Chapter 8: Evolution
Lesson 8.4: Macroevolution and the Origin of Species

Fast or slow? Which is better, the direct route or the scenic route? Each has its advantages, depending on the situation. And that describes evolution. It can be fast or slow, depending on the situation.

Lesson Objectives

• Describe two ways that new species may originate.
• Differentiate between allopatric, peripatric, parapatric, and sympatric speciation.
• Identify the different patterns of macroevolution
• Distinguish between gradualism and punctuated equilibrium.
• Understand the concept of extinction and how it affects evolution.

Vocabulary

• allopatric speciation
• behavioral isolation
• coevolution
• convergent evolution
• divergent evolution
• geographic isolation
• gradualism
• parapatric speciation
• peripatric speciation
• punctuated equilibrium
• speciation
• sympatric speciation
• temporal isolation

Introduction

Macroevolution is evolution over geologic time above the level of the species. One of the main topics in macroevolution is how new species arise. The process by which a new species evolves is called speciation. How does speciation occur? How does one species evolve into two or more new species?
Origin of Species

To understand how a new species forms, it’s important to review what a species is. A species is a group of organisms that can breed and produce fertile offspring together in nature. For a new species to arise, some members of a species must become reproductively isolated from the rest of the species. This means they can no longer interbreed with other members of the species. How does this happen? Usually they become geographically isolated first.

The macroevolution of a species happens as a result of speciation. Speciation is the branching off of individuals from the species they originally were. Over time, as natural selection occurs, individuals may build up adaptations that are no longer compatible with others in their species. This is most often due to geographic isolation or reproductive isolation from other individuals within the species.

Once the DNA is different enough, or they are no longer able to interbreed, they are now a different species that has branched off from the main species. At this point, they would be a new entry on a cladogram. How quickly does this process happen? If evolution for most species takes a very long time, it would be logical to think the same would happen for speciation. However, there are two major accepted different hypotheses on the pace of evolution due to speciation. Arguments for both hypotheses are sound and there has been no evidence found so far to disprove either one.

Types of Speciation

Speciation is the changing of individuals within a population so they are no longer part of the same species. This most often occurs due to geographic isolation or reproductive isolation of individuals within the population. As the species evolve and branch off, they cannot interbreed with members of the original species any longer. There are four types of speciation that can occur based on reproductive or geographic isolation, among other reasons and environmental factors.

How Does Speciation Occur?

Most of the time, speciation occurs through divergent evolution. Divergent evolution is when a species becomes less similar and changes into new species. The original species that branches off is then known as the most recent common ancestor of the new species. That is the process that causes speciation, but what triggers divergent evolution?

Charles Darwin described the mechanism of evolution which he called natural selection. The basic idea behind natural selection is that species undergo changes and accumulate adaptations that are favorable for their environments. After enough adaptations have built up, the species is no longer the same as it was and speciation has occurred.

Where do these changes come from? Microevolution is the changing of the species on a molecular level like with DNA mutations. If they are significant mutations, they will cause adaptations that may or may not be favorable for their environment. Natural selection will work on these individuals and the ones with the most favorable adaptations survive to create the new species.

Changes in species can also happen on a larger scale. Macroevolution examines those changes. One of the most common causes of speciation is called geographic isolation. This is when a population of a species is separated from the original population and over time, the two populations accumulate different adaptations and undergo speciation. If they were brought back together after the speciation has happened, they will no longer be able to interbreed and are therefore not the same species anymore.

Sometimes speciation happens because of reproductive isolation. Unlike geographic isolation, the population is still together in the same area, but something causes some of the individuals to no longer be able to mate and produce offspring with the original species. This could be something along the lines of a change in mating season or a different mating ritual. In some cases, males and females of
the species are special colors of have distinct markings. If these mating indicators were to change, the original species may no longer recognize the new individuals as potential mates.

There are four types of speciation. Allopatric speciation and peripatric speciation are caused by geographic isolation. Parapatric speciation and sympatric speciation are the other two types and are generally due to reproductive isolation.

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**Geographic Isolation**

**Allopatric Speciation**

The prefix *allo-* means "other". When paired with the suffix *-patric*, meaning "place", it becomes clear that allopatric is a type of speciation caused by geographic isolation. The individuals that are isolated are literally in an "other place". The most common mechanism for geographic isolation is an actual physical barrier that gets between members of a population. This can be something like as small as a fallen tree for small organisms or as large as being split by oceans.

Allopatric speciation does not necessarily mean the two distinct populations cannot interact or even breed at first. If the barrier causing the geographic isolation can be overcome, some members of the different populations may travel back and forth. However, a majority of the populations will stay isolated from each other and as a result; they will diverge into different species.

Assume that some members of a species become geographically separated from the rest of the species. If they remain separated long enough, they may evolve genetic differences. If the differences prevent them from interbreeding with members of the original species, they have evolved into a new species. Speciation that occurs in this way is called allopatric speciation. An example is described in Figure 8.29.

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**Figure 8.29** Allopatric Speciation in the Kaibab Squirrel. The Kaibab squirrel is in the process of becoming a new species.

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**Peripatric Speciation**

This time, the prefix *peri-* means "near". So when added to the suffix *-patric*, it translates into "near place". Peripatric speciation is actually a special type of allopatric speciation. There is still some
sort of geographic isolation, but there is also some sort of instance that causes very few individuals to survive in the isolated population compared to allopatric speciation.

In peripatric speciation, it may be an extreme case of geographic isolation where only a few individuals are isolated, or it could follow not only a geographic isolation, but also some sort of disaster that kills off all but a few of the isolated population. With such a small gene pool, rare genes are passed down more often, which causes genetic drift. The isolated individuals quickly become incompatible with their former species and have become a new species.

--- Reproductive Isolation

Parapatric Speciation

The suffix -patric still means "place" and when the prefix para-, or "beside", is attached, it implies that this time the populations are not isolated by a physical barrier and are instead "beside" each other. Even though there is nothing stopping the individuals in the entire population from mixing and mating, that does not happen in parapatric speciation. For some reason, individuals within the population only mate with individuals in their immediate area.

Some factors that could influence parapatric speciation include pollution or an inability to spread seeds for plants. However, in order for it to be classified as parapatric speciation, the population must be continuous with no physical barriers. If there are any physical barriers present, it needs to be classified as either peripatric or allopatric isolation.

Sympatric Speciation

The final type of speciation is called sympatric speciation. Putting the prefix sym-, meaning "same" with the suffix -patric which means "place" gives the idea behind this type of speciation. Amazingly enough, the individuals in the population are not separated at all and all live in the "same place". So how do the populations diverge if they live in the same space?

The most common cause for sympatric speciation is reproductive isolation. Reproductive isolation may be due to individuals coming into their mating seasons at different times or preference of where to find a mate. In many species, choice of mates may be based on their upbringing. Many species return to where they were born to mate. Therefore, they would only be able to mate with others who were born in the same place, no matter where they move and live as adults.

The following example shows one way this can occur.

1. Hawthorn flies lay eggs in hawthorn trees (see Figure 1.27). The eggs hatch into larvae that feed on hawthorn fruits. Both the flies and trees are native to the U.S.
2. Apple trees were introduced to the U.S. and often grow near hawthorn trees. Some hawthorn flies started to lay eggs in nearby apple trees. When the eggs hatched, the larvae fed on apples.
3. Over time, the two fly populations—those that fed on hawthorn trees and those that preferred apple trees—evolved reproductive isolation. Now they are reproductively isolated because they breed at different times. Their breeding season matches the season when the apple or hawthorn fruits mature. This is a form of temporal isolation, which occur when individuals are active at different times of the day, seasons, or mating periods.
4. Because they rarely interbreed, the two populations of flies are evolving other genetic differences. They appear to be in the process of becoming separate species.
Patterns of Macroevolution

New species evolve through a process called speciation. When we study macroevolution, we look at the overall pattern of change that caused the speciation to occur. This includes the diversity, speed, or direction of the change that caused the new species to emerge from the old one.

Speciation generally happens at a very slow pace. However, scientists can study the fossil record and compare the anatomy of previous species with that of today's living organisms. When the evidence is put together, distinct patterns emerge telling a story of how speciation probably happened over time.

Speciation of one species can affect the evolution of other species if they have a close relationship in an ecosystem. When populations of different species come together to form a community, they often depend on each other in some way for survival or to make life easier. This is especially apparent in food webs and food chains and in particular predator and prey relationships. If one of these species were to change, other species may also need to change.

Convergent Evolution

The word *converge* means "to come together". This pattern of macroevolution happens with distinctly different species become more similar in structure and function. Usually, this type of macroevolution is seen in different species that live in similar environments. The species are still different from one another, but they often fill the same niche in their local area.

One example of convergent evolution is seen in North American hummingbirds and Asian fork-tailed sunbirds. Even though the animals look very similar, if not identical, they are separate species that come from different lineages. They evolved over time to become more alike by living in similar environments and performing the same functions.

Divergent Evolution

Nearly the opposite of convergent evolution is divergent evolution. The term *diverge* means "to split apart". Also called adaptive radiation, this pattern is the typical example of speciation. One lineage breaks into two or more separate lines that each give rise to even more species over time. Divergent evolution is caused by changes in the environment or migration to new areas. It happens particularly quickly if there are few species already living in the new area. New species will emerge to fill the available niches.

Divergent evolution was seen in a type of fish called the charicidae. The jaws and teeth of the fish changed based on available food sources as they inhabited new environments. Many lines of charicidae emerged over time giving rise to several new species of fish in the process. There are about 1500 known species of charicidae in existence today, including piranhas and tetras.
Coevolution

All living things are affected by the other living organisms around them that share their environment. Many have close, symbiotic relationships. The species in these relationships tend to cause each other to evolve. If one of the species changes, then the other will also change in response so the relationship can continue.

For instance, bees feed off of flowers of plants. The plants adapted and evolved by having the bees spread the pollen to other plants. This allowed the bees to get the nutrition they needed and the plants to spread their genetics and reproduce.

Coevolution occurs in flowering plants and the species that pollinate them. The flower and bird in Figure 8.31 are a good example. They have evolved matching structures.

Figure 8.31: Results of Coevolution in a Flower and Its Pollinator. The very long mouth part of this hummingbird has coevolved with the tubular flower it pollinates. Only this species of bird can reach the nectar deep in the flower. What might happen to the flower if the bird species went extinct?

Timing of Macroevolution

Is evolution slow and steady? Or does it occur in fits and starts? It may depend on what else is going on, such as changes in climate and geologic conditions.

- When geologic and climatic conditions are stable, evolution may occur gradually. This is how Darwin thought evolution occurred. This model of the timing of evolution is called gradualism.
- When geologic and climatic conditions are changing, evolution may occur more quickly. Thus, long periods of little change may be interrupted by bursts of rapid change. This model of the timing of evolution is called punctuated equilibrium. It is better supported by the fossil record than is gradualism.

Gradualism

Charles Darwin believed that evolutionary changes happened slowly, or gradually, over very long periods of time. He got this idea from new findings in the field of geology. He was certain that small adaptations built up over time.

The first of these hypotheses is called gradualism, or phyletic gradualism. Just as the name implies, this is a gradual accumulation of adaptations over a long period of time. The Earth is around 4.6 billion years old. Even though it seems like speciation happens rapidly when we see it, gradualism proposes that there were many adaptations that slowly added up over a steady, long period of time. We did not notice those small changes until they led to a clearly new species. Therefore, speciation and subsequently evolution, happens because of those steady changes over long periods of time.

Punctuated Equilibrium

Opponents of Darwin, like William Bateson, argued that not all species evolve gradually. This camp of scientists believes that change happens very rapidly with long periods of stability and no change
in between. Usually the driving force of change is some sort of change in the environment that necessitates a need for quick change.

The other main hypothesis about the pace of speciation and evolution is called punctuated equilibrium. Its name is also descriptive of the hypothesis. This hypothesis claims that species stay in a state of stasis for very long periods of time and then a relatively short period of quick, successive changes occur to cause speciation and the new species evolves suddenly. Like Darwin, the group that believes in punctuated equilibrium looks to the fossil record for evidence of this phenomenon. There are many "missing links" in the fossil record. This lends evidence to the idea that there really aren't any intermediate forms and large changes happen suddenly. The idea of punctuated equilibrium assumes that transitional forms between the species were only around for such a short period of time that none were preserved as fossils and may be a "missing link" forever.

Extinction

When every individual in a population has died off, an extinction has occurred. This, obviously, ends the species and no more speciation is able to happen for that lineage. When some species die out, others tend to flourish and take over the niche the now extinct species once filled.

Many different species have gone extinct throughout history. Most famously, the dinosaurs went extinct. The extinction of the dinosaurs allowed mammals, like humans, to come into existence and thrive. However, descendants of the dinosaurs still live on today. Birds are a type of animal that branched off from the dinosaur lineage.

Lesson Summary

• New species arise in the process of speciation. Allopatric speciation occurs when some members of a species become geographically separated. They then evolve genetic differences. If the differences prevent them from interbreeding with the original species, a new species has evolved. Sympatric speciation occurs without geographic separation.
• Coevolution occurs when species evolve together. This often happens in species that have symbiotic relationships. Examples include flowering plants and their pollinators.
• Darwin thought that evolution occurs gradually. This model of evolution is called gradualism. The fossil record better supports the model of punctuated equilibrium. In this model, long periods of little change are interrupted by bursts of rapid change.

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