The Origin of Species 14

Waialeale, a mountain on the Hawaiian island of Kauai, is one of the rainiest places on Earth. Here 15 meters of rain a year is not unusual. The Alakai swamp lies at an elevation of 1300 meters on the flanks of the mountain. This boggy forest is one of the best places to see honeycreepers, birds unique to the Hawaiian Islands. Walking on a trail through the forest, you might see an apapane, a common red honeycreeper that uses its curved bill to eat nectar and caterpillars. The bright red iiwi laps up nectar with its long ivory-colored beak. You would be unlikely to spot the greenish akialoa, which has a needle-sharp beak half as long as its body. It was last seen in 1973 and may be extinct. Other honeycreepers have stout hooked bills used for crushing twigs to get insects, or short heavy beaks for cracking seeds. There are twenty-odd species of honeycreepers on the various islands, and several extinct species are known. Why do honeycreepers live only in the Hawaiian Islands? How did they get here? Why are there so many kinds? All honeycreepers are thought to be descended from a single ancestral species—maybe a finch—that reached the islands perhaps 5 million years ago. Speciation—how new species such as the diverse forms of honeycreepers arise—is the subject of this chapter.

Organizing Your Knowledge

Exercise 1 (Module 14.1)

Briefly explain why it might be difficult to apply the biological species concept in each of the following situations.

1. Fossils of "Java Man" and "Peking Man" are both thought to represent a single species—*Homo erectus*.

2. A tiger and a lion can interbreed in a zoo and produce a hybrid offspring called a tiglon.

3. Dogs come in many shapes and sizes, from Chihuahuas to Saint Bernards.

4. There are many strains and species of *Streptococcus* bacteria, which reproduce asexually.

5. Among *Clarkia* wildflowers in California, flowers of population A can interbreed and produce fertile offspring when crossed with flowers from population B. Similarly, B can interbreed with C. But A and C cannot successfully interbreed.

6. One bird guide calls flycatchers of the genus *Empidonax* "the bane of bird-watchers." Several species look so much alike that birders can distinguish them only by their songs.

7. A song sparrow population in Baja, California, is separated from other song sparrows by over a hundred miles of desert.

Exercise 2 (Module 14.2)

Review the reproductive barriers that separate species by categorizing the following examples. State whether each barrier is prezygotic (Pre) or postzygotic (Post), and then name the specific kind of barrier (such as temporal isolation or hybrid inviability) it exemplifies. The chart in Module 14.2 is a helpful summary.

	Pre or Post	*Kind of Barrier*	*Example*
1.	_____	_____	The salamanders *Ambystoma tigrinum* and *A. maculatum* breed in the same areas. *A. tigrinum* mates from late February through March. *A. maculatum* does not start mating until late March or early April.
2.	_____	_____	Two species of mice are mated in the lab and produce fertile hybrid offspring, but offspring of the hybrids are sterile.
3.	_____	_____	When fruit flies of two particular species are crossed in the lab, their offspring are unable to produce eggs and sperm.
4.	_____	_____	A zoologist observed two land snails of different species that were trying to mate with little success because they apparently did not "fit" each other.
5.	_____	_____	Male fiddler crabs (genus *Uca*) wave their large claws to attract the attention of females. Each species has a slightly different wave.
6.	_____	_____	When different species of tobacco plants are crossed in a greenhouse, the pollen tube usually bursts before the eggs are fertilized.
7.	_____	_____	Blackjack oak (*Quercus marilandica*) grows in dry woodlands, and scrub oak (*Q. ilicifolia*) grows in dry, rocky, open areas. Pollen of one species seldom pollinates the other.
8.	_____	_____	The tiglon offspring of a lion and a tiger are often weak and unhealthy.

Exercise 3 (Module 14.3)

Formation of new species often begins with geographical isolation. For each of the organisms listed below, name two geographical barriers that might lead to allopatric speciation.

1. Daisy
2. Mouse
3. Trout
4. Oak tree
5. Sparrow
6. Sea star

Exercise 4 (Module 14.4)

Web/CD Activity 14A *Exploring Speciation on Islands*

Speciation and adaptive radiation often occur on islands like the Galápagos, Hawaiian Islands, and Madagascar (Module 38.2). But for geographical isolation to occur, an island does not have to be a bit of land in the midst of an ocean. An evolutionary island could be, for example, a patch of grassland surrounded by forest. List three other examples and the kinds of species that could be isolated and evolve in each.

1.

2.

3.

Exercise 5 (Modules 14.5 – 14.6)

Web/CD Activity 14B *Polyploid Plants*

New species can result if a change in chromosome number produces a reproductive barrier that isolates organisms from their parent populations. Study the examples given in the Web/CD Activity and Modules 14.5 and 14.6. Then state whether you think each of the organisms in italics below would be able to reproduce (yes or no), whether it could represent a new species (yes or no), and how many chromosomes it would have.

	Reproduction	*New Species*	*No. of Chrom.*	*Example*
1.	_____	_____	_____	A flower has 18 chromosomes ($2n = 18$). Nondisjunction occurs, and diploid gametes are formed. The *zygotes formed* are tetraploids, capable of self-fertilization when mature.
2.	_____	_____	_____	A tree has 22 chromosomes ($2n = 22$). Nondisjunction produces a diploid pollen grain, which fertilizes a normal haploid egg. The resulting polyploid zygote develops into a *full-grown tree.*
3.	_____	_____	_____	Antelope of two different species mate in a zoo. Species A has 36 chromosomes; species B has 34 chromosomes. They produce a *hybrid offspring.*
4.	_____	_____	_____	A lily of species A has 16 chromosomes. Species B has 20 chromosomes. A hybrid with 18 chromosomes undergoes nondisjunction, producing a *lily* that is capable of self-pollination.
5.	_____	_____	_____	A botanist treats some tissue from a strawberry plant ($2n = 14$) with a chemical that causes nondisjunction. This doubles the number of chromosomes in a cell. This cell is then cultured on a special medium, until it eventually develops into a *strawberry plant* that can self-pollinate.
6.	_____	_____	_____	Pollen from the cell-cultured strawberry in question 5 is placed on the flower of a plant of the parent species, producing a triploid *hybrid zygote.*

Exercise 6 (Module 14.8)

Contrast the gradualist model of speciation with the punctuated equilibrium model by completing the chart below.

	Gradualism	*Punctuated Equilibrium*
1. Long-term tempo of evolution smooth or jumpy?		
2. Same processes as microevolution, or different process?		
3. Kind of evidence in fossil record?		
4. Speciation fast or slow?		
5. Continuous change through life of species, or quick change and stability?		

Exercise 7 (Module 14.7, 14.9, and Summary)

This chapter describes many examples of speciation. Match each description below with the correct species.

_____ 1. Diverged after a population was split by the Grand Canyon.
_____ 2. Different species evolved in separated Death Valley springs.
_____ 3. A new species evolved in the tunnels of the London Underground.
_____ 4. Different diets led to reproductive barriers in a laboratory experiment.
_____ 5. Divergence is leading to speciation in this California ring species.
_____ 6. These birds are unique to the Hawaiian Islands.
_____ 7. Different species have different beaks, but sometimes hybridize

A. salamanders
B. honeycreepers
C. antelope squirrels
D. Darwin's finches
E. mosquitoes
F. fruit flies
G. pupfish

Exercise 8 (Summary)

Use the concepts and terms from this chapter to complete the following story about (imaginary) butterflies and asters.

The yellowspot butterfly is found over hundreds of square miles of land in the delta of an African river. Its primary food source is a species of purple aster—a flower related to daisies and dandelions. Patches of asters are scattered in sunny meadows in the delta, some several miles apart. The butterflies do not usually venture far for food. Each patch of asters supports a separate [1]_____ of yellowspots, but because the butterflies sometimes wander and mate with butterflies in other areas, all the butterflies have been classified as members of the same [2]_____.

Insect taxonomists noted that one population of yellowspots was centered across the main river channel from the other populations. They suspected that the river might

act as a [3]_____ to the butterflies, since they do not usually fly far over water. The researchers examined the butterflies from the isolated population and found that the butterflies from across the river were a bit smaller than most yellowspots and more orange in color, so the researchers nicknamed them "orangespots." The biologists found that the differences in appearance were inherited. They suspected these could reflect [4]_____ due to chance differences in the butterflies that founded the orangespot population. The researchers also noted that the environment was slightly warmer and drier on the far side of the river, so [5]_____ may have caused the change in the butterfly population there.

The scientists suspected that the two populations could represent different species. To test this hunch, they had to find out whether butterflies from the far side of the river could [6]_____ with individuals from the main population. The biologists captured some butterflies from both areas and placed them in a cage. Surprisingly, the orangespots and yellowspots ignored each other. The researchers found that the female butterflies rest on leaves and flash their wing spots to attract the males. Yellowspot females flash their wings at a much faster rate than orangespot females. Apparently the wing-flashing display acts as a [7]_____-zygotic reproductive barrier. Apparently, [8]_____ keeps the two populations of butterflies from interbreeding. In one instance, the eggs of an orangespot female were fertilized by a yellowspot male, but the embryos soon died. Apparently, there is also a [9]_____ -zygotic reproductive barrier between the butterflies. The particular type of barrier is [10]_____ in this case. The researchers realized that the yellowspot and orangespot butterflies are separate [11]_____, incapable of interbreeding.

A study of river sediments showed that the channel separating the two butterfly populations formed about a thousand years ago, when the river shifted course. It has indeed acted as a geographical barrier, [12]_____ the two populations from one another and eventually leading to [13]_____ speciation. Biologists were particularly interested in how quickly (in geological terms) the new butterfly species must have evolved. This rapidity would seem to support the [14]_____ model of species evolution.

While studying the habits of the butterflies, the biologists found a group of asters with oval-shaped leaves and slightly larger flowers than all the others. A study of their chromosomes showed that the unusual plants were [15]_____, having more than the usual two sets of chromosomes. All the other purple asters in the area had two sets of chromosomes and a $2n$ chromosome number of 26. The unusual plants were [16]_____, having four sets of chromosomes, for a total of 52. [17]_____ must have occurred during meiosis in one of the diploid asters, creating diploid gametes. Because the plant could self-pollinate, zygotes were formed with four sets of chromosomes. The plants that developed from these zygotes could interbreed with one another, but they were reproductively [18]_____ from the parent species. They represented a new [19]_____, produced in one generation through the process of [20]_____ speciation.

Testing Your Knowledge

Multiple Choice

1. Two animals are considered different species if they
   a. look different.
   b. cannot interbreed.
   c. live in different habitats.
   d. are members of different populations.
   e. are geographically isolated.

2. Which of the following is the first step in allopatric speciation?
   a. genetic drift
   b. geographical isolation
   c. polyploidy
   d. hybridization
   e. formation of a reproductive barrier

3. The science of naming and classifying organisms is called
   a. biology.
   b. polyploidy.
   c. genetics.
   d. taxonomy.
   e. gradualism.

4. Most of the time, species are identified by their appearance. Why?
   a. If two organisms look alike, they must be the same species.
   b. This is the criterion used to define a biological species.
   c. If two organisms look different, they must be different species.
   d. This is the most convenient way of identifying species.
   e. Most organisms reproduce asexually.

5. A new species can arise in a single generation
   a. through geographical isolation.
   b. in a very large population that is spread over a large area.
   c. if a change in chromosome number creates a reproductive barrier.
   d. if allopatric speciation occurs.
   e. according to the gradualist model of speciation.

6. The evolution of numerous species, such as Darwin's finches, from a single ancestor is called
   a. adaptive radiation.
   b. sympatric speciation.
   c. gradualism.
   d. nondisjunction.
   e. geographical isolation.

7. According to the _____ model, evolution occurs in spurts; species evolve relatively rapidly, then remain unchanged for long periods.
   a. nondisjunction
   b. gradualist
   c. adaptive radiation
   d. punctuated equilibrium
   e. geographical isolation

8. Sympatric speciation is
   a. the appearance of a new species in the same area as the parent population.
   b. the process by which most animal species have evolved.
   c. initiated by the appearance of a geographical barrier.
   d. the emergence of many species from a single ancestor.
   e. especially important in the evolution of island species.

9. Individuals of different species living in the same area may be prevented from interbreeding by responding to different mating dances. This is called
   a. ecological isolation.
   b. hybrid breakdown.
   c. mechanical isolation.
   d. temporal isolation.
   e. behavioral isolation.

10. It is unlikely that the human population will give rise to a new species because
    a. the human population is too large.
    b. geographical isolation is unlikely to occur.
    c. a change in chromosome number would be fatal.
    d. the human population is too diverse.
    e. natural selection cannot affect humans.

Essay

1. Give three situations in which it might be difficult to use the test of interbreeding to determine whether two organisms are of the same or different species.

2. Describe step by step how geographical isolation could lead to speciation.

3. Describe what has to happen for two species with different numbers of chromosomes to interbreed and produce a fertile hybrid. Will this hybrid be able to interbreed with either of its parents? Why? How common is this in nature?

4. State whether a large, widely distributed population or a small, isolated population is more likely to undergo speciation, and explain why.
5. Compare the gradualist and the punctuated equilibrium models of species evolution. What would the fossil record of speciation look like if it supported the gradualist model? What would it look like if punctuated equilibrium was the case? Which model does the fossil record seem to support most often? Why?

Applying Your Knowledge

Multiple Choice

1. Three species of frogs—*Rana pipiens, Rana clamitans,* and *Rana sylvatica*—all mate in the same ponds, but they pair off correctly because they have different calls. This illustrates a ____ and ____ .
   a. prezygotic barrier . . . behavioral isolation.
   b. postzygotic barrier . . . hybrid breakdown.
   c. prezygotic barrier . . . temporal isolation.
   d. postzygotic barrier . . . behavioral isolation.
   e. prezygotic barrier . . . gametic isolation.
2. Which of the following reproductive barriers actually prevents individuals of different species from mating with each other?
   a. hybrid inviability
   b. hybrid sterility
   c. gametic isolation
   d. hybrid breakdown
   e. behavioral isolation
3. Bullock's oriole and the Baltimore oriole are closely related, but are they the same species? To find out, you could see whether they
   a. sing similar songs.
   b. look alike.
   c. live in the same areas.
   d. have the same number of chromosomes.
   e. successfully interbreed.
4. Sometimes two quite different populations interbreed to a limited extent, so that it is difficult to say whether they are clearly separate species. This does not worry biologists much because it
   a. is quite rare.
   b. is true for almost every species.
   c. supports the theory of punctuated equilibrium.
   d. may illustrate the formation of new species in progress.
   e. happens only among plants, not among animals.
5. Two species of water lilies in the same pond do not interbreed because one blooms at night and the other during the day. The reproductive barrier between them is an example of
   a. temporal isolation.
   b. gametic isolation.
   c. mechanical isolation.
   d. hybrid breakdown.
   e. ecological isolation.
6. Comparison of fossils with living humans seems to show that there have been no significant physical changes in *Homo sapiens* in 30,000 to 50,000 years. What might an advocate of punctuated equilibrium say about this?
   a. It is about time for humans to undergo a burst of change.
   b. That is about how long we have been reproductively isolated.
   c. It is impossible to see major internal changes by looking at fossils.
   d. You would expect lots of changes in the skeleton in that time period.
   e. Lack of change is consistent with the punctuated equilibrium model.
7. Which of the following is an example of a postzygotic reproductive barrier?
   a. One species of frog mates in April; another mates in May.
   b. Two fruit flies of different species produce offspring that are sterile.
   c. The sperm of a marine worm only penetrate eggs of the same species.
   d. One species of flower grows in forested areas, another in meadows.
   e. Two pheasant species perform different courtship dances.
8. Lake Malawi, in the African Rift Valley, is home to over a hundred species of cichlid fishes, each with a slightly different diet and habits. All these fishes probably evolved from one ancestor, an example of
   a. sympatric speciation.
   b. hybrid breakdown.
   c. adaptive radiation.
   d. gradualism.
   e. punctuated equilibrium.

9. A botanist found that a kind of white daisy had a diploid chromosome number of 16. In the same area, he found a yellowish daisy. Its cells contained 24 chromosomes. He found that the yellowish daisy was a polyploid descendant of the white daisies. Which of the following would describe this unusual plant? P: tetraploid, Q: triploid, R: probably sterile, S: a new species.
   a. P R S
   b. Q R
   c. Q R S
   d. P S
   e. Q S

10. A fossil expert finds an impression of an ancient marine creature called a trilobite in a layer of rock. In the adjacent layer is another species of trilobite, clearly related to the first but quite different in form. If the expert is a gradualist, how might he or she interpret this?
   a. This kind of change is exactly what gradualism would predict.
   b. Sympatric speciation must have occurred.
   c. Intermediate forms could have existed but were not fossilized.
   d. Internally, the creatures were identical; only the outer shell changed.
   e. This kind of abrupt transition is rare in the fossil record.

Essay

1. There are dozens of species of small rodents, such as rats and mice, in western North America, but relatively few species, ranging over much larger areas, in the east. Suggest a hypothesis related to speciation that might explain this.

2. The mating of a horse and a donkey produces a mule, which is strong and hard working, but sterile. A horse cell contains 64 chromosomes, a donkey cell 62 chromosomes. How many chromosomes would you expect to find in a cell from a mule? Why? Explain why a mule is sterile.

3. A dog (*Canis familiaris*) and a coyote (*Canis latrans*) will readily mate in captivity, and their offspring are healthy and fully fertile. Are we justified in saying they are distinct species? What might this tell us about the history of dogs and coyotes?

4. In terms of speciation, how might freshwater streams in a desert be like islands in the ocean?

5. Various sections of the Hawaiian Islands were formed by lava flows at different times. Kenneth Kaneshiro compared older populations of fruit flies living in older habitats with presumably younger populations living in more recently formed habitats. He found that male fruit flies in both areas are generally eager to mate, but females of older populations are much more selective about their partners than females of newer populations. Suggest a hypothesis to explain why this might be the case.

6. In the Hawaiian Islands, there are several native species of moths in the genus *Hedylepta* that feed exclusively on bananas. Other related species specialize in palms, grasses, or legumes. Bananas were brought to Hawaii by the native Polynesians about a thousand years ago. Why might the banana-eating species be of particular interest to biologists working out the details of the punctuated equilibrium theory?

7. Critics of evolution often say things like, "Sure, moths and bacteria can adapt to a changing environment. But peppered moths are still peppered moths, and *Streptococcus* is still *Streptococcus*. Nobody has ever seen a new *species* evolve." Is this criticism valid? How would you respond to this comment?

Extending Your Knowledge

1. The Nature Conservancy is an environmental organization that buys land to protect rare and endangered species of plants and animals. Are there any Nature Conservancy preserves near your home or college? What species are protected? How did these species come to be located there? Why are they rare?

2. The desire to name and categorize things seems to be a basic human characteristic. This may be why many people like to collect things. Some biologists believe that we have gotten carried away with this desire to classify when it comes to the idea of species. They think that the concept of a "species" is just that—only a concept. They believe that a species is not a real biological entity, only a convenient idea. There are just too many flaws and exceptions in the species concept for it to be valid. Populations, however, are real. Based on what you know and have read in this chapter, do you think species are real or not? What kinds of evidence or information might support each side of this discussion?