**15-1 The Puzzle of Life's Diversity**

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

**Individuals do NOT evolve. Populations evolve.**

**15-1**

**Voyage of the *Beagle***

In 1831, Darwin sailed England aboard the H.M.S. *Beagle* for a voyage around the world, collected plant and animal specimens.

Darwin observed that many plants and animals were well suited to the environments they inhabited. Darwin was puzzled by where different species lived and did not live.

Grasslands in some regions were similar to one another but were inhabited by very different animals

**The Galápagos Islands**

Darwin observed that the Galápagos Islands were close together but had different vegetation. He observed that the characteristics of many animals and plants varied noticeably among the islands.

On Hood Island, the tortoises have long necks where vegetation is sparse.

On Isabel Island, the tortoises have dome-shaped shells where vegetation is closer to the ground

Darwin observed that the characteristics of many animals and plants varied noticeably among the different islands of the Galápagos.

Darwin wondered if animals living on different islands had once been members of the same species.

These separate species would have evolved from an original South American ancestor species

**15-2 Ideas That Shaped Darwin's Thinking**

**Hutton (1795) and Lyell (1833) and Geological Change**

Geological forces operate very slowly, over millions of years (earthquakes, mountains moving, rivers, glaciers).

Hutton and Lyell both explained that Earth had to be much more than a few thousand years old

This understanding of geology influenced Darwin:

* + - If the Earth could change over time, life might change as well.
		- It would have taken many years for life to change in the way Lyell suggested.

This would have been possible only if the Earth were extremely old.

**Lamarck's Evolution Hypotheses CAUTION – Scientists do not believe this today!**

Jean-Baptiste Lamarck recognized that:

* + - * living things have changed over time.
			* all species were descended from other species.
			* organisms were adapted to their environments.
* **Lamarck proposed that by selective use or disuse of organs, organisms acquired or lost certain traits during their lifetime. These traits could then be passed on to their offspring. Over time, this process led to change in a species.**
	+ **Tendency Toward Perfection**

Lamarck proposed that all organisms have an innate tendency toward complexity and perfection. They are continually changing and acquiring features that help them live more successfully in their environments.

* + **Use and Disuse**

Lamarck proposed that organisms could alter the size or shape of particular organs by using their bodies in new ways.

* + **Inheritance of Acquired Traits**

Lamarck thought that acquired characteristics could be inherited.

He believed that if an animal acquired a particular feature in its lifetime, that feature would be passed on to its offspring.

**Evaluating Lamarck's Hypotheses**

Lamarck’s hypotheses of evolution are incorrect in several ways.

Lamarck did not know:

* + - * how traits are inherited.
			* that an organism’s behavior has no effect on its heritable characteristics.

However, he paved the way for the work of later biologists.

**Population Growth**

In 1798, Thomas Malthus published a book in which he noted that babies were being born faster than people were dying.

The only forces he observed that worked against this growth were war, famine, and disease.

**Malthus reasoned that if the human population continued to grow unchecked, sooner or later there would be insufficient living space and food for everyone.**

When Darwin read Malthus’s work, he realized that this reasoning applied to plants and animals.

If all the offspring of almost any species survived for several generations, they would overrun the world.

This information was central to Darwin’s explanation of evolutionary change.

**15-3 Darwin Presents His Case**

In 1859, Darwin published his book, *On the Origin of Species* by *Means of Natural Selection*

In his book, Darwin:

* + - proposed a mechanism for evolution called natural selection.
		- presented evidence that evolution has been taking place for millions of years—and continues in all living things.
		- **Inherited Variation and Artificial Selection**

Members of each species vary from one another in important ways.

Darwin argued that this variation mattered.

Darwin noted that plant and animal breeders would breed only the largest hogs, the fastest horses, or the cows that produced the most milk.

Darwin termed this process **artificial selection**.

**How is natural variation used in artificial selection?**

**Artificial selection** is the selection by humans for breeding of useful traits from the natural variation among different organisms.

**Evolution by Natural Selection**

Darwin compared processes in nature to artificial selection.

By doing so, he developed a scientific hypothesis to explain how evolution occurs.

It’s a good idea to view: *Darwin’s Dangerous Idea*

Main Ideas in The Origin of Species

1. Variation - Members of each species vary from one another in important ways (color, shape, strength, size of muscles, quantity of fur, pigments, ability to see well, etc.) As a result, some individuals survived longer and produced more offspring.
2. **Overproduction. All living things produce more offspring than could possibly survive.**
3. Competition. The **struggle for existence** means that members of each species **compete** regularly to obtain food, living space, and other necessities of life
4. **Survival of the Fittest.** The ability of an individual to survive and reproduce in its specific environment is **fitness**. Darwin proposed that fitness is the result of adaptations. An **adaptation** is any inherited characteristic that increases an organism's chance of survival. Successful adaptations enable organisms to become better suited to their environment and better able to survive and reproduce. Darwin called this process survival of the fittest. Because of its similarities to artificial selection, Darwin referred to the survival of the fittest as **natural selection**. In natural selection, the traits being selected contribute to an organism's fitness in its environment.

**Over time, natural selection results in changes in the inherited characteristics of a population. These changes increase a species' fitness in its environment.**

**The fittest individuals in the context of evolution are those that produce the largest number of viable fertile offspring and thus pass on the most genes to the next generation.**

**5. Speciation**

Natural selection produces organisms that have different structures, establish different niches, or occupy different habitats.

Each living species has descended, with changes, from other species over time. Darwin referred to this principle as descent with modification. When populations of organisms cannot mate with each other, they become distinct species (more on this in Chapter 16).

**Evidence of Evolution**

**Darwin argued that living things have been evolving on Earth for millions of years. Evidence for this process could be found in the fossil record, the geographical distribution of living species, homologous structures of living organisms, and similarities in early development, or embryology.**

 **1. The Fossil Record**

Darwin saw fossils as a record of the history of life on Earth. By comparing fossils from older rock layers with fossils from younger layers, scientists could document that life on Earth has changed over time

**2. Geographic Distribution of Living Species (and isolation)**

Darwin decided that all Galápagos finches could have descended with modification from a common mainland ancestor. Darwin’s theory was 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. Because of these similar selection pressures, different animals ended up evolving certain features in common.

When continents were connected, species could interbreed. After they separated, species evolved independently of one another. This is why unique organisms are found on islands like Australia.

**3. Homologous Body Structures**

Structures that have different mature forms but develop from the same embryonic tissues are called **homologous structures**. Similarities and differences in homologous structures help biologists group animals according to how recently they last shared a common ancestor. Not all homologous structures serve important functions.

The organs of many animals are so reduced in size that they are just vestiges, or traces, of homologous organs in other species.

These organs are called **vestigial** organs.

**4. Similarities in Embryology**

The early stages, or embryos, of many animals with backbones are very similar.

The same groups of embryonic cells develop in the same order and in similar patterns to produce the tissues and organs of all vertebrates.

 **5. Comparative biochemistry. Darwin did not know about this. More about this later…...**

**Strengths and Weaknesses of Evolutionary Theory**

Scientific advances in many fields of biology, geology, and physics have confirmed and expanded most of Darwin’s hypotheses.

Evolutionary theory continues to change as new data are gathered and new ways of thinking arise.

**16-1 Genes and Variation**

**How Common Is Genetic Variation?**

Many genes have at least two forms, or alleles. (T and t)

A **population** is a group of individuals of the same species that interbreed.

A **gene pool** consists of all genes, including all the different alleles, that are present in a population.

The relative frequency of an allele is the number of times the allele occurs in a gene pool, compared with the number of times other alleles for the same gene occur. Relative frequency is often expressed as a percentage.

In genetic terms, **microevolution** is any change in the relative frequency of alleles in a population.

The two main sources of genetic variation are:

* 1. mutations
	2. genetic shuffling that results from sexual reproduction.

Crossing-over increases the number of genotypes that can appear in offspring.

Sexual reproduction produces different phenotypes, but it does not change the relative frequency of alleles in a population.

**16-2 Evolution as Genetic Change**

Natural selection affects which individuals survive and reproduce and which do not. If an individual dies without reproducing, it does not contribute its alleles to the population’s gene pool. If an individual produces many offspring, its alleles stay in the gene pool and may increase in frequency.

Populations, not individual organisms, can evolve over time.

**Natural selection on single-gene traits can lead to changes in allele frequencies and thus to evolution.**

Organisms of one color may produce fewer offspring than organisms of other colors.

For example, a lizard population is normally brown, but has mutations that produce red and black forms.

Red lizards are more visible to predators, so they will be less likely to survive and reproduce. Therefore, the allele for red color will become rare. Black lizards may warm up faster on cold days. This may give them energy to avoid predators. In turn, they may produce more offspring.

The allele for black color will increase in relative frequency.

A random change in allele frequency is called **genetic drift**.

In small populations, individuals that carry a particular allele may leave more descendants than other individuals do, just by chance. Over time, a series of chance occurrences of this type can cause an allele to become common in a population. Genetic drift may occur when a small group of individuals colonizes a new habitat.

Individuals may carry alleles in different relative frequencies than did the larger population from which they came. The new population will be genetically different from the parent population.

When allele frequencies change due to migration of a small subgroup of a population it is known as the **founder effect.**

**Evolution Versus Genetic Equilibrium**

The **Hardy-Weinberg principle** states that allele frequencies in a population will remain constant unless one or more factors cause those frequencies to change.

When allele frequencies remain constant it is called **genetic equilibrium**.

**Five conditions are required to maintain genetic equilibrium from generation to generation:**

* + - **there must be random mating,**
		- **the population must be very large,**
		- **there can be no movement into or out of the population,**
		- **there can be no mutations, and**
		- **there can be no natural selection.**

**16-3 The Process of Speciation**

**Speciation** is the formation of new species.

A species is a group of organisms that breed with one another and produce fertile offspring.

**What factors are involved in the formation of new species?**

The gene pools of two populations must become separated for them to become new species.

**As new species evolve, populations become reproductively isolated from each other.**

When the members of two populations cannot interbreed and produce fertile offspring, **reproductive isolation** has occurred.

Reproductive isolation can develop in a variety of ways, including:

* + - behavioral isolation
		- geographic isolation
		- temporal isolation
* **Behavioral isolation** occurs when two populations are capable of interbreeding but have differences in courtship rituals or other reproductive strategies that involve behavior. (Many closely related birds have different mating rituals).
* **Geographic isolation** occurs when two populations are separated by geographic barriers such as rivers or mountains. (Squirrels separated by the Grand Canyon were probably descended from a common ancestor) Geographic barriers do not guarantee the formation of new species.

If two formerly separated populations can still interbreed, they remain a single species.

**Temporal isolation** occurs when two or more species reproduce at different times.

**Testing Natural Selection in Nature**

Studies showing natural selection in action involve descendants of the finches that Darwin observed in the Galápagos Islands. The finches Darwin saw were different, but he hypothesized that they had descended from a common ancestor.

Peter and Rosemary Grant tested Darwin’s hypothesis, which relied on two testable assumptions:

For beak size and shape to evolve, there must be enough heritable variation in those traits to provide raw material for natural selection.

Differences in beak size and shape must produce differences in fitness, causing natural selection to occur. The Grants tested these hypotheses on the medium ground finch on Daphne Major, one of the Galápagos Islands. During the rainy season, there is plenty of food. During droughts, food becomes scarce. Individual birds with different-sized beaks had different chances of survival during a drought. When food was scarce, individuals with large beaks were more likely to survive. The Grants provided evidence of the process of evolution.

Beak size can be changed by natural selection.