How Populations Evolve

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Charles Darwin made sense out of biology. He looked at what many others had seen and had an idea that no one had ever thought of—evolution through the mechanism of natural selection. This idea is as important to biology as the atom is to chemistry. Natural selection explains both the diversity of life and its adaptation to the environment. Copernicus and Galileo discovered where we fit in the universe. Einstein showed us our place in space and time. Darwin revealed our relationship to the living world. It all started on an ocean voyage, when Darwin was only 22 years old. This chapter starts with Darwin's voyage of discovery and explains where that voyage has since taken us in our understanding of life.

Organizing Your Knowledge

Interactive Module 13A

Web/CD Activity 13A *Darwin and the Galápagos Islands*
Web/CD Activity 13B *The voyage of the* Beagle: *Darwin's Trip Around the World*

Charles Darwin was not the first person to ponder the origin of species. Match each of the following with his place in unraveling the history of life. Don't focus on names and dates, but rather on how ideas about the origin and history of life have changed over the centuries.

A. Darwin
B. Lyell
C. Wallace
D. Anaximander
E. Aristotle
F. Lamarck
G. Buffon

_____ 1. Ancient Greek who believed living things have changed
_____ 2. Greek philosopher who believed species to be fixed
_____ 3. Fossils led this Frenchman to believe the Earth is old
_____ 4. Proposed that acquired characteristics are inherited
_____ 5. Believed in gradual geological change, not catastrophes
_____ 6. Wrote *The Origin of Species*, explaining "descent with modification"
_____ 7. Conceived a theory of evolution identical to Darwin's

Exercise 3 (Modules 13.3)

In addition to fossils, there are other kinds of evidence for evolution. Name the category of evidence to which each of the following examples belongs.

Category	*Example*
_____	1. Fertilized eggs of earthworms, insects, and snails all go through the same pattern of cell division.
_____	2. The DNA of humans and chimpanzees is about 98% identical.
_____	3. Remains of upright-walking but small-brained apes have been found in Africa.
_____	4. All animals with backbones have 12 pairs of nerves extending from the brain.
_____	5. A protein called albumin is very similar in dogs and wolves, less similar in dogs and cats.
_____	6. The farther an island is from the mainland, the more different its plants and animals are from those on the mainland.
_____	7. Animals called trilobites were common in the oceans 300 million years ago, but they have been extinct for millions of years.

Exercise 4 (Modules 13.4 – 13.7)

Read these modules, and then review selection and population genetics by completing the following story.

If you think that the more you mow your lawn, the meaner the weeds get, you may be right. Researchers have found that in lawns that are mown regularly, the dandelions fight back! Of course, dandelions don't "know" what they are doing. But the dandelions in a regularly mown lawn reproduce faster than their ancestors in more "natural" environments.

[1]_____, the English scientist who first devised the theory of [2]_____, would have explained it this way: Not all dandelions are alike; they [3]_____ in color, size, and rate of maturation. Many of these characteristics are [4]_____, or passed on to offspring. Every dandelion flower is capable of producing hundreds, perhaps thousands, of white-tufted seeds in a season. This constitutes an [5]_____ of offspring, because [6]_____ are limited; not every dandelion seed will find just the right environment in which to grow. Darwin speculated that those individuals whose inherited characteristics [7]_____ them best to their environment would be more likely to [8]_____ and [9]_____ than less [10]_____ individuals. Their type would become more common in the next generation. Darwin called this phenomenon [11]_____. Many examples of natural selection are known, including the evolution of [12]_____ resistance in insects. Those whose genes protect them best from being poisoned leave more descendants. Resistant insects are seen in greater and greater numbers in succeeding generations. Less resistant individuals die out. Reproduction is central to natural selection; in fact, natural selection can be defined as [13]_____ success in reproduction.

Natural selection is at work when you mow the lawn. It might be helpful to discuss the dandelions in terms of [14]_____ genetics, the study of how genes affect population changes. The dandelions in your lawn make up a [15]_____, a group of individuals of the same species. The species is all dandelions, the group of populations whose individuals can interbreed. Depending on where you live, your lawn may be more or less [16]_____ from other dandelion populations. Through some quirk of nature, dandelions only reproduce asexually, even though they continue to produce nectar and pollen. So unlike most other flowers, dandelions in your lawn cannot cross-pollinate with other populations, although seeds may blow in from elsewhere, and seeds from your lawn might blow across town.

The characteristics of dandelions—color, height, shape of root system, and so on—are dictated by their genes. All the genes in the dandelion population make up the [17]_____. Apparently, the height of dandelions when they mature and produce seed and how long it takes to do this are controlled by genes, and these traits can vary from dandelion to dandelion. If you mow the lawn often enough, the slower-growing, taller dandelions get lopped off before they can produce any seeds. In terms of reproductive success, these dandelions are the less [18]_____ individuals in the population. Since they don't produce many offspring, this slow type will not be as numerous in the next generation, and their [19]_____ will make up a smaller proportion of the gene pool. On the other hand, dandelions that don't have to grow as tall or take as long to produce seed can reproduce between mowings. Their genes, and their fast-growing traits, will be better represented in the next generation. Such a small change in the frequencies of alleles in the gene pool is called [20]_____.

This story illustrates a familiar example of natural selection. Over time, the shorter, faster-growing dandelions will predominate in the lawn. Note that natural selection involves differences between individuals, but individual dandelions do not evolve. An individual does not change its growth rate. But because there is variation in the survival and reproduction of individuals with different characteristics, the [21]_____ of dandelions evolves.

L. Number of *R* alleles in gene pool ____ ____ ____
M. Number of *r* alleles in gene pool ____ ____ ____
N. Allele frequencies
(number of *R* alleles/200
or number of *r* alleles/200) Frequency of *R*: p = ____ Frequency of *r*: q = ____
O. What happened to the genotype and allele frequencies in the second generation?

What would you predict for the third generation? Why?

Exercise 6 (Modules 13.10 – 13.12)

(10) Web/CD Activity 13D *Cause of Microevolution*

The Hardy-Weinberg equilibrium is an idealized model. Equilibrium is maintained only if five conditions are met. This happens only in the fertile imaginations of biologists, not in real populations. Real populations always deviate from one or more of the conditions, and their gene pools change over time. The Hardy-Weinberg equilibrium is nevertheless a useful standard with which to compare real populations whose gene pools are changing.

Let's continue to look at the wildflower population introduced in Exercise 5. If it is like other real populations, its gene pool is changing. For each of the scenarios below, state which of the Hardy-Weinberg conditions the population deviates from, and explain what agent of microevolution causes the gene pool to change. Also state which of these deviations would cause the flowers to adapt to their environment.

1. A windstorm blows in hundreds of seeds from a nearby meadow, where nearly all the flowers are yellow.

2. A cosmic ray hits one of the red flowers just as a developing egg cell is replicating its DNA. Quite by chance, a red allele is transformed into a yellow allele.

3. The flowers tend to grow in red or yellow patches. A landslide buries and kills a huge patch of red flowers.

4. The red pigment in the petals of the red flowers is poisonous and tends to protect them from beetles that eat the developing seeds. The yellow flowers are not protected in this way.

5. The bees that pollinate the flowers tend to develop a "search image." Once they start visiting flowers of a certain color, they stick to that color. So pollen from red flowers is more likely to be delivered to other red flowers, and pollen from yellow flowers is more likely to fertilize other yellow flowers.

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 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.