LESSON 19.2

Getting Started

Objectives

19.2.1 Identify the processes that influence survival or extinction of a species or clade.

19.2.2 Contrast gradualism and punctuated equilibrium.

19.2.3 Name two important patterns in macroevolution.

19.2.4 Explain the evolutionary characteristics of coevolving organisms.

Student Resources

Study Workbooks A and B, 19.2 Worksheets

Spanish Study Workbook, 19.2 Worksheets

Lab Manual B, 19.2 Data Analysis Worksheet

BIOLOGY.com Lesson Overview • Lesson Notes • Activity: Data Analysis • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 456–461.

Answers

IN YOUR NOTEBOOK Macroevolution is evolutionary change that occurs over a long period of time and across many species. Comparison of fossils over time can show general trends within and among clades.

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, II, III, IV, V

CONTENT

C.3.a, C.3.b, C.3.c, C.3.d, C.3.e

INQUIRY

A.1.e, A.2.a, A.2.e

19.2 Patterns and Processes of Evolution

Key Questions

What processes influence whether species and clades survive or become extinct?

How fast does evolution take place?

What are two patterns of macroevolution?

What evolutionary characteristics are typical of coevolving species?

Vocabulary

macroevolutionary patterns
background extinction
mass extinction
gradualism
punctuated equilibrium
adaptive radiation
convergent evolution
coevolution

Taking Notes

Concept Map Construct a concept map that includes the patterns of macroevolution shown in this lesson.

THINK ABOUT IT The fossil record shows a parade of organisms that evolved, survived for a time, and then disappeared. More than 99 percent of all species that have lived on Earth are extinct. How have so many different groups evolved? Why are so many now extinct?

Speciation and Extinction

What processes influence whether species and clades survive or become extinct?

The study of life's history leaves no doubt that life has changed over time. Many of those changes occurred within species, but others occurred in larger clades and over longer periods of time. These grand transformations in anatomy, phylogeny, ecology, and behavior, which usually take place in clades larger than a single species, are known as **macroevolutionary patterns.** The ways new species emerge through speciation, and the ways species disappear through extinction, are among the simplest macroevolutionary patterns. The emergence, growth, and extinction of larger clades, such as dinosaurs, mammals, or flowering plants are examples of larger macroevolutionary patterns.

Macroevolution and Cladistics Paleontologists study fossils to learn about patterns of macroevolution and the history of life. Part of this process involves classifying fossils. Fossils are classified using the same cladistic techniques, based on shared derived characters, that are used to classify living species. In some cases, fossils are placed in clades that contain only extinct organisms. In other cases, fossils are classified into clades that include living organisms.

Remember that cladograms illustrate hypotheses about how closely related organisms are. Hypothesizing that a fossil species is *related* to a living species is not the same thing as claiming that the extinct organism is a direct *ancestor* of that (or any other) living species. For example, **Figure 19–9** does not suggest that any of the extinct species shown are direct ancestors of modern birds. Instead, those extinct species are shown as a series of species that descended, over time, from a line of common ancestors.

In Your Notebook *Explain what macroevolution is and how fossils can show macroevolutionary trends.*

FIGURE 19–8 Paleontologists at Work The white covering protects the fossils until they can reach a museum.

UbD Teach for Understanding

ENDURING UNDERSTANDING The diversity of life is the result of ongoing evolutionary change. Species alive today have evolved from ancient common ancestors.

GUIDING QUESTION What are some patterns in which evolution has occurred?

EVIDENCE OF UNDERSTANDING *After completing the lesson, give students the following assessment to show whether they understand the difference between gradualism and punctuated equilibrium.* Divide the class into small groups, and have each group model either gradualism or punctuated equilibrium using familiar objects that have changed over time, such as automobiles, athletic shoes, or modes of communication. Each group's final product should include a poster that uses pictures to show how the objects have changed over time and annotations that describe the changes and whether the changes best model gradualism or punctuated equilibrium.

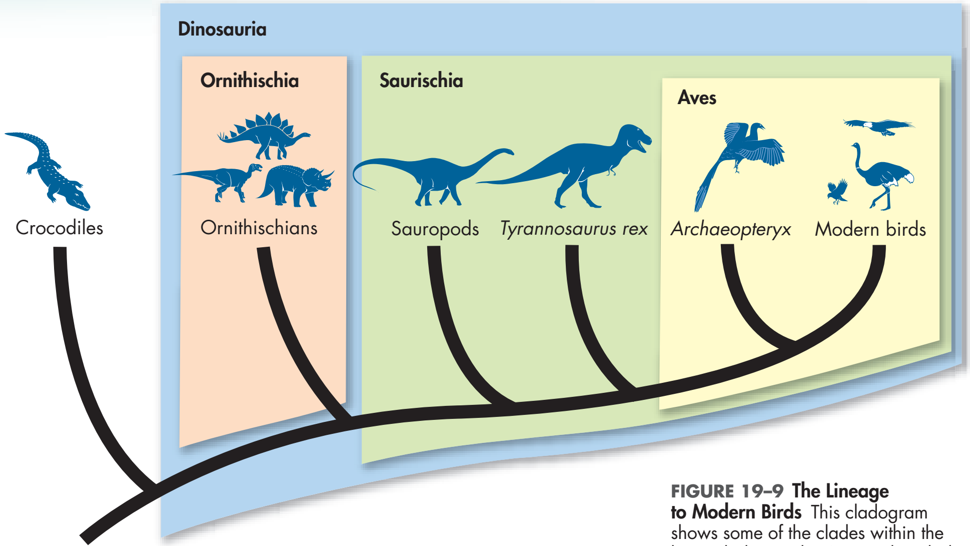


FIGURE 19–9 The Lineage to Modern Birds This cladogram shows some of the clades within the large clade Reptilia. Notice that clade Dinosauria is represented today by modern birds. **Classify** *What are the two major clades of dinosaurs?*

Adaptation and Extinction Throughout the history of life, organisms have faced changing environments. When environmental conditions change, processes of evolutionary change enable some species to adapt to new conditions and thrive. Species that fail to adapt eventually become extinct. Interestingly, the rates at which species appear, adapt, and become extinct vary among clades, and from one period of geologic time to another.

Why have some clades produced many successful species that survived over long periods of time, while other clades gave rise to only a few species that vanished due to extinction? Paleontologists have tried to answer this question by studying macroevolutionary patterns of speciation and extinction in different clades over time.

One way to think about this process is in terms of species diversity. The emergence of new species with different characteristics can serve as the "raw material" for macroevolutionary change within a clade over long periods. In some cases, the more varied the species in a particular clade are, the more likely the clade is to survive environmental change. This is similar to the way in which genetic variation serves as raw material for evolutionary change for populations within a species. **If the rate of speciation in a clade is equal to or greater than the rate of extinction, the clade will continue to exist. If the rate of extinction in a clade is greater than the rate of speciation, the clade will eventually become extinct.**

The clade Reptilia (part of which is shown in **Figure 19–9**) is one example of a highly successful clade. It not only includes living organisms like snakes, lizards, turtles and crocodiles, but also dinosaurs that thrived for tens of millions of years. As you know, most species in the clade Dinosauria are now extinct. But the clade itself survived, because it produced groups of new species that successfully adapted to changing conditions. One of those groups survives and thrives today—we call them birds.

Biology In-Depth

ARCHAEOPTERYX

The first specimen of *Archaeopteryx* was discovered in 1860, just one year after Darwin published *On the Origin of Species*. As skeletal details emerged, it seemed like the perfect "missing link" between reptiles and birds. *Archaeopteryx* had a number of reptilian features including the presence of claws on its fingers, teeth, and a long, bony tail. It also had a number of avian characteristics, like feathers, a backwards-facing big toe, and a wishbone. There are eight known specimens of *Archaeopteryx* today, all dating to the late Jurassic, about 150 million years ago. It is widely accepted as the oldest known bird, though scientists continue to find new specimens and to refine the origin and evolution of birds and flight.

Teach

Lead a Discussion

Have students read about and discuss macroevolutionary patterns, speciation, and extinction.

Ask What are macroevolutionary patterns? *(grand, large-scale transformations that usually occur in clades larger than one species)*

Ask What does speciation result in? *(new species)*

Ask What does extinction result in? *(the disappearance of a species or clade)*

Ask How do the relative rates of speciation and extinction within a clade determine the fate of the clade as a whole? *(If the rate of speciation exceeds the rate of extinction, the clade will continue to exist. If the rate of extinction exceeds the rate of speciation, the clade will eventually become extinct.)*

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** If students have trouble understanding the idea of the extinction of clades, refer to **Figure 19–9.**

Ask What is the only group of dinosaurs in the diagram that is not extinct? *(modern birds)* Point out that, if modern birds were extinct, the entire clade shown in the diagram would be extinct. Since modern birds are not extinct, the clade is still surviving.

LPR **Less Proficient Readers** Have students work in groups of five. In each group, assign a different student to each of the four questions above. Have the student locate in the text the answer to his or her assigned question. Then, have each student state for his or her group the assigned question, the answer to the question, and the location of the answer in the text.

Address Misconceptions

Evolution—Ever Unfolding Some students may have the idea that in order for the theory of evolution by natural selection to be valid, evidence of a complete unbroken chain of fossil organisms will have to be pieced together one day. Explain that a current description of evolution is not limited to studying fossils. Rather, it is the combined results of research in genetics, cladistics, ecology, chemistry, and geology. We will never have an unbroken chain of fossils, but that in no way invalidates evolution by natural selection.

Answers

FIGURE 19–9 Ornithischia and Saurischia

Teach continued

Build Reading Skills

To be proficient readers, students need to learn how to compare and contrast topics they read about. Have students read about patterns of extinction, and then have each student write a short paragraph comparing and contrasting background extinction and mass extinction. Remind students to include both similarities and differences in their paragraphs. Then, have several students share their paragraphs with the class and compile a list of similarities and a list of differences on the board, based on the content of their paragraphs.

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Students who would have difficulty preparing a written paragraph comparing and contrasting background extinction and mass extinction should instead prepare a bulleted list of words and phrases that describe how background extinction and mass extinction are similar to one another and another bulleted list describing how they are different.

ELL Focus on ELL: Access Content

ALL SPEAKERS Have students use the **Think-Pair-Share** strategy to help them understand extinction. Pair beginning and intermediate speakers with advanced and advanced high speakers. Have students take turns reading aloud the information about patterns of extinction, one paragraph at a time. As students finish reading each paragraph, ask them a question about the content of the paragraph. Have each pair discuss a response and then share the response with other pairs. Follow up by having each pair of students develop a written question about patterns of extinction. Have one student in each pair read aloud his or her prepared question, and then call on another student to answer.

Study Wkbks A/B, Appendix S14, Think-Pair-Share.

MYSTERY CLUE Because most organisms need oxygen, a sharp reduction in oxygen would have killed many living things. Students can go online to **Biology.com** to gather their evidence.

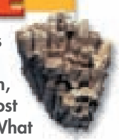
BIOLOGY.com Have students use data to infer causes of extinction events in **Data Analysis: Explaining Extinctions.**

Patterns of Extinction Species are always evolving and competing—and some species become extinct because of the slow but steady process of natural selection. Paleontologists use the term **background extinction** to describe this kind of "business as usual" extinction. In contrast, a **mass extinction** is an event during which many species become extinct over a relatively short period of time. A mass extinction isn't just a small increase in background extinction. In a mass extinction, entire ecosystems vanish, and whole food webs collapse. Species become extinct because their environment breaks down and the ordinary process of natural selection can't compensate quickly enough.

Until recently researchers looked for a single cause for each mass extinction. For example, geologic evidence shows that at the end of the Cretaceous Period, a huge asteroid crashed into Earth. The impact threw huge amounts of dust and water vapor into the atmosphere, causing global climate change. At about the same time, dinosaurs and many other species became extinct. It is reasonable to infer, then, that the asteroid played a significant role in this mass extinction. Many mass extinctions, however, were probably caused by several factors, working in combination: volcanic eruptions, moving continents, *and* changing sea levels, for example.

After a mass extinction, biodiversity is dramatically reduced. But this is not bad for all organisms. Extinction offers new opportunities to survivors. And as speciation and adaptation produce new species to fill empty niches, biodiversity recovers. But this recovery takes a long time—typically between 5 and 10 million years. Some groups of organisms survive a mass extinction, while other groups do not.

MYSTERY CLUE



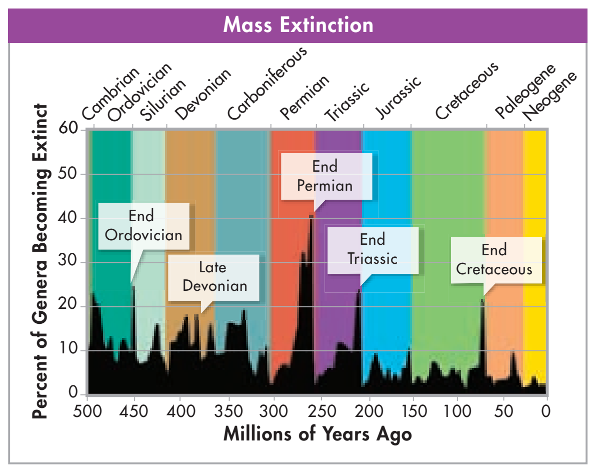
Evidence indicates that before the Permian extinction, the oceans lost most of their oxygen. What effect do you think the loss of oxygen had on most organisms?

Analyzing Data

Extinctions Through Time

The graph shows how the rate of extinction has changed over time. Study the graph, and then answer the questions.

1. **Interpret Graphs** What is plotted on the *y*-axis?
2. **Analyze Data** Which mass extinction killed off the highest percentage of genera?
3. **Draw Conclusions** Describe the overall pattern of extinction shown on the graph.
4. **Infer** What evidence is this graph probably based on?



Analyzing Data

PURPOSE Students will interpret a graph about rates of extinction over time.

PLANNING Remind students to read all the labels on the graph. Discuss what the vertical color bars indicate. *(periods of the geologic time scale)*

ANSWERS

1. percent of genera becoming extinct
2. the extinction at the end of the Permian Period (about 41 percent)
3. According to the graph, extinctions have occurred throughout the history of life, with the percentage of extinctions fluctuating.
4. The graph is probably based on evidence from the fossil record.

Rate of Evolution

How fast does evolution take place?

How quickly does evolution operate? Does it always take place at the same speed? **Evidence shows that evolution has often proceeded at different rates for different organisms at different times over the long history of life on Earth.** Two models of evolution—gradualism and punctuated equilibrium—are shown in **Figure 19–10.**

Gradualism Darwin was impressed by the slow, steady pace of geologic change. He suggested that evolution also needed to be slow and steady, an idea known as **gradualism.** The fossil record shows that many organisms have indeed changed gradually over time.

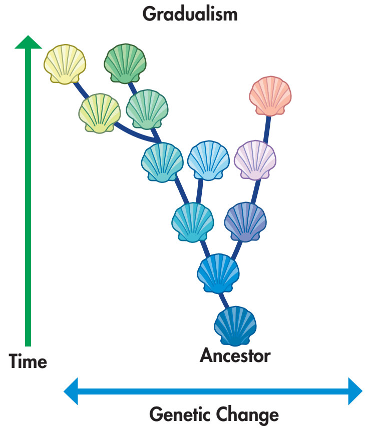
Punctuated Equilibrium However, numerous examples in the fossil record indicate that the pattern of slow, steady change does not always hold. Horseshoe crabs, for example, have changed little in structure from the time they first appeared in the fossil record. Much of the time, these species are said to be in a state of equilibrium. This means that their structures do not change much even though they continue to evolve genetically.

Every now and then something happens to upset this equilibrium for some species. **Punctuated equilibrium** is the term used to describe equilibrium that is interrupted by brief periods of more rapid change. (Remember that we use *rapid* here relative to the geologic time scale. For geologists, rapid change can take thousands of years!) The fossil record does reveal periods of relatively rapid change in particular groups of organisms. In fact, some biologists suggest that most new species are produced during periods of rapid change.

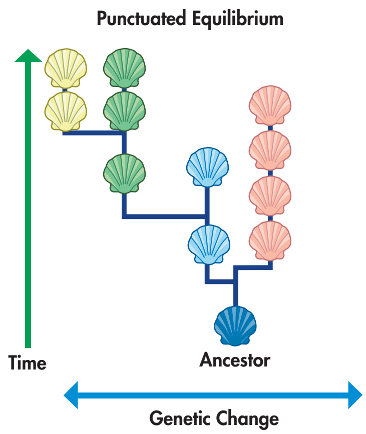
Rapid Evolution After Equilibrium There are several reasons why evolution may proceed at different rates for different organisms at different times. Rapid evolution may occur after a small population becomes isolated from the main population. This small population can evolve faster than the larger one because genetic changes spread more quickly among fewer individuals. Rapid evolution may also occur when a small group of organisms migrates to a new environment. That's what happened with the Galápagos finches. In addition, mass extinctions open many ecological niches, creating new opportunities for those organisms that survive. It's not surprising, then, that groups of organisms that survive mass extinctions evolve rapidly in the several million years after the extinction.

In Your Notebook *In your own words, describe gradualism and punctuated equilibrium.*

FIGURE 19–10 Models of Evolution Biologists have considered two different patterns for the rate of evolution, gradualism and punctuated equilibrium. These illustrations are simplified to show the general trend of each model. **Interpret Visuals** *How do the diagrams illustrate these two models?*



Gradualism involves a slow, steady change in a particular line of descent.



Punctuated equilibrium involves stable periods interrupted by rapid changes.

Build Study Skills

Before students read the text following the heading **Rate of Evolution,** have them preview the information. Write the following questions on the board to help them think about the main points.

- Why did Darwin think evolution was a gradual process? *(He thought biologic change happened like the slow, steady pace of geologic change.)*
- Why are horseshoe crabs an example of a species in a state of equilibrium? *(The species has not changed for a very long time.)*
- How is punctuated equilibrium different from gradualism? *(Gradualism consists of slow, steady change in species. Punctuated equilibrium consists of rapid change in species following a period of equilibrium.)*
- When might rapid evolution take place? *(after a small population becomes isolated; when a small group migrates to a new environment; after a mass extinction)*

After students have completed their preview, ask them to read the text. Follow up by asking volunteers to provide oral responses to the questions above.

DIFFERENTIATED INSTRUCTION

LPR Less Proficient Readers Help struggling readers understand the difference between gradualism and punctuated equilibrium by studying **Figure 19–10.** Point out that the number and final positions of the shells in both diagrams are the same. The only difference is how they got there.

Ask In the diagrams, what is indicated by a horizontal shift in the placement of a shell? *(a color change)*

Ask The paths of the shells in the top diagram are slightly curved. What kind of change does this indicate? *(gradual change)*

Ask The paths of the shells in the bottom diagram are made of straight lines. What do straight horizontal lines indicate? *(sudden change)* What do straight vertical lines indicate? *(periods of no change)*

How Science Works

PUNCTUATED EQUILIBRIUM

Stephen J. Gould and Niles Eldredge proposed the idea of punctuated equilibrium in 1972. Calling their idea a "novel interpretation" as opposed to a new discovery, Gould and Eldredge reasoned that there must be an explanation for why sudden appearances and disappearances of species in the fossil record are so common. While Darwin and others pointed to the incomplete fossil record to explain the lack of intermediates, Gould and Eldredge interpreted "stasis as data"—remarking that the fact species don't seem to change in the fossil record is important in itself and not just the artifact of an imperfect fossil record.

Answers

FIGURE 19–10 The diagram representing gradualism shows a slow, steady change in shell color in a particular line of descent; the diagram representing punctuated equilibrium shows stable periods interrupted by rapid changes.

IN YOUR NOTEBOOK Sample answer: Gradualism is a pattern of slow and steady change from one form to another. Punctuated equilibrium is a pattern of sudden, rapid changes in form between long periods of little change.

Teach continued

Expand Vocabulary

Write the term *adaptive radiation* on the board. Tell students that an understanding of each word that makes up this term will help make the meaning of the term clear. Tell students that *adaptive* means "having a capacity for or tendency toward adaptation," and *radiation* means "the action of spreading around as if from a center."

Ask How does the definition of the word *adaptive* relate to the term *adaptive radiation*? *(Adaptive radiation cannot occur in the absence of adaptation, which, in evolution, designates genetically determined characteristics that enhance fitness.)*

Ask How does the definition of the word *radiation* relate to the term *adaptive radiation*? *("Spreading as if from a center" describes the evolution of several species from a single or small group of species.)*

DIFFERENTIATED INSTRUCTION

L1 **Special Needs** Have students work with a partner to complete a **Vocabulary Word Map** for the term *adaptive radiation.* Have students write the term in the top box and then list attributes in the bottom boxes. Circulate among the pairs as they work, asking questions about the attributes identified in their vocabulary word maps.

Study Wkbks A/B, Appendix S32, Vocabulary Word Map. **Transparencies,** GO17.

Answers

FIGURE 19–11 sirenians; Yes, it is surprising because sirenians are aquatic and look nothing like elephants, which are terrestrial.

Adaptive Radiation and Convergent Evolution

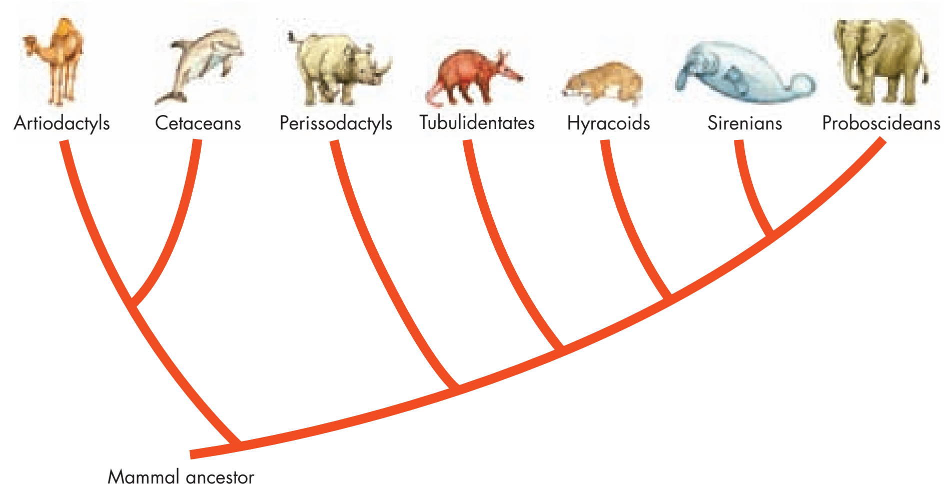
What are two patterns of macroevolution?

As paleontologists study the fossil record, they look for patterns. **Two important patterns of macroevolution are adaptive radiation and convergent evolution.** As you'll see, Darwin noted both patterns while aboard the *Beagle.*

Adaptive Radiation Studies of fossils and living organisms often show that a single species or small group of species has diversified over time into a clade containing many species. These species display variations on the group's ancestral body plan, and often occupy different ecological niches. These differences are the product of an evolutionary process called adaptive radiation. **Adaptive radiation** is the process by which a single species or a small group of species evolves over a relatively short time into several different forms that live in different ways. An adaptive radiation may occur when species migrate to a new environment or when extinction clears an environment of a large number of inhabitants. In addition, a species may evolve a new feature that enables it to take advantage of a previously unused environment.

▶ ***Adaptive Radiations in the Fossil Record*** Dinosaurs—one of several spectacular adaptive radiations of reptiles—flourished for about 150 million years during the Mesozoic. The fossil record documents that in the dinosaurs' heyday, mammals diversified but remained small. After most dinosaurs became extinct, however, an adaptive radiation of mammals began. That radiation, part of which is shown in **Figure 19–11,** produced the great diversity of mammals of the Cenozoic Era.

FIGURE 19–11 Adaptive Radiation This diagram shows part of the adaptive radiation of mammals. Note how the groups of animals shown have adapted to many different ways of life—including two groups which have become aquatic. **Interpret Visuals** ***According to this diagram, which mammal group is most closely related to elephants? Does this surprise you? Explain.***



UbD Check for Understanding

FOLLOW-UP PROBES

Ask During a particular geologic period, land areas rose, draining shallow seas and creating moist tropical habitats. Explain why you would expect adaptive radiation to have taken place after these events. *(Adaptive radiation often occurs after major changes in environments. New niches form, which provide opportunities for new species to evolve.)*

ADJUST INSTRUCTION

If students have difficulty responding to the question, use an analogy. Ask them to think about what happens when an apartment building is built on newly cleared land. *(The organisms that lived on the land move or die, and many people move in.)* Explain how the new homes or apartments are like new niches.

FIGURE 19–12 Convergent Evolution Mammals that feed on ants and termites evolved independently five times. Although each species is unique, each has evolved powerful front claws, a long hairless snout, and a tongue covered with sticky saliva. These adaptations are useful for hunting and eating insects.

▶ ***Modern Adaptive Radiations*** Galápagos finches and Hawaiian honeycreepers are two examples of adaptive radiations in modern organisms. In each of these cases, numerous species evolved from a single founding species. Both finches and honeycreepers evolved different beaks and behaviors that enable each of them to eat different kinds of food.

Convergent Evolution Sometimes, groups of organisms evolve in different places or at different times, but in similar environments. These organisms start out with different structures on which natural selection can operate. But they face similar selection pressures. In these situations, natural selection may mold different body structures in ways that perform similar functions. Because they perform similar functions, these body structures may look similar. Evolution produces similar structures and characteristics in distantly related organisms through the process of **convergent evolution.** Convergent evolution has occurred often in both plants and animals. For example, mammals that feed on ants and termites evolved not once, but five times, in different regions as shown in **Figure 19–12.** Remember how Darwin noted striking similarities among large, distantly related grassland birds? Emus, rheas, and ostriches are another example of convergent evolution.

Coevolution

What evolutionary characteristics are typical of coevolving species?

Sometimes the life histories of two or more species are so closely connected that they evolve together. Many flowering plants, for example, can reproduce only if their flowers attract a specific pollinator species. Pollinators, in turn, may depend on the flowers of certain plants for food in the form of pollen or nectar. The process by which two species evolve in response to changes in each other over time is called **coevolution.** **The relationship between two coevolving organisms often becomes so specific that neither organism can survive without the other. Thus, an evolutionary change in one organism is usually followed by a change in the other organism.**

Lead a Discussion

Draw students' attention to the subsection **Convergent Evolution.** Explain that convergent evolution describes situations in which unrelated organisms evolve similar structures and traits due to similar environmental pressures.

Ask What similar structures evolved in the animals shown in **Figure 19–12?** *(powerful front claws, a long snout, and a tongue covered with sticky saliva)*

Ask What do these adaptations allow each of these animals to do? *(eat ants)*

Ask What structures do birds and bats have in common that can be attributed to convergent evolution? *(wings)*

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Have students use a **Main Ideas and Details Chart** to organize information about convergent evolution. Have them enter the term *convergent evolution* as the main idea in their charts. Then, ask students to work in pairs to brainstorm details related to this main idea and enter them in their charts. Call on students to read aloud details they have included in their charts. Use their responses to identify any misconceptions students have about this topic, and address those in a discussion to increase the depth of students' understanding.

Study Wkbks A/B, Appendix S28, Main Ideas and Details Chart. **Transparencies,** GO13.

ELL **English Language Learners** Use the color coding in **Figure 19–12** to help ELL students understand convergent evolution. Begin by pointing to the illustration of the nine-banded armadillo and its label. Then move your finger to the continent of North America on the map. With the aid of an advanced speaker, explain that the border of the label box and the area of the animal's range are the same color. Then, point to the common echidna and link it to the continent of Australia on the map. Repeat the process for all the animals shown. The advanced speaker can also help you explain the process of convergent evolution and clarify the idea that all the animals have similar adaptations for feeding on ants.

Biology In-Depth

THE BIRDS AND THE BEES

An unusual example of coevolution occurs between certain orchids and insects. These plants are pollinated by species of insects in which the males emerge in the spring before the females. The orchid flowers have evolved shapes and odors that mimic the stimuli presented by the female insects. The males fly around in search of female insects. In doing so, the males encounter the insect-mimicking orchid flowers and try to mate with them. In the process, they pollinate the orchids. Some plants and their pollinators are so highly adapted to each other that only one species is able to pollinate a given plant. For example, in Hawaii, *Brighamia* flowers can be pollinated only by nectar-feeding birds called Hawaiian honeycreepers. However, the birds have declined in number, and now the plants also face extinction.

LESSON 19.2

Teach continued

Lead a Discussion

Ask students to read about coevolution.

Ask What is coevolution? *(two species evolving in response to changes in each other)*

Ask How do the organisms in **Figure 19–13** demonstrate coevolution? *(Monarch caterpillars have evolved a tolerance for milkweed toxin.)*

DIFFERENTIATED INSTRUCTION

L3 Advanced Students Have students research the relationship between the yucca moth and the yucca plant. Ask them to share their findings with the class.

Assess and Remediate

EVALUATE UNDERSTANDING

Call on students to explain why evolution might proceed rapidly in some circumstances and slowly in others. Then, have students complete the 19.2 Assessment.

REMEDIATION SUGGESTION

L1 Struggling Students If some students struggle to answer **Question 2b,** point out that when organisms move from one place to another, their new environment may have significantly different conditions than their old one.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

FIGURE 19–13 Plants and Herbivorous Insects Milkweed plants produce toxic chemicals. But monarch caterpillars not only can tolerate this toxin, they also can store it in their body tissues to use as a defense against *their* predators.

Flowers and Pollinators Coevolution of flowers and pollinators is common and can lead to unusual results. For example, Darwin discovered an orchid whose flowers had a long structure called a spur. Way down at the bottom of that 40-centimeter-long spur is a supply of nectar, which could serve as food for any insect able to reach it. But what insect could reach it? Darwin predicted that some pollinating insect must have some kind of feeding structure that would allow it to reach the nectar. Darwin never saw that insect. But about 40 years later, researchers discovered a moth with a 40-centimeter-long feeding tube that matched Darwin's prediction!

Plants and Herbivorous Insects Plants and herbivorous insects also demonstrate close, albeit less "friendly," coevolutionary relationships. Insects have been feeding on flowering plants since both groups emerged. Over time, many plants evolved bad-tasting or poisonous compounds that discourage insects from eating them. Some of the most powerful natural poisons are compounds developed by plants in response to insect attacks. But once plants began to produce poisons, natural selection on herbivorous insects favored any variants that could alter, inactivate, or eliminate those poisons. Time and again, a group of insects, like the caterpillar in **Figure 19–13,** evolved a way to deal with the particular poisons produced by a certain group of plants.

19.2 Assessment

Review Key Concepts

1. a. **Review** How does variation within a clade affect the clade's chance of surviving environmental change?
   b. **Compare and Contrast** How is mass extinction different from background extinction?
2. a. **Review** Explain how punctuated equilibrium is different from gradualism.
   b. **Relate Cause and Effect** Why would evolution speed up when a small group of organisms migrates to a new environment?
3. a. **Review** What is adaptive radiation?
   b. **Relate Cause and Effect** When might adaptive radiation result in convergent evolution?
4. a. **Review** What is coevolution?
   b. **Apply Concepts** Describe an example of coevolution.

Apply the Big idea

Evolution

5. What role does the environment play in convergent evolution?

BIOLOGY.com Search Lesson 19.2 GO • Self-Test • Lesson Assessment

Assessment Answers

1a. In general, it increases the chance of surviving environmental changes.

1b. In a mass extinction, many species become extinct over a relatively short period of time because their environment breaks down and natural selection cannot compensate quickly enough. Background extinction is a continuous process because some species are always becoming extinct by the slow, steady process of natural selection.

2a. Punctuated equilibrium consists of brief periods of rapid change that interrupt periods of little change. Gradualism is a slow, steady pace of change in species.

2b. Genetic changes spread more quickly through a small population; there may be new opportunities (niches) for the newly arrived organisms.

3a. Adaptive radiation is the process by which a single species or small group of species evolves over a relatively short time into several different forms with different ways of life.

3b. Adaptive radiation may result in convergent evolution as unrelated organisms face similar environments and evolve similar structures.

4a. process by which two species evolve in response to changes in each other

4b. Sample answer: evolution in monarch caterpillars of tolerance to milkweed toxins

5. Big idea Sample answer: The environment in one place can be similar to the environment in another place. Similar environments exert similar pressures on different species and may result in adaptations of structures to perform similar functions.