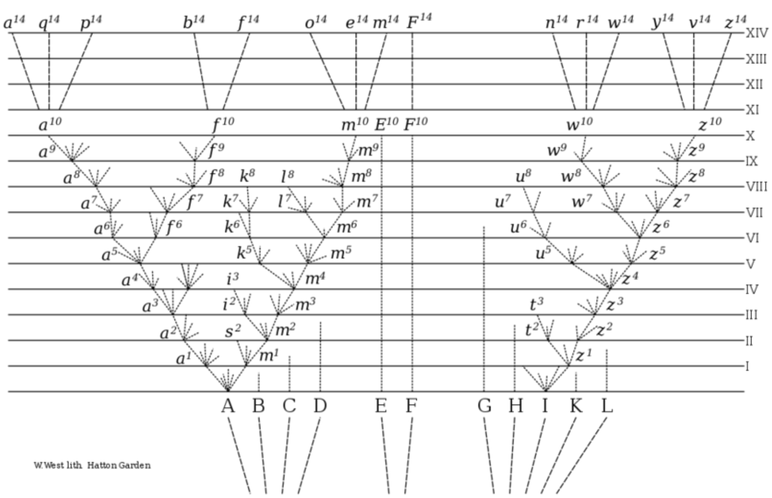


FIGURE 1.27

Darwin drew this version of the "Tree of Life" to represent how species evolve and diverge into separate directions. Each point on the tree where one branch splits off from another represents the common ancestor of the species on the separate branches.

An interactive Tree of Life can be found at http://www.wellcometreeoflife.org/interactive/.

Lesson Summary

- Microevolution results from evolutionary changes that are small and do not lead to the creation of a new species.
- Macroevolution refers to large evolutionary changes that result in new species.
- The creation of a new species is called speciation.
- Allopatric speciation occurs when groups from the same species are geographically isolated physically for long periods.
- Sympatric speciation occurs when groups from the same species stop interbreeding, because of something other than physical separation, such as behavior.
- The rate of evolution is a measurement of the speed of evolution.

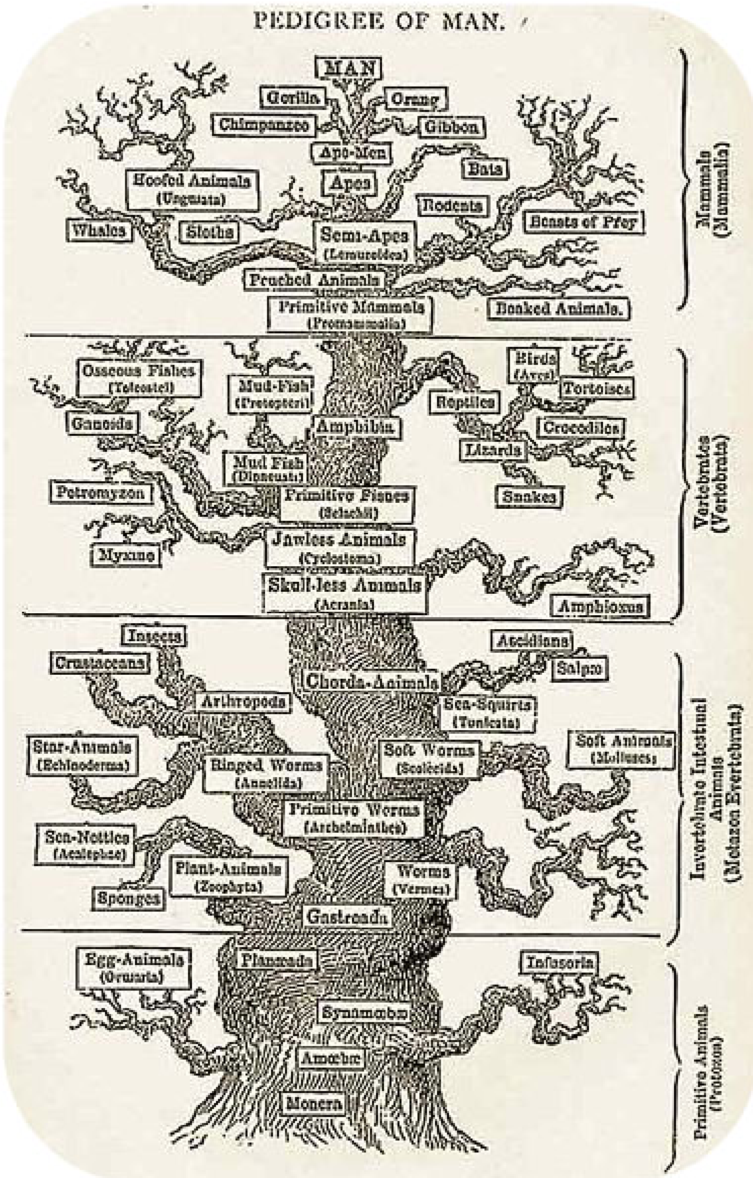


FIGURE 1.28
Scientists have drawn many different versions of the "Tree of Life" to show different features of evolution. This Tree of Life was made by Ernst Haeckel in 1879.

- Evolutionary trees are used to represent the relationships between different species and their common ancestors.

Review Questions

Recall

1. What is the difference between macroevolution and microevolution?
2. What do the branches on the Tree of Life represent?
3. Which organism has a faster rate of evolution: a human or a bacterium?
4. What are two possible reasons why organisms to evolve and adapt?

Apply Concepts

5. How do you know if two related organisms are members of the same species?
6. Why do the squirrels on opposite side of the Grand Canyon look different?
7. How is artificial selection different from natural selection?
8. What, other than physical isolation, could cause a species to split into two different directions of evolution?

Critical Thinking

9. "We have no current evidence of evolution occurring." Is the above statement true or false? Why or why not?

Further Reading / Supplemental Links

- Yeh, Jennifer, Modern Synthesi, (From Animal Sciences).
- Darwin, Charles, Origin of the Specie, Broadview Press (Sixth Edition), 1859.
- Ridley, Matt, The Red Queen: Sex and the Evolution of Human Nature, Perennial Books, 2003.
- Ridley, Matt, Genome, Harper Collins, 2000.
- Sagan, Carl, Cosmos, Edicions Universitat Barcelona, 2006.
- Carroll, Sean B., The Making of the Fittest: DNA and the Ultimate Forensic Record of Evolution, Norton, 2006.
- Dawkins, Richard, The Blind Watchmaker, W.W. Norton & Company, 1996.
- Dawkins, Richard, The Selfish Gene, Oxford University Press, 1989.
- Diamond, Jared, The Third Chimpanzee: The Evolution and Future of the Human Animal, HarperCollins, 2006.
- Mayr, Ernst, What Evolution Is, Basic Books. 2001.
- Zimmer, Carl, Smithsonian Intimate Guide to Human Origins, Smithsonian Press, 2008.

Points to Consider

- How old is the Earth?
- When did the first life forms develop?
- For how much of Earth's history have humans existed?

1.4 History of Life on Earth

Lesson Objectives

- Explain how geologists and paleontologists use evidence to determine the history of Earth and life on Earth.
- Define the age of the earth as four to five billion years old.
- Explain how scientists need to know what the environment (what chemicals were around, the temperature, etc.) was like on Earth billions of years ago to know how life formed.

Check Your Understanding

- What are fossils?
- How does the fossil record contribute to the evidence of evolution?

Vocabulary

Cambrian explosion A sudden burst of evolution that may have been triggered by an environmental change(s); made the environment more suitable for a wider variety of life forms; occurred during the Cambrian Period.

extinct Something that does not exist anymore; a group of organisms that has died out without leaving any living representatives.

geologic time scale A time scale used to describe when events happened in the history of Earth.

mass extinction An extinction when many species go extinct during a relatively short period of time.

stromolites Fossils made of algae and a kind of bacteria; some of the oldest fossils on Earth.

The Age of Earth

How old is Earth? How was it formed? How did life begin on Earth? These questions have fascinated scientists for centuries. During the 1800s, geologists, paleontologists and naturalists found several forms of physical evidence that confirmed that Earth is very old.

The evidence includes:

- Fossils of ancient sea life on dry land far from oceans. This supported the idea that the earth changed over time and that some dry land today was once covered by oceans.

- The many layers of rock. When people realized that rock layers represent the order in which rocks and fossils appeared, they were able to trace the history of Earth and life on Earth.
- Indications that volcanic eruptions, earthquakes and erosion that happened long ago shaped much of the earth's surface. This supported the idea of an older Earth.

Over 4 Billion Years

The earth is at least as old as its oldest rocks. The oldest rock minerals found on Earth so far are crystals that are at least 4.404 billion years old. These tiny crystals were found in Australia. Likewise, Earth cannot be older than the solar system. The oldest possible age of Earth is 4.57 billion years old, the age of the solar system. Therefore, the age of Earth is between 4.4 and 4.57 billion years.

Origin of Life on Earth

There is good evidence that life has probably existed on Earth for most of Earth's history. Fossils of blue-green algae found in Australia are the oldest fossils of life forms on Earth. They are at least 3.5 billion years old (**Figure** 1.29).

FIGURE 1.29
Some of the oldest fossils on Earth are made of algae and a kind of bacteria, found along the coast of Australia.

Life from Random Reactions

How did evolution begin? It started with the first signs of life. How did life begin 3.5 to 4 billion years ago? In order to answer this question, scientists need to know what kinds of materials were available at that time. We know that the ingredients for life were present at the beginning of Earth's history. Scientists believe early Earth did not contain oxygen gas, but did contain other gases, including:

- Nitrogen
- Carbon dioxide
- Carbon monoxide
- Water vapor
- Hydrogen sulfide

Where did these ingredients come from? Some chemicals were in water and volcanic gases. Other chemicals would have come from meteorites in space. Energy to drive chemical reactions was provided by volcanic eruptions and lightning. Today, we have evidence that life on Earth came from random reactions between chemical compounds, which formed molecules. These molecules created proteins and nucleic acids (RNA or DNA), and then cells.

How long did it take to form the first life forms? As much as 1 billion years (**Figure** 1.30). Many scientists still study the origin of the first life forms because there are many questions left unanswered, such as, "Did proteins or nucleic acids develop first?"

FIGURE 1.30
Some clues to the origins of life on Earth come from studying the early life forms that developed in hot springs, such as the Grand Prismatic Spring at Yellowstone National Park. This spring is approximately 250 feet deep and 300 feet wide.

Geologic Time Scale

Geologists and other earth scientists use **geologic time scales** to describe when events happened in the history of Earth. The time scales can be used to show when both geologic events and events affecting plant and animal life occurred. The geologic time scale in **Figure** 1.31 illustrates the timing of events like:

- Earthquakes
- Volcanic eruptions
- Major erosion
- Meteorites hitting Earth
- The first signs of life forms
- Mass extinctions

Evolution of Major Life Forms

Life on Earth began about 3.5 to 4 billion years ago. The first life forms were single-cell organisms similar to bacteria. The first multicellular organisms did not appear until about 610 million years ago. Many of the modern types of organisms we know today evolved during the next ten million years, in an event called the **Cambrian explosion**. This sudden burst of evolution may have been caused by some environmental changes that made the environment more suitable for a wider variety of life forms.

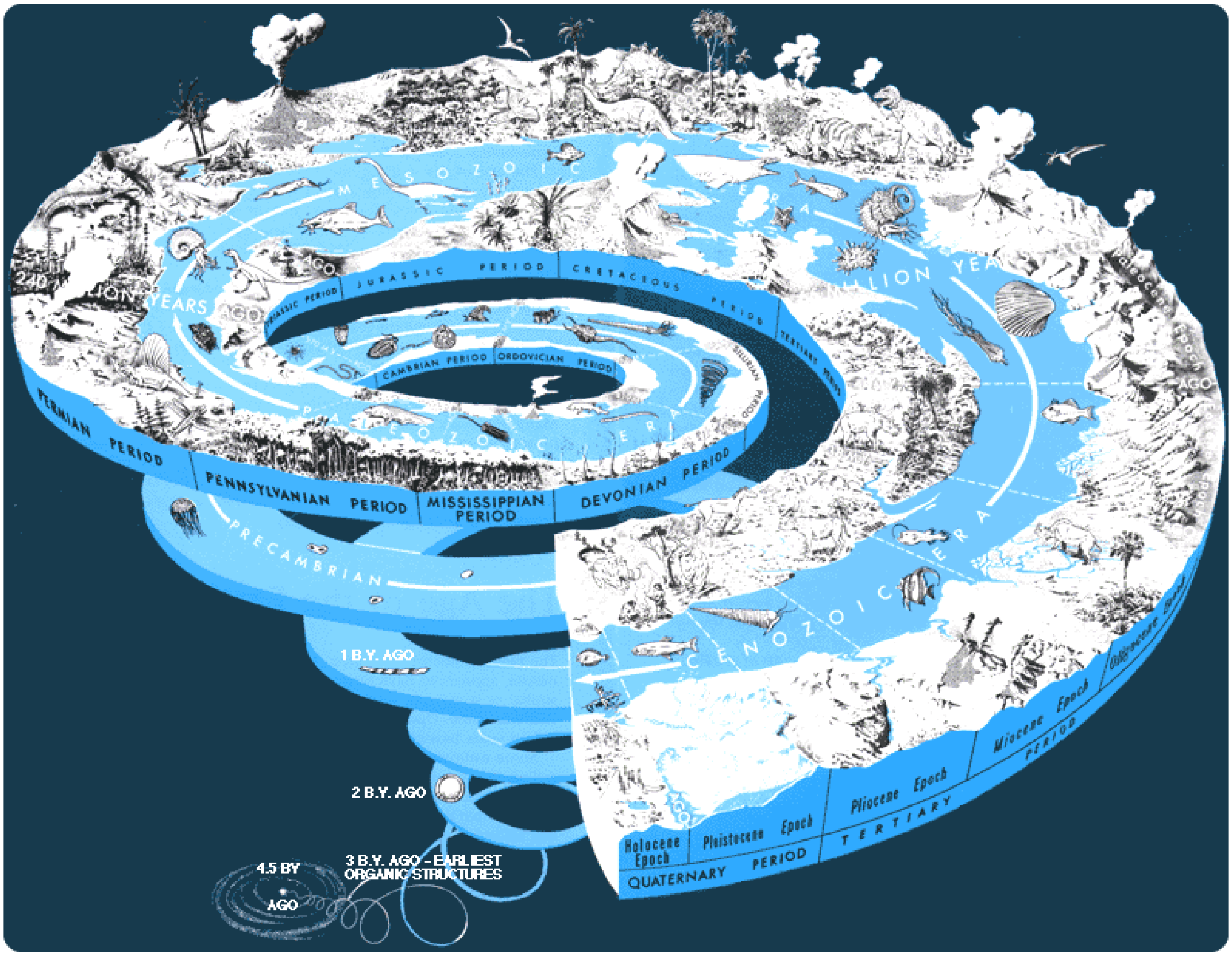


FIGURE 1.31

The geologic time scale of Earth's past is organized according to events which took place during different periods on the time scale. Geologic time is the same as the age of the earth: between 4.404 and 4.57 billion years. Look closely for such events as the extinction of dinosaurs and many marine animals.

Plants and fungi did not appear until roughly 500 million years ago. They were soon followed by arthropods (insects and spiders). Next came the amphibians about 300 million years ago, followed by mammals around 200 million years ago and birds around 100 million years ago.

Even though large life forms have been very successful on Earth, most of the life forms on Earth today are still prokaryotes – small, single-celled organisms. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; in fact, it is estimated that 99% of the species that have ever lived on Earth no longer exist.

The basic timeline of a 4.6 billion year old Earth includes the following:

- About 3.5 - 3.8 billion years of simple cells (prokaryotes).
- 3 billion years of photosynthesis.
- 2 billion years of complex cells (eukaryotes).
- 1 billion years of multicellular life.

- 600 million years of simple animals.
- 570 million years of arthropods (ancestors of insects, arachnids and crustaceans).
- 550 million years of complex animals.
- 500 million years of fish and proto-amphibians.
- 475 million years of land plants.
- 400 million years of insects and seeds.
- 360 million years of amphibians.
- 300 million years of reptiles.
- 200 million years of mammals.
- 150 million years of birds.
- 130 million years of flowers.
- 65 million years since the non-avian dinosaurs died out.
- 2.5 million years since the appearance of *Homo*.
- 200,000 years since the appearance of modern humans.
- 25,000 years since *Neanderthals* died out.

Mass Extinctions

An organism goes **extinct** when all of the members of a species do not exist anymore. Extinctions are part of natural selection. Species often go extinct when their environment changes and they do not have the traits they need to survive. Only those individuals with the traits needed to live in a changed environment survive (**Figure** 1.32).

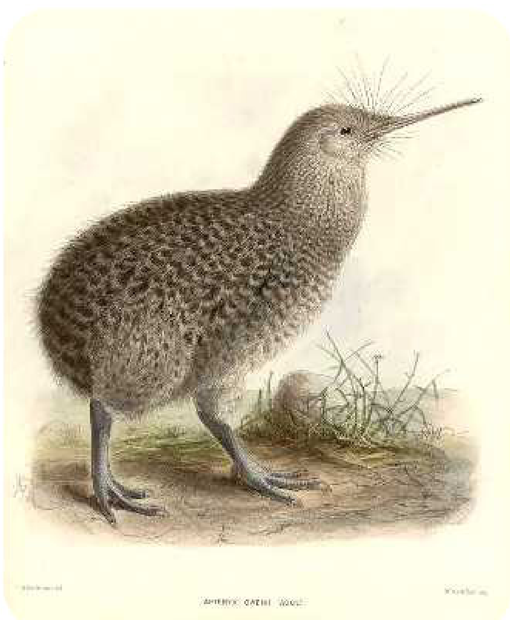


FIGURE 1.32

Humans have caused many extinctions by introducing species to new places. For example, many of New Zealand's birds have adapted to nesting on the ground. This was possible because there were no land mammals in New Zealand until Europeans arrived and brought cats, fox and other predators with them. Several of New Zealand's ground nesting birds, such as this flightless kiwi, are now extinct or threatened because of these predators.

Mass extinctions, such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and earthquakes (**Figure** 1.33).

Since life began on Earth, there have been several major mass extinctions. If you look closely at the geological time scale, you will find that at least five major massive extinctions have occurred in the past 540 million years. In each mass extinction, over 50% of animal species died. The total number of mass extinctions could be as high as 20.

FIGURE 1.33
The fossil of Tarbosaurus, one of the land dinosaurs that went extinct during one of the mass extinctions.

Two of the largest extinctions are described below:

- At the end of the Permian period about 99.5% of individual organisms went extinct! Up to 95% of marine species perished, compared to "only" 70% of land species. Some scientists theorize that the extinction was caused by the formation of Pangea, or one large continent made out of many smaller ones. One large continent has a smaller shoreline than many small ones, so reducing the shoreline space may have caused so much marine life to go extinct (**Figure** 1.34).

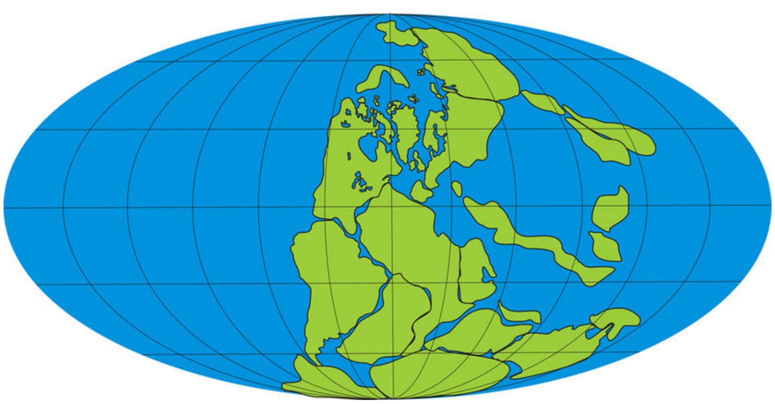


FIGURE 1.34
The supercontinent Pangaea encompassed all of today's continents in a single land mass. This configuration limited shallow coastal areas which harbor marine species, and may have contributed to the dramatic event which ended the Permian - the most massive extinction ever recorded.

- At the end of the Cretaceous period, or 65 million years ago, all dinosaurs (except those which led to birds) went extinct (**Figure** 1.35). Some scientists believe a possible cause is a collision between the Earth and a comet or asteroid. The collision could have caused tidal waves, changed the climate, and reduced sunlight by 10-20%. A decrease in photosynthesis would have resulted in less plant food, leading to the extinction of the dinosaurs.

Evidence for the extinction of dinosaurs by asteroid includes a iridium-rich layer in the earth, dated at 65.5 million years ago. Iridium is rare in the Earth's crust, but common in comets and asteroids. Maybe the asteroid that hit the earth left the iridium behind.

FIGURE 1.35
The fossil record demonstrates the presence of dinosaurs, which went extinct over 65 million years ago.

After each mass extinction, new species develop to fill the habitats where old species lived. This is well documented in the fossil record (**Figure** 1.36).

Lesson Summary

- During the 1800s, geologists, paleontologists and naturalists found several forms of physical evidence that confirmed that the earth is over 4 billion years old.
- Geologists and other earth scientists use geologic time scales to describe when events occurred throughout the history of Earth.
- The first life forms were single-celled organisms, prokaryotic organisms, similar to bacteria.
- Mass extinctions, such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and major earthquakes changed the environment.

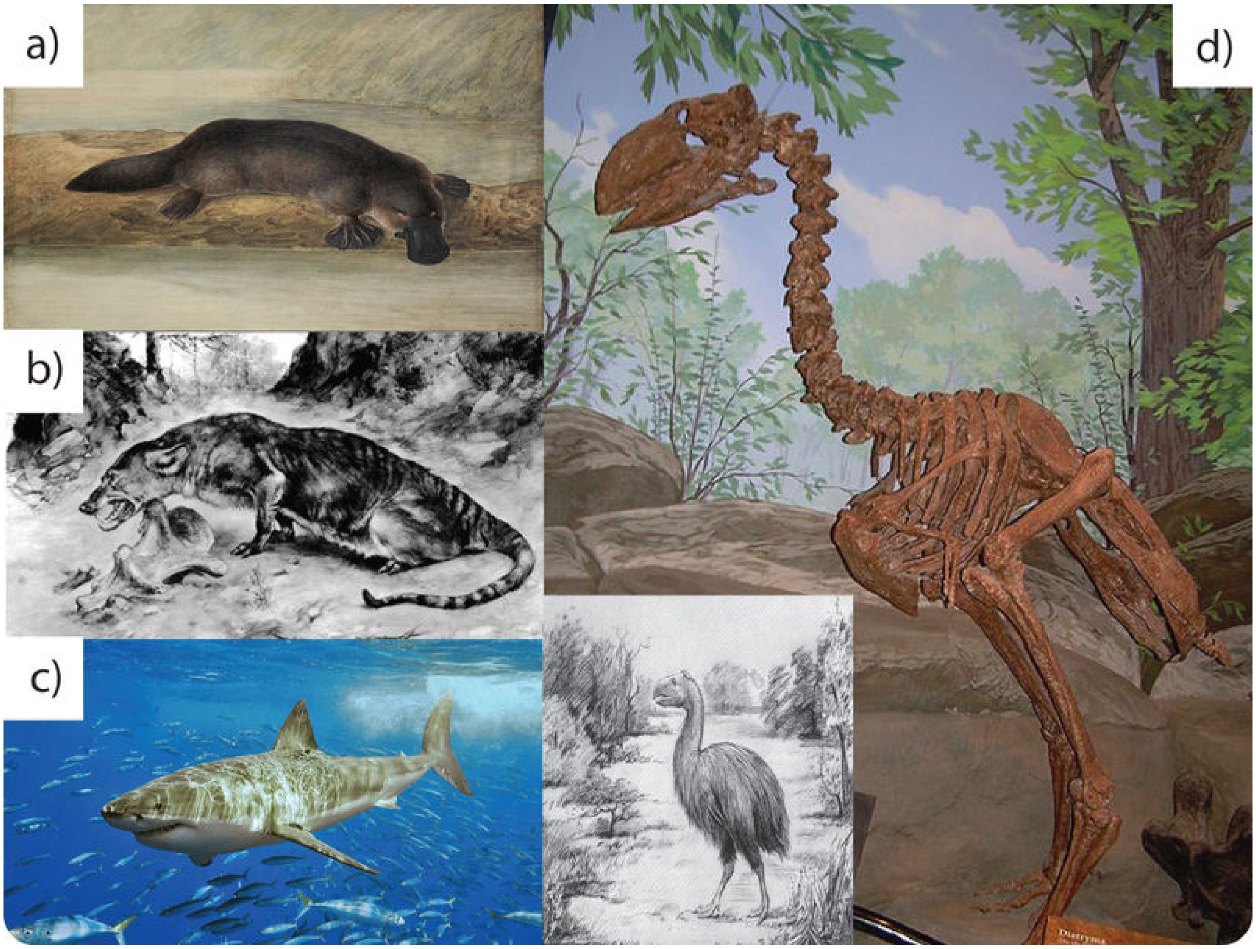


FIGURE 1.36

Mammals and birds quickly invaded ecological niches formerly occupied by the dinosaurs. Mammals included monotremes (A), marsupials, and hoofed placentals (B). Modern sharks (C) patrolled the seas. Birds included the giant, flightless Gastornis (D).

Review Questions

Recall

1. How do scientists determine the age of a rock or fossil today?
2. How do we know the maximum and minimum possible age of the Earth?
3. How long ago did life start on Earth?
4. When did mammals first appear on Earth?
5. What kinds of events are recorded on a geological time scale?

Apply Concepts

6. Why is it difficult to determine how life started on Earth?

7. Why are extinctions a part of natural selection?

Think Critically

8. In order to develop the best theory for the extinction of the dinosaurs, what other information might be useful?

9. You are a scientist investigating the origin of life on earth? Ask three questions that will help you complete your investigation.

Further Reading / Supplemental Links

- Stein, Sara, The Evolution Book, Workman, N.Y., 1986.
- Yeh, Jennifer, Modern Synthesis, (From Animal Sciences).
- Darwin, Charles, Origin of the Species, Broadview Press (Sixth Edition), 1859.
- Ridley, Matt, The Red Queen: Sex and the Evolution of Human Nature, Perennial Books, 2003.
- Ridley, Matt, Genome, Harper Collins, 2000.
- Sagan, Carl, Cosmos, Edicions Universitat Barcelona, 2006.
- Carroll, Sean B., The Making of the Fittest: DNA and the Ultimate Forensic Record of Evolution, Norton, 2006.
- Dawkins, Richard, The Blind Watchmaker, W.W. Norton & Company, 1996.
- Dawkins, Richard, The Selfish Ge Oxford University Press, 1989.
- Diamond, Jared, The Third Chimpanzee: The Evolution and Future of the Human Animal, HarperCollins, 2006.
- Mayr, Ernst, What Evolution Is, Basic Books, 2001.
- Zimmer, Carl, Smithsonian Intimate Guide to Human Origins, Smithsonian Press, 2008.
- http://en.wikipedia.org/

Points to Consider

- What are prokaryotic organisms?
- Compare and contrast prokaryotes and eukaryotes.

1.5 References

1. George Richmond. . Public Domain
2. Dave souza. . GNU-FDL
3. Storpilot. . Public Domain
4. Steve Herrmann; MindStorm. . Used under license from shutterstock.com
5. Childzy. . GNU-FDL
6. Mike Weston. . CC-BY 2.0
7. John Gould. . Public Domain
8. . . Public Domain
9. NASA. . Public Domain
10. USFWS. . Public Domain
11. Obli. . GNU-FDL
12. Tangopaso. . GNU-FDL
13. Mila Zinkova. . GNU-FDL
14. TimVickers. . Public Domain
15. Onyshchenko. . Used under license from shutterstock.com
16. Wilhelm Leche. . Public Domain
17. Romanes, G. J.. . Public Domain
18. Henry Gray. . Public Domain
19. Michael Ströck. . GNU-FDL
20. NCBI. . Public Domain
21. Stubblefield Photography. . Used under license from shutterstock.com
22. Colin M.L. Burnett.. . Wikimedia Commons
23. Ellen Levy Finch. . GNU-FDL
24. NPS. . Public Domain
25. Stavenn. . GNU-FDL
26. Ferderic B. . Used under license from shutterstock.com
27. Charles Darwin. . Public Domain
28. Ernst Haeckel. . Public Domain
29. Markus Gann. . Used under license from shutterstock.com
30. NPS. . Public Domain
31. USGS. . Public Domain
32. G.D. Rowley. . Public Domain
33. Thomas Ihle. . GNU-FDL
34. Evskaya_Daria_Igorevna. . Used under license from shutterstock.com
35. Pavel Riha, Jim H.. . CC-BY-SA 3.0, CC-BY-SA 2.0
36. John Lewin, Charles R. Knight, Terry Goss, Ninjatacoshell, Unknown. . (a)Public Domain (b)Public Domain (c)CC-BY-SA 3.0 (d)CC-BY-SA 3.0 (e)Public Domain