10 What Is a Species?

INVESTIGATION • 3–4 CLASS SESSIONS

OVERVIEW

In this activity students learn about the biological species concept in defining species and how it provides information about where new species are in the process of separation from closely related species. Students then investigate the factors that lead to reproductive isolation of species.

KEY CONTENT

1. Species evolve over time. The millions of species that live on the earth today are related by descent from common ancestors.
2. Taxa are classified in a hierarchy of groups and subgroups based on genealogical relationships.
3. The broad patterns of behavior exhibited by animals have evolved by natural selection as a result of reproductive success.
4. Scientists have found that the original definition of species as groups of organisms with similar morphology does not reflect underlying evolutionary processes.
5. The biological species concept defines a species as a population of individuals that actually or can potentially interbreed in nature to produce fertile offspring.
6. Scientific explanations must adhere to such criteria as the application of appropriate evidence, consistently logical reasoning, and basis in accepted historical and current scientific knowledge.

KEY PROCESS SKILLS

1. Students communicate and defend a scientific argument.
2. Students apply evidence and reasoning to formulate a logical claim for where populations are in the process of speciation.

MATERIALS AND ADVANCE PREPARATION

For the teacher

transparency of Scoring Guide: GROUP INTERACTION (GI)

transparency of Scoring Guide: UNDERSTANDING CONCEPTS (UC)

For each group of four students

set of 14 Species Pairs Cards

set of 8 Reproductive Barrier Cards

chart paper* (optional)

markers* (optional)

For each student

Student Sheet 10.1, "Supporting a Scientific Argument" (optional)

Scoring Guide: GROUP INTERACTION (GI) (optional)

Scoring Guide: UNDERSTANDING CONCEPTS (UC) (optional)

**Not supplied in kit*

Decide in advance if you will hand out Student Sheet 10.1, "Supporting a Scientific Argument," or have students record this information in their science notebooks.

Masters for Scoring Guides are in Teacher Resource IV: Assessment.

SL-00114T

TEACHING SUMMARY

Getting Started

- Students write their understanding of the concept of a species.

Doing the Activity

- Review the claim-evidence-and-reasoning approach of the activity and, with the class, apply it to examples in the Student Book.
- Students make claims based on evidence and reasoning about where in the process of separation species are from one another.
- (GI ASSESSMENT) Students sort pairs of species based on the barriers to reproduction that isolate them and prevent gene flow.
- (LITERACY) Students write definitions in their own words for the types of isolation, and conduct an Informal Meeting of the Minds to discuss their definitions.

Follow-up

- (UC ASSESSMENT) Discuss the biological species concept as providing a snapshot of where two populations are in the process of separation.
- The class discusses factors that might lead to speciation.

GETTING STARTED

1 Begin the activity by writing the following three questions on the chalkboard or an overhead transparency.

a. What is a species?

b. Some examples of species are: ____________________.

c. How do biologists decide if two populations are of the same or different species?

Tell students to write the questions and their answers in their science notebooks or, if you would like to collect and read their answers, on an index card or piece of paper. Students' answers will provide you with formative assessments for you to determine what students already know and to adjust your instruction if necessary. For example, if most students were introduced to taxonomy in middle school and know that a species is the most fundamental unit of classification, you need not emphasize this concept.

Some students are likely to say a species is a group of organisms that share some common characteristics. Their examples are likely to vary widely, and some may be at a higher level of classification than the species level. Oak trees, for example, are members of a genus that includes several hundred species. Everyday examples of two species are the domestic dog and domestic cat. Another that students might mention is humans and chimpanzees. Students are likely to say that biologists decide whether organisms are in the same or different species based on their appearance. However, some may have been introduced to the idea that members of the same species are able to mate and produce fertile offspring, possibly citing the example of the mating of horses and donkeys to produce sterile mules. Stress that early classification systems focused on the observable characteristics of organisms, but modern systems do not.

10 What Is a Species?

1 Think about the many different types of organisms you see in a typical day. In addition to humans, you might see mammals such as dogs and cats; birds such as robins and pigeons; insects such as ants and flies; and plants ranging from dandelions to oak trees. On a farm or at the zoo or aquarium, you would see even more examples.

The original idea of different types, or species, of organisms was based on the observable differences in their appearances. A species was defined as a group of organisms with similar physical characteristics. Beginning in the late 1700s, species became the basic unit of classification.

As scientists learned more about evolution and the causes of differences among groups of organisms, their ideas about species changed. Scientists now know that some populations of organisms that appear identical are in fact different species, and others that appear different are the same species. The original species concept was replaced by concepts that focus on evolutionary relationships.

There are now several alternative definitions for species. In this activity, you will explore the **biological species concept.** This method of defining a species is based on whether the organisms actually or can potentially breed with each other to produce fertile offspring. If they can, they are of the same species. This approach gives evolutionary biologists and conservationists a snapshot of where species are in the process of separation from one another. The classification of populations into the same or separate biological species may affect their conservation status. For example, if two populations are determined to be in separate species, it is more likely that both will be considered for protection.

The pickerel frog (a) and moor frog (b) are two species of frogs in the Rana *genus.*

a

b

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Other species concepts are applied in other fields of biology. For example, evolutionary biologists use a phylogenetic species concept, which defines a species as a distinct lineage and reflects the evolutionary relationships among taxa.

Challenge

▶ How do new species separate from existing species?

MATERIALS

FOR EACH GROUP OF FOUR STUDENTS

set of 14 Species Pair Cards
set of eight Reproductive Barrier Cards

BACKGROUND INFORMATION

The Biological Species Concept

ACCORDING TO THE biological species concept, a **biological species** is all of the populations of individuals that actually or can potentially breed with each other in nature to produce fertile offspring. The result of this interbreeding is movement of genes, called **gene flow,** throughout the species. Members of the same species share a common group of genes—a **gene pool**—and a common evolutionary history. Should members of different populations mate but produce no or no fertile offspring or very rarely breed with each other even when present in the same location, they are considered different biological species.

OTHER WAYS TO CATEGORIZE SPECIES

The biological species concept is straightforward, but it turns out that there are a number of areas where it is not helpful. For example, many species, such as bacterial species, do not reproduce sexually. The concept also does not fit many plant species that crossbreed under natural or artificial conditions. Also, the concept cannot be applied to fossil organisms because their breeding cannot be observed.

Nevertheless, the biological species concept gives scientists a snapshot of the evolution of new species in many groups of plants and animals. As you review the examples on the following pages, keep in mind that the populations that share a common gene pool are most likely in the early stages of separation from one another. This is likely to be the case if individuals in the two populations meet the following two conditions:

- They usually breed together if they meet in the wild.
- Their breeding produces offspring able to produce their own offspring. ■

DOING THE ACTIVITY

2 Remind students that they applied the claim-evidence-and-reasoning approach to scientific argumentation in Activity 5, "Using Fossil Evidence to Investigate Whale Evolution." Review this approach to scientific discussion and argumentation. Explain to students that they will take this approach in determining where in the process of separation species are from one another (early, mid, or late). To do this, they must first have a working concept of what a species is.

Stress that the biological species concept differs from the original concept for defining species, and it stresses the importance of successful reproduction in the wild and the sharing of a common set of genes, or gene pool.

3 If you would like students to enter their work on optional Student Sheet 10.1, "Supporting a Scientific Argument," distribute it now. If not, have students set up space in their notebooks for Example 1.

Procedure

Part A: Species Separation

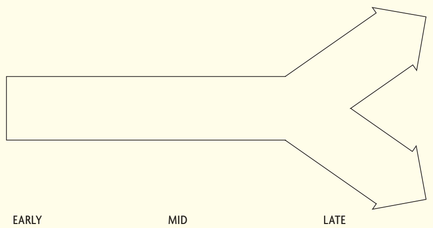
2 1. Read the information on the biological species concept in the box on the previous page.

3 2. In your science notebook, prepare an entry like the one below. It should take up about one-fourth of a notebook page.

Species Separation	
Example number/ organism name	
Claim	
Evidence to support the claim	
Reasoning	

3. On another page in your science notebook, across the entire page, draw and label an arrow like the one shown below. The arrow shows a continuum from early to late for the process of separation of new species from existing species.

4 4. Work as a class with your teacher to complete some of the examples on the following pages.



5. Following your teacher's instructions, complete some of the following examples with your group and some on your own.

4 Work through as many examples as necessary with the class until you think students are ready to work on them more independently. As you work together, be sure students understand the following about the parts of scientific argument:

The claim portion is a statement about the placement of species as early, mid, or late in the process of separation as follows:

- Early means they are either still one species, or that they have just begun separation.
- Mid means they are separating.
- Late means they are at the end of separation and they have most likely split into two species.

Note that this is a continuum, and students may wish to use designations such as early–mid or mid–late if the evidence is incomplete or inconclusive. The evidence portion of argumentation for these examples refers to what happens with mating and offspring. In the reasoning setup, students should include a statement about how the mating and offspring results affect the exchange of genes and sharing of a common gene pool, which indicates where in separation the species are likely to be. This reasoning relies on the biological species concept and ties the evidence back to the claim.

5 Next, instruct students to work in groups to complete enough examples to give them adequate practice applying the claims-evidence-and-reasoning approach to species separation. Circulate around the room, and determine whether you need to review students' ideas before they complete the remaining assigned examples independently. Sample answers follow.

- ***Example 1: Red and Purple Sea Urchins***

  Claim: Late

  Evidence: The eggs can be fertilized in the lab but the embryos do not survive.

  Reasoning: Even though the eggs can be artificially fertilized, the offspring do not survive. Therefore, they cannot exchange genes and share a common gene pool, and they have most likely split.

- ***Example 2: Eastern and Great Plains Narrowmouth Frogs***

  Claim: Mid

  Evidence: Even though they might encounter each other, the two frogs usually do not choose to mate with their own kind based on mating call.

  Reasoning: Since they usually do not breed, they are not exchanging genes and sharing a common gene pool, and are further along in separation as a result.

- ***Example 3: Northern and California Spotted Owls***

  Claim: Early–mid

  Evidence: The owls' ranges overlap, and they can breed to produce fertile offspring, but rarely do so.

  Reasoning: Because they can breed and produce fertile offspring, they can exchange genes and share a common gene pool, even if rarely. This means they must be early to midway in the separation process.

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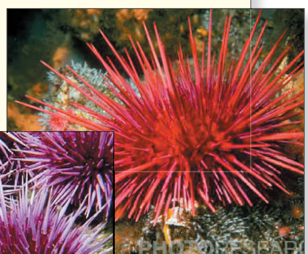
6. In your science notebook, record each of the following:
   - The example number and the name of the organisms
   - Your claim: a statement about what stage of separation the species are in
   - Place the names of the organisms at the appropriate stage of separation (early, mid, late) along the arrow you drew in Step 3.
   - Your evidence: the information about the mechanism of the separation between species
   - Your reasoning: an explanation of the mechanism of separation that supports your claim. Refer to the biological species concept to explain each species' stage in the separation process.
7. Repeat Step 6 for all of your assigned examples.

The Separation of Species

EXAMPLE 1

Red and Purple Sea Urchins

Red and purple sea urchins live in shallow ocean waters along the eastern Pacific coast from Alaska to Mexico. The sperm of one of these organisms fertilizes the eggs of the other only in the laboratory, where scientists mix the eggs with much higher concentrations of sperm than are likely in the wild. The embryos produced, however, do not survive beyond the very early stages of development. ■



Red sea urchins

Purple sea urchins

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- ***Example 4: Horses and Donkeys***

  Claim: Late

  Evidence: They can breed but do not produce fertile offspring. Sometimes female mules breed with horses or donkeys and do produce live offspring.

  Reasoning: If they breed, there are offspring, but the offspring are always infertile. Therefore, they cannot exchange genes and share a common gene pool and have most likely split.

- ***Example 5: Dogs and Wolves***

  Claim: Early

  Evidence: Dogs and wolves do mate and produce fertile offspring.

  Reasoning: If dogs and wolves can mate to produce fertile offspring, they can exchange genes and share a common gene pool, which means they are one species or early in separation.

- ***Example 6: Midas Cichlid and Arrow Cichlid Fish***

  Claim: Late

  Evidence: The cichlids do not mate in the wild, and their offspring by selective breeding do not live.

  Reasoning: If they do not mate in the wild and the offspring of controlled breeding do not live, they have most likely split, and there is no exchange of genes or common gene pool.

- ***Example 7: Blue and Red Cichlid Fish***

  Claim: Early–mid

  Evidence: The fish do not breed in nature, but can be bred in a lab to produce fertile offspring.

  Reasoning: The fish can breed to produce fertile offspring. And, they are very similar to each other. This means they share a common gene pool and they are likely to be one species, or early in the separation process.

- ***Example 8: Green Lacewings***

  Claim: Early–mid

  Evidence: If mated in a lab, the lacewings produce fertile offspring. They look identical, but small genetic changes resulting in a different mating signals make them unlikely to breed in the wild.

  Reasoning: If the lacewings are mated, they exchange genes and share a common gene pool. But they also have a different mating call, making them likely to be in a relatively early stage of separation.

- ***Example 9: Copper-resistant and Copper-tolerant Yellow Monkey Flowers***

  Claim: Early–mid

  Evidence: When scientists cross the plants many die early, but some live.

  Reasoning: If some of the plants live, those few can exchange genes and share a common gene pool, which means they are not as separated as they would be if they couldn't.

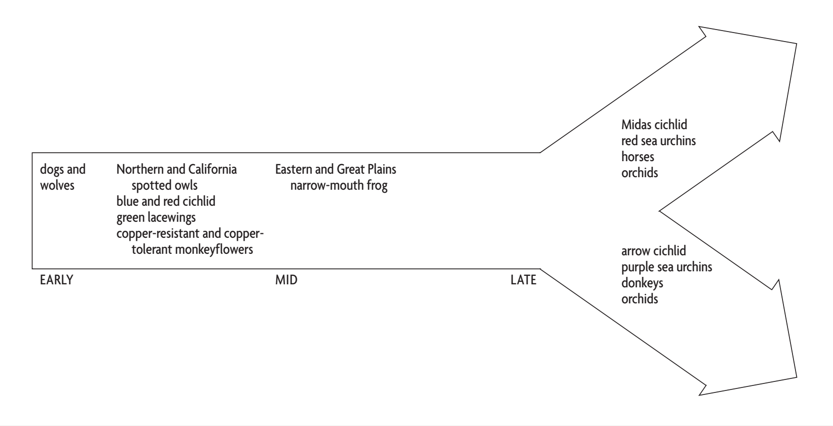
- ***Example 10: Orchids***

  Claim: Late

  Evidence: The orchids flower on different days and cannot be bred to produce hybrids.

  Reasoning: If the orchids cannot reproduce fertile offspring in nature or in the lab they cannot exchange genes or share a common gene pool, which means they have most likely split.

A sample response arrow is shown below.



EXAMPLE 2

Eastern and Great Plains Narrowmouth Frogs

The eastern narrowmouth frog's range extends along the east coast of the United States from the Carolinas to Florida and west into parts of Oklahoma and Texas, where it lives in moist areas. The Great Plains narrowmouth frog's range is from Baja California in Mexico to eastern Texas, eastern Oklahoma, and northern Missouri, where it lives in drier regions. These two types of frogs occasionally breed naturally in the areas where they overlap, but the fertility of their offspring is not known. Most of the time the frogs select mates of their own type, perhaps because of differences in their mating calls. The two groups of frogs are distinguished by their colors. ■

Great Plains narrow mouth frog (top), Eastern narrow mouth frog (bottom)

EXAMPLE 3

Northern and California Spotted Owls

Northern spotted owls range from northwestern California to western Oregon, Washington, and Canada. California spotted owls are found in the Sierra Nevada from northern to southern California. The two owl populations overlap in parts of northern California. Field observations and genetic evidence suggest that when birds of each type come into contact they have bred and produced fertile offspring. These offspring have a hybrid (mixed) genetic makeup. However, this cross-breeding is rare. Northern and California spotted owls show some differences in appearance and genetics. ■

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EXAMPLE 4

Horses and Donkeys

A female horse and a male donkey can mate to produce a mule. Horses have 64 chromosomes, while donkeys have 62. The mule is born with 63 chromosomes that cannot divide evenly, and this makes mules sterile. Although there are some cases of female mules breeding successfully with male horses or donkeys to produce live but infertile offspring, there are no known cases of male mules breeding successfully with female mules, donkeys, or horses. ■

The mule is the sterile offspring of a horse and a donkey.

EXAMPLE 5

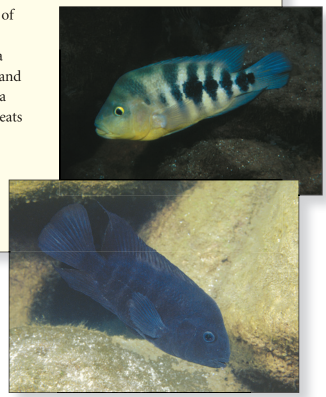
Dogs and Wolves

There is great variety among domesticated dogs, which were bred from wolves approximately 10,000 years ago. Most dogs can breed with one another and have puppies that show a mix of the traits of the parent dogs. For example, a breeder of designer dogs can mate a boxer and a poodle to produce a boxerdoodle. Dogs from different breeds often mate to produce a mixed breed dog, commonly called a mutt. Dogs can also breed with wolves to produce fertile offspring. These mixed offspring can reproduce with similar dogs, other dog breeds, or wolves. Genetic analysis reveals very little difference between dogs and wolves. Wolves are much more similar genetically to dogs than to coyotes. ■

EXAMPLE 6

Midas Cichlid and Arrow Cichlid Fish

Scientists are studying two types of cichlid fish in a volcanic lake in Nicaragua. The Midas cichlid is a bottom-feeder, has a wide body, and eats algae. The arrow cichlid has a slender body for swimming and eats winged insects. The two types of fish select mates of their own kind, and fail to reproduce live offspring when people try to breed them. ■



Arrow cichlid (top), Midas cichlid (bottom)

EXAMPLE 7

Blue and Red Cichlid Fish

Two very similar types of cichlid fish live in Lake Victoria in Africa. One is blue, and the other is red. Females of these two types prefer mates of the same color, and in nature these two types of fish do not breed. However, in a lab, when they are put in lighting conditions where they cannot see the color of the other fish, they will freely mate with fish of the other color. In these lab conditions, the females would now mate with either color male, and produce fully fertile offspring. ■

WHAT IS A SPECIES? • ACTIVITY 10

EXAMPLE 8

Green Lacewings

Two populations of lacewings that look identical and live in the same locations do not mate in the wild because they have different mating signals. Female lacewings exhibit a strong preference in the wild for males with a similar mating call. Genetic analysis suggests that the changes in mating call result from changes in just a small number of genes, but that these changes prevent the mating of males and females with different mating calls. When mated in the laboratory, offspring of these two types of lacewings are fertile. ■

EXAMPLE 9

Copper-resistant and Copper-tolerant Yellow Monkey Flower

Copper is toxic to most plants. However, scientists have observed a few plants that have developed a tolerance for copper. One of those is the yellow monkey flower. When scientists crossed copper-tolerant plants with plants sensitive to copper, many of the hybrid plants did not survive. In early growth stages, their leaves turned yellow and they died soon after. ■

EXAMPLE 10

Orchids

Three populations of orchids each flower at different times of the year for just a single day. Therefore, even though these orchids grow in the same tropical forest area, there is no chance that members of one population will fertilize the other in the wild. ■

6 (GI ASSESSMENT) Distribute a set of 14 Species Pair Cards to each group of four students. Inform students that this activity asks them to demonstrate their ability to work together in their groups to complete the Procedure. If necessary, distribute copies of the GROUP INTERACTION (GI) Scoring Guide. Review the guidelines for the GI Scoring Guide.

7 Tell students to work through the rest of the Procedure steps. Groups should work together to organize the cards and record the groupings they have formed. Most importantly, they should note the common barrier to reproduction by which they formed each of the groupings of species. If students are having problems, suggest that they select only one criterion to begin their sorting, but allow them to work as independently as possible.

8 Hold a brief class discussion about how groups classified the barriers to reproduction, and named their groupings. Allow members of each group to briefly show their classifications and describe the choices they made. You might also provide chart paper and markers for students to display their systems. Highlight the similarities and differences between the systems that the different groups used by listing them on the board or overhead.

Do not hand out the sets of Reproductive Barrier Cards, which represent the groupings scientists put together, to each team until Procedure Step 12. Explain that scientists look for patterns in their observations and make the kinds of observations students made to group the barriers to reproduction that are described on the cards.

SCIENCE & GLOBAL ISSUES/BIOLOGY • EVOLUTION

Part B: The Formation of New Species

Evolutionary biologists focus on the question of how new species and other taxa arise. As you have learned, two populations that have different physical characteristics might still belong to the same species if they can interbreed to produce fertile offspring and do so in nature. This interbreeding allows gene flow, with the two populations sharing a common gene pool.

How do new species arise? According to the biological species concept, two populations must be reproductively isolated. Reproductive isolation is caused by several kinds of barriers. Once they become reproductively isolated, the two populations will no longer share a common gene pool. Each population will change independently of the other. Eventually the two populations could evolve into two separate species.

6 8. With your group, spread the Species Pair Cards out on a table.

7 9. Examine the information on each card carefully, noting the barriers to reproduction between the two species described on the card.

10. Sort the cards into groups based on the barriers to reproduction. Work with your group to agree on a name that describes each kind of barrier. While doing so,
    - listen to and consider the explanations of your group members.
    - if you disagree, explain how and why you disagree.

11. In your science notebook, write the title: Our Groupings. Beneath this title, list the groups that you created and the names you picked to describe each group. Be sure to record which species pairs belong to each group.

8 12. Following your teacher's instructions, your team will present your groupings to the class. As you look at other students' groupings, observe the similarities and differences between their systems and yours. Discuss your observations with your team members.

13. Your group will receive eight Reproductive Barrier Cards from your teacher. Each card represents a barrier that leads to reproductive isolation of related species. Based on the information described on the Reproductive Barrier Cards, place each Species Pair Card under one of the Reproductive Barrier Cards.

14. Record this new set of groupings in your science notebook under the title Scientific Groupings.

9 15. List the isolating mechanisms you examined in this activity. Write a definition for each mechanism in your own words.

10 16. List the two types of reproductive isolation in this section, and describe them in your own words.

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SUGGESTED ANSWERS

Habitat Isolation: Garter snakes, insects

Behavioral Isolation: Meadowlarks, fireflies, blue and red cichlids

Geographic Isolation: Squirrels

Temporal Isolation: Lacewings, orchids

Mechanical Isolation: Flowering plants, damselflies

Gametic Isolation: Purple and white sea urchins

Reduced Hybrid Viability: Frogs

Hybrid sterility: Lions and tigers, horses and donkeys

9 Suggested definitions for the types of isolation follow.

Behavioral isolation: mating songs are too different for potential mates to recognize, or the animals have different courtship rituals

Habitat isolation: two species live in the same area but in slightly different habitats, such as in or on different parts of the same plant.

Temporal isolation: the two species breed at different times of the year.

Mechanical isolation: the two species do not have the anatomical structures necessary for mating.

Gametic isolation: sperm and eggs cannot interact.

10 (LITERACY) Sample definitions for the two types of reproductive isolation follow.

Hybrid sterility: members of species can mate, but their offspring are sterile.

Reduced hybrid viability: two species can mate, but the offspring do not live long enough to reproduce their own offspring.

When students have completed Procedure Step 15, conduct an Informal Meeting of the Minds. Direct students to find a partner from another group and to discuss their definitions for the types of barriers, citing an example or two for each. Circulate around the room as students talk. Ask pairs to share their definitions with the class. You may wish to have them learn the scientific names for the different barriers, but it is more important that they can describe them, how they work, and give an example or two. If you wish, assign this task as homework. Begin the next class period with a review of the information.

WHAT IS A SPECIES? • ACTIVITY 10

11 *Analysis*

1. Why is appearance alone no longer considered sufficient evidence for classifying organisms?
2. Explain how geographic isolation can lead to speciation.
3. Lions and tigers do not overlap in range and do not breed in nature. In captivity, a male lion may mate with a female tiger and produce offspring. Although more rare, a male tiger may also mate with a female lion to produce offspring. In both cases, the male offspring are sterile, while the females might or might not be fertile. Explain where lions and tigers are on the speciation continuum, according to the biological species concept. Support your answer with evidence and reasoning.
4. How did your groupings of the reproductive barriers in Part B resemble or differ from those used by scientists as shown by the cards in Step 13?
5. Why do you think you came up with a different set of groups in Part B than scientists do in their groupings?
6. Did any of the species pairs in Part B show more than one barrier to reproduction? List examples, and describe the barriers they display.
7. Describe the barriers that are causing reproductive isolation for each of the following from Part A:
   a. Red and purple sea urchins
   b. Eastern and Great Plains narrowmouth frogs
   c. Northern and California spotted owls
8. Two related species of frogs appear to be very similar, but they have different mating calls. In addition, one species breeds in the fall, and the other breeds in the spring. What mechanisms contribute to reproductive isolation of these species?
9. Two related species of birds appear to be similar, but when they breed, their offspring rarely survive past a few days old. What mechanism leads to reproductive isolation of these species?
10. A genetic change occurs in the gene pool of a population of a single flower species with large white tubular flowers. This species is normally pollinated by a species of large bee that is attracted to large white tubular flowers. Pollination is essential for these flowers to produce seeds. In some individuals, one genetic change leads to the production of much smaller flowers. Explain how this could lead to speciation in the population.

KEY VOCABULARY	
biological species	**gene pool**
biological species concept	
gene flow	species

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11 (UC ASSESSMENT) Analysis Questions 2 and 3 are an opportunity to apply the UNDERSTANDING CONCEPTS (UC) Scoring Guide to assess students' understanding of geographic isolation and speciation. Review the UC Scoring Guide, and tell the class your expectations for satisfactory work.

As you discuss the activity and the answers to the Analysis Questions, emphasize to students that for some of the examples there is a fair amount of grey area for scientists who are trying to determine where in speciation the populations are. This illustrates why the biological species concept is considered just a snapshot of what is going on with speciation. Stress the growing emphasis in the field of classification on the importance of the evolutionary relationships among taxa, using the phylogenetic species concept. Discuss also the importance in science of applying evidence and logical reasoning in making claims from which to build arguments and explanations. Discuss some of the examples. Ask students if they felt the information they were given in this activity provided the evidence to make a solid claim. Note that in some cases, evidence about breeding success was not provided because it is not available. Missing evidence affects the certainty of a claim. Emphasize the importance of logical reasoning, which requires an understanding of the appropriate concept(s), in this case the biological species concept, and the development of reasonable connections and inferences between the evidence and the concept.

In regard to species conservation introduce the importance of where in the process of separation from one another two populations are. In the United States the Endangered Species Act (ESA) protects species and subspecies, and in the case of vertebrates may also protect "distinct population segments" that are considered significant in relation to the entire species. Thus the species or subspecies designation of a population may determine whether it gets ESA protection if the animal is threatened.

Ask students to volunteer to list the factors that lead to speciation. They should be able to mention all of the types that were given on the Reproductive Barrier Cards in Part B. Write those on the board. Ask students what all of these types of barriers have in common. Discuss the idea that all of these are barriers that keep populations apart and no longer able to breed. This means they can no longer exchange genes with one another. As this activity demonstrates, there are more barriers than just geographic isolation that may keep populations from reproducing. Some barriers occur even if the two populations live in the same area. For example, two populations that live in the same area might have different mating seasons or mating calls. Also, geographic isolation alone is not always enough to lead to speciation. Some populations might still mate and produce live offspring if they are brought together after being geographically isolated.

SAMPLE RESPONSES

1. Scientists concluded from evolutionary evidence that some species that look identical are different species and others that appear different are the same species.
2. (UC ASSESSMENT) A complete and correct response will include a description of the types of geographic features that can stop gene flow, prevent the sharing of a gene pool, and lead to the separation of species.

   Sample Level-3 Response:
   Two populations can get separated by physical features on earth such as the formation of mountains, canyons, rivers, or glaciers. Or a population moves far away from the original population. This could stop gene flow between the populations, prevent them from sharing a common gene pool, and lead to speciation.

3. (UC ASSESSMENT) A complete and correct response will explain the placement of lions and tigers on the speciation continuum, and cite evidence and reasoning from the biological species concept to support the answer.

   Sample Level-3 Response:
   Lions and tigers are late in the speciation process, but not completely separate. The evidence for this is that they do not produce fertile male offspring even when mated in captivity, while some female offspring are fertile. According to the biological species concept, the offspring of a biological species are fertile, so lions and tigers, with the exception of some female offspring, do not meet this part of the definition of a biological species.

4. Students' answers will vary, but should be based on students' recognition of differences between their systems and the system illustrated on the Reproductive Barrier Cards. For example, some students may have classified as behavioral isolation the two species of damselflies as species that cannot mate because the males cannot hold onto the females. These students may have interpreted the holding on as a behavior that may be part of a courtship ritual of some type rather than as a result of mechanical isolation.
5. Students may suggest they do not have as many examples as scientists do, or that they lumped or split categories differently than scientists.

6. Lions and tigers show both geographic isolation and hybrid sterility.
7. a. Reduced hybrid viability
   b. Behavioral isolation
   c. Geographic isolation
8. Behavioral (the different mating calls) and temporal (mating at different times)
9. Reduced hybrid viability
10. The change could lead to the need for different pollinators because of mechanical isolation. If the pollinator of one group cannot pollinate the other group (and vice versa) due to differences in the size of the flowers, these two groups of organisms will become reproductively isolated, even though they grow in the same area.

REVISIT THE CHALLENGE

Review these key points about species separation and the biological species concept:

- To be of the same species two populations must be able to breed and choose to breed when they come in contact. If they do not breed successfully, there cannot be a flow of genes from one population to the other and the populations will not share a gene pool. This means they are reproductively isolated, and therefore, likely to be later in separation from one another.
- All species are continually in the process of separation from one another. For some species the biological species concept determines a snapshot of where on the continuum of separation they are.
- When female offspring of hybrids between two populations are fertile but males are not (as in the case of mules), the offspring are not considered to be fully fertile, and the horses and donkeys are considered to be late in separation. Again, this is because gene flow cannot continue freely between the horse and donkey populations. In this case, the mules are essentially a dead end, and cannot continue a lineage of offspring.
- There are a variety of factors that lead to speciation.