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Science Standard
7.3.a.

Student Edition

California Education and the Environment Initiative

Shaping Natural Systems through Evolution

California Education and the Environment Initiative

Approved by the California State Board of Education, 2010

The Education and the Environment Initiative Curriculum is a cooperative endeavor of the following entities:

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California Natural Resources Agency

California State Board of Education

California Department of Education

Department of Resources Recycling and Recovery (CalRecycle)

Key Partners:

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Office of Education and the Environment

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Pupfish

The team of divers meets at the bottom of a rocky desert hill. They climb up to a limestone cave and look down at a deep blue pool. In fact, this pool is so deep that no one has ever found the bottom. Devil's Hole is the home of the endangered Devil's Hole pupfish *(Cyprinodon diabolis)*.

California's Changing Environment

The strange scene looks like something out of a science fiction movie. Twice every year, desert fish biologists meet to count the number of pupfish in Devil's Hole. They lower themselves into the warm water. They adjust their masks and scuba tanks. After descending to a depth of 80 feet, the divers slowly rise past a series of limestone shelves. They count the tiny pupfish all the way up.

Pupfish are tiny desert fishes that look a little like minnows. Most of them are about one inch long. Females are yellowish-brown on their backs, and males are blue and brown with violet-colored gills. Biologists believe that the ancestors of today's pupfish appeared 20,000 years ago. They occupied the deep inland lakes that once covered much of California. Here is how biologists believe the pupfish appeared.

Twenty-five thousand years ago, an intense uplifting and tilting of the Sierra Nevada mountain range began. Volcanoes and earthquakes thrust the existing range higher and higher. The peaks grew so high that they blocked much of the rainfall from reaching the east side of the Sierras. Over

Devil's Hole

time, the large inland lakes east of the Sierras began to evaporate, and many species did not have enough habitat to survive and became extinct.

As the lakes evaporated, they formed many smaller ponds, resulting in small populations of pupfish that were physically isolated from each other. Only organisms that had the adaptive trait to deal with the now-harsh environment survived. These individuals reproduced, passing on their survival features to the next generation of pupfish. Because each desert environment was different, or because the individuals had different traits that allowed them to survive, survive, these groups of pupfish evolved (speciated) into different species with unique traits.

Devil's Hole pupfish

Pupfish Adaptations

Today, several species of pupfish are found in a few isolated ponds, creeks, and pools. Salt Creek pupfish (*Cyprinodon salinus salinus*) live in the shallow water of Salt Creek in Death Valley National Park. They are able to live in water that is three times saltier than any ocean. These pupfish hatch in the springtime, when rains fill the creek. They grow to adulthood in two to three months. When they breed, they leave their eggs in the algae of the streambed. Many of the pupfish die in the summertime, when Salt Creek dries out.

A few miles south and east of Death Valley, near Tecopa, California, the Tecopa pupfish (*Cyprinodon nevadensis calidae*) lived in the salty, warm pools. They had survived by eating algae in the 108° F water with no predators for thousands of years. Unfortunately, the owner of the hot springs in the area built canals and bathhouses for visitors in the 1940s. He brought in mosquito fish to eat the Insects that might otherwise have bothered his guests. After he built the canals, the pupfish began washing downstream, out of their unique habitats. The mosquito fish ate the pupfish that did not wash away. As result, in 1970, the Tecopa pupfish was listed as endangered; by 1978, it was extinct.

Mosquito fish

Devil's Hole

Devil's Hole is 35 miles east of Death Valley, in the Amargosa Valley. From the mouth of the cavern, you look down on Ash Meadows National Wildlife Refuge. The refuge was established in 1984 to protect 13 threatened and endangered species, including the Devil's Hole pupfish. The National Wildlife Refuge also provides a habitat for at least 24 other pupfish species found nowhere else in the world.

There is an abundance of water in Ash Meadows. An ancient desert aquifer stretches for 100 miles just below the surface. It feeds seven major springs in the area. An underground fault acts as a dam and forces the water to the surface. This water is called *fossil water*, because geologists believe that it entered the ground around 10,000 years ago.

Human Intervention

In the 1960s and 1970s, farmers, ranchers, and developers made a plan to use this precious desert water. They planted and irrigated crops by pumping water from the aquifer. They diverted the natural springs. All these changes influenced the natural systems in the area. Native plants, fish, and wildlife disappeared.

The tiny pupfish helped to create public awareness about the problem of water diversion. The pupfish are dependent on algae to live. In Devil's Hole, they feed and deposit their eggs on a small limestone shelf where algae grow. When the water was pumped out of the aquifer for irrigation, the water level in Devil's Hole fell below the shelf. The algae dried up and the pupfish began to die.

In 1967, the Devil's Hole pupfish was declared an endangered species. In

Ash Meadows National Wildlife Refuge

1969, the Desert Fishes Council brought the issue to the people. The *Save the Pupfish* slogan could be seen everywhere, from bumper stickers to store windows. In 1972, the people of the United States brought a lawsuit against land developers and the State of Nevada. The case went all the way to the Supreme Court. Eventually the Court ruled in favor of the pupfish. It established a minimum water level that had to be maintained in the pools in the area.

Scientists at Ash Meadows National Wildlife Refuge

Pupfish Population Now

Until 2005, the population of pupfish in Devil's Hole had either grown or remained stable. The divers counted 300 to 500 pupfish in 1995. In the fall of 2005, however, the count suddenly dropped to 85. By the next spring, it was under 40. What happened to the pupfish? Fish biologists do not know. They are still studying the environment to understand why the population decreased.

Biologists know that genetic variation in the pupfish allowed it to survive geological changes 10,000 years ago. Since then, however, this very small population of pupfish has existed in complete isolation and has had few predators. There was little change in the pupfish's environment until the late 1960s. For all these reasons, biologists think that this small, isolated population may have very little genetic variation. If this is correct, then it may be that no individuals have the inherited traits that would enable them to survive changes in the environment.

The divers slowly return to the surface of Devil's Hole. They push up their masks and talk to one another about how many pupfish they found. One of the fish experts is still leaning over the spawning shelf, counting the fish one last time. When the verdict is in, there are 38 pupfish in the warm clear pool. This is the same number as last year. Even though the number is low, the divers sigh with relief. They are expecting that the pupfish count will be higher in the fall.

Pupfish provide an excellent example of how evolution occurs, especially in isolated populations. The disappearing pupfish at Devil's Hole are causing experts to ask how changing environmental factors affect species that are thousands of years old. This year, they will be checking water quality, nutrients, and studying the way that the angle of the Sun affects the growth of algae in the pool. They are also looking at raising Devil's Hole pupfish in the laboratory, in order to protect this rare little fish from extinction.

Tegula funebralis (black turban snail)

Part 1

The *Tegula funebralis* snail, also known as the black turban snail, lives in tidepools along the coast of California. The *Tegula* snail eats algae which grows on the rocks in the tidepools. *Tegula* snails can live above the tide line for short periods.

Octopi, sea stars, and crabs eat *Tegula* snails. Octopi, sea stars, and crabs are generally found in deeper areas in tidepools. There are more of these predators in Southern California tidepools than in northern California tidepools.

Tegula snails in northern California behave differently from the snails in Southern California. In northern California, these snails prefer to live in deeper areas of the tidepools. In Southern California, these snails tend to live in shallower areas of the tidepools.

Part 2

Scientists wanted to know if the difference in behavior between the northern and Southern California *Tegula* snails was an inherited behavior or a learned behavior.

They conducted an experiment by placing a sample with both northern and Southern *Tegula* snails in a deep area within a tidepool.

During the experiment, the scientists observed that when predators were in the tidepool with the snails, both the northern and Southern California snails moved to shallower areas in the tidepool. The difference they discovered was that the Southern California snails moved more quickly and to higher areas in the tidepool than the northern California snails.

The scientists concluded that the predators were more likely to eat the northern California snails.

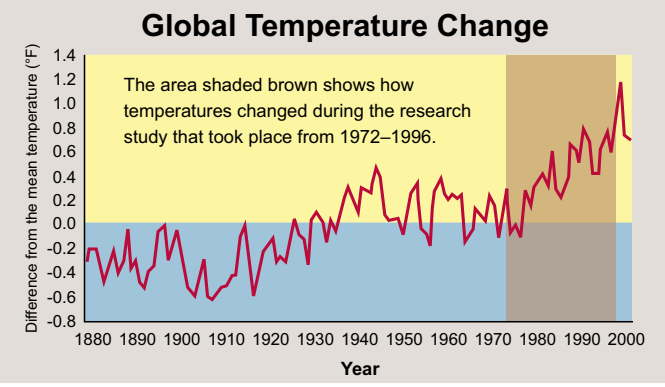
Purple Pitcher Plant Mosquito:

This non-biting mosquito lives its entire life on a purple pitcher plant. These mosquitoes are found in the northeastern United States, and they hibernate during the winters, which can be quite cold in that part of the country. Several genes control the timing of the onset of hibernation in mosquitoes. The length of the day, not temperature, is the cue for hibernation to begin. The timing of the onset of hibernation is critical to the mosquito's survival; if hibernation is begun too early, the mosquito will not have enough nutrients stored in its body to last throughout the winter. On the other hand, if it delays the beginning of hibernation for too long, it will freeze to death. The mosquito most likely to survive and reproduce is the one whose hibernation begins at just the right time—the one that has the most time to eat before hibernating but does not freeze to death.

Purple pitcher plant

What the Scientists Found:

Christina Holzapfel and her husband William Bradshaw are biologists. They have been collecting and examining mosquitoes from New England for over 30 years. They noticed two important changes during that time. In New England, winter temperatures went up by an average of 4.4° F (2.4° C). That means that mosquitoes could eat and reproduce later into the year. The behavior of the mosquitoes also changed: they began to hibernate, on average, nine days later.



Purple pitcher plant mosquito

Kauai Field Cricket:

Field crickets live on the island of Kauai in Hawaii. Male crickets have small scrapers on their wings. Rubbing the wings together makes a chirping sound that attracts female crickets to mate; but the chirping also attracts flies. A deadly fly called *Ormia ochracea* recently arrived in Kauai from North America. It lays its eggs on the bodies of the field crickets, and the eggs develop into maggots (the larvae of the fly). The maggots burrow into the body of the cricket to eat, killing the cricket in the process.

Normal Kauai field cricket

What the Scientists Found:

Marlene Zuk is a Professor of Biology at the University of California, Riverside. In 1991, she began studying field crickets in Kauai, and she found that the size of their population dropped every year. By 2001, there were hardly any crickets left, because most of them had been eaten by the maggots of the fly that had been introduced onto the island. However, a new mutation appeared in the cricket population that resulted in some male crickets having flat wings. These wings could not make a chirping sound. Male crickets depend upon “singing,” the chirping sound made by their wings, to attract females during mating season. But even though this mutation and new trait made it more difficult to mate, it protected these silent male crickets from the flies by making it more difficult for the flies to find them. By 2003, over 90% of male crickets had flat, silent wings. Scientists believe that mutant males gather near male crickets that can still sing so that females can find and mate with them.

Flatwing Kauai field cricket

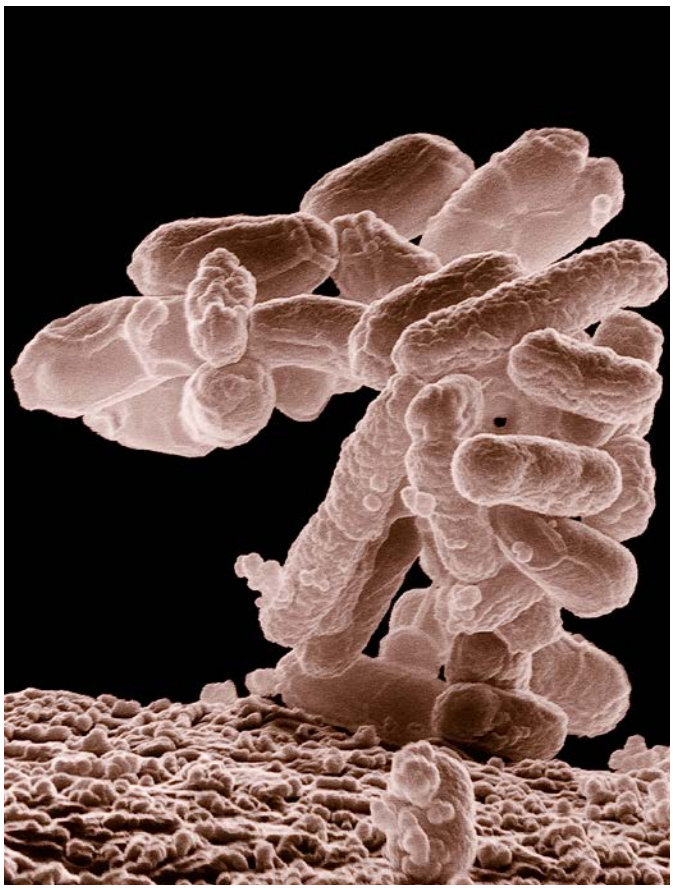
Eschericia coli (E. coli):

E. coli is a kind of bacteria that grows in the lower intestines of animals. It can also be grown easily in Petri dishes in laboratories, and it reproduces rapidly. In a laboratory setting, *E. coli* eat glucose, a kind of sugar. Other kinds of nutrients are also put in Petri dishes, though *E. coli* usually cannot use them.

Petri dishes

What the Scientists Found:

Richard Lenski is a Biologist at Michigan State University. Twenty years ago, he took a single *E. coli* cell, fed it, and watched it reproduce. He paid attention to what kinds of food the bacteria could use. He continued to feed the next generation of bacteria, and the next. From that first cell, he has now grown over 44,000 generations of bacteria. Each generation exhibited new genetic mutations. In the 31,500th generation, Lenski noticed something new about his bacteria. Some of them had a genetic mutation that allowed them to use a nutrient called citrate. His first *E. coli* could not use citrate, but these new bacteria could. The bacteria with this trait began to increase in his laboratory population.



E. coli

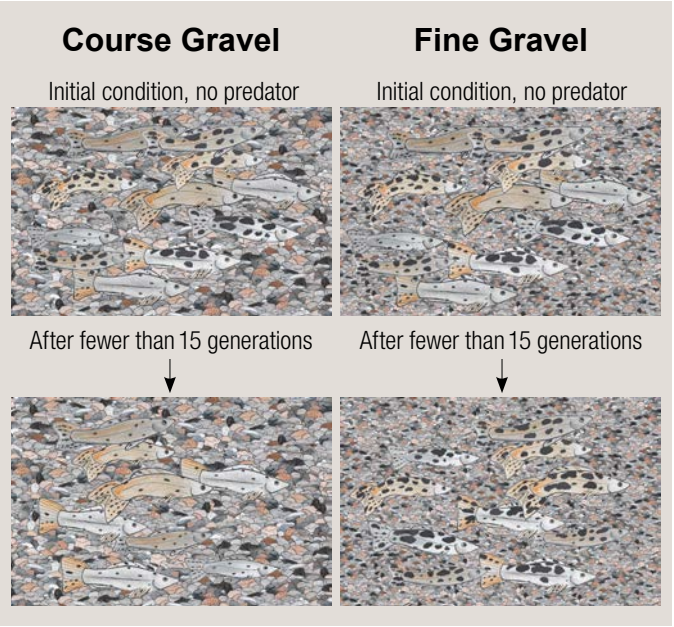
Guppies:

Some guppies live in pools and streams on the island of Trinidad. Different parts of each stream contain different-looking guppies. Some pools are full of fish with bright colors or spots that stand out against the bottom of the pool. Others contain rather drab guppies that are camouflaged against the bottom of the pool. Guppies that are brightly colored or show up well in their pool are more likely to attract mates. Guppies that do not stand out are less likely to be eaten by predators.

Guppy

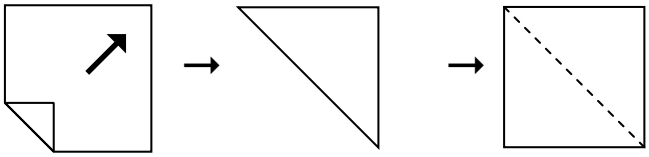
What the Scientists Found:

Biologist John Endler studies guppies in the wild and in the laboratory. Endler thought that guppies with spots that were noticeable against the colors of the pool would have more success in attracting mates. He also realized that noticeable spots would probably make the guppy more visible to predators. But in pools with an absence of predators, he wondered if guppy populations would have a higher number of individuals with those spots, because of the advantage the spots would give the guppy at mating time. In order to answer this question, he conducted an experiment. He put guppies into two tanks; some of the guppies had smaller spots and others had larger ones. One tank had coarse gravel at the bottom and the other had fine gravel. Then he waited. After fewer than 15 generations, the overall appearance of the guppy populations in each tank changed. Endler's setup kept the guppies free from predators, and populations evolved spots that made the fish show up well against the bottom of the pool. This finding confirmed Endler's idea that, in the absence of predators, the guppies that were the easiest to see were more likely to attract mates and pass on their genes.

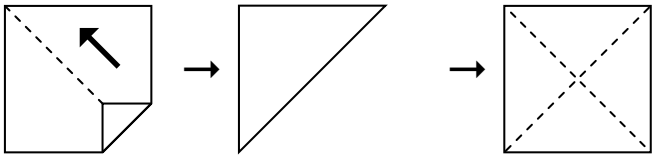


Guppy adaptation

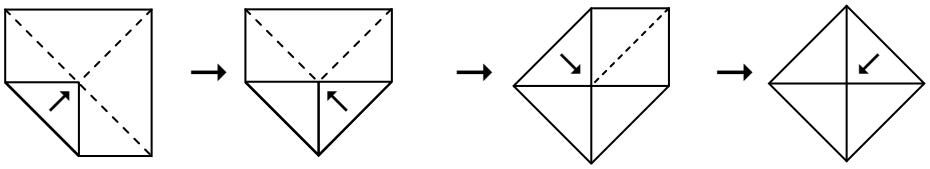
Step 1: Fold square in half diagonally.



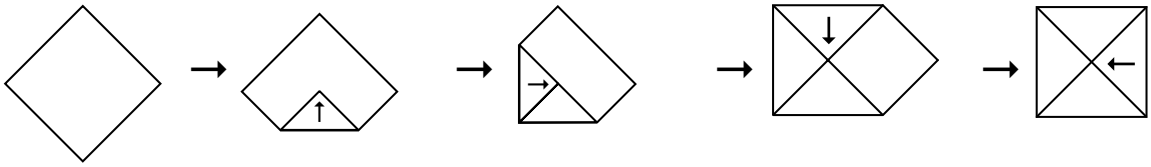
Step 2: Unfold and fold square in half on other diagonal.



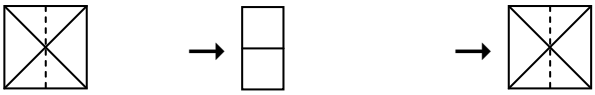
Step 3: Fold all 4 points of square to center. This is side 1.



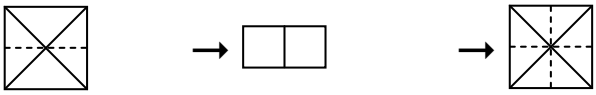
Step 4: Turn square over to side 2. Fold all 4 points of square to center again. This makes square even smaller.



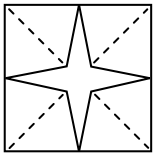
Step 5: Fold square in half vertically. Unfold.



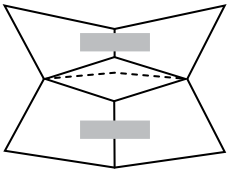
Step 6: Fold square in half horizontally. Unfold.



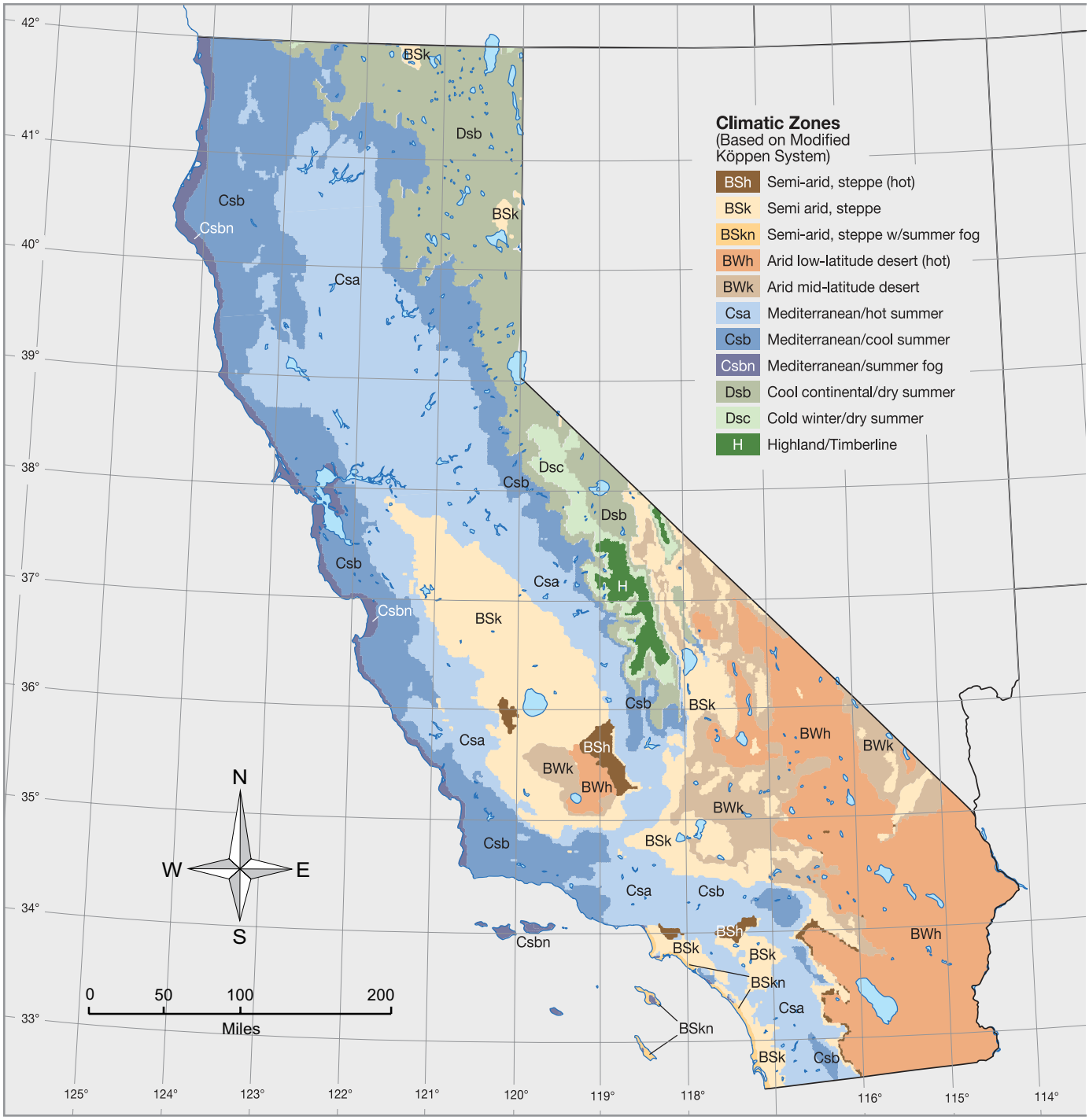
Step 7: With side 1 down, open side 2 so that two “flaps” can be taped together on the side seams. Tape the other 2 flaps across the side seams.



Step 8: The thumb fits into the lower slot and pointer finger into the upper slot created by the taped together flaps. Side 1 becomes the inside of the beak and Side 2 the outside.



At this point, each student should have a bird beak that can be opened and closed.


Climatic Zones
(Based on Modified Köppen System)
BSh Semi-arid, steppe (hot)
BSk Semi arid, steppe
BSkn Semi-arid, steppe w/summer fog
BWh Arid low-latitude desert (hot)
BWk Arid mid-latitude desert
Csa Mediterranean/hot summer
Csb Mediterranean/cool summer
Csbn Mediterranean/summer fog
Dsb Cool continental/dry summer
Dsc Cold winter/dry summer
H Highland/Timberline
N
W
E
S
0 50 100 200
Miles
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°
125°
124°
123°
122°
121°
120°
119°
118°
116°
115°
114°

Semi-arid, steppe (hot): The temperatures in this climate are high. It is hot and dry, but has more moisture than a desert—enough to support grasslands and other kinds of plants.

Semi-arid, steppe: The temperatures in this climate range is on the high end. Temperatures rarely drop below freezing. It is warm but not hot. While it is dry, it has more moisture than a desert—enough to support grasslands and other kinds of plants.

Semi-arid, steppe/summer fog: The temperatures in this climate are mild. It rarely drops below freezing. It is dry, but it has more moisture than a desert, enough to support grasslands and other kinds of plants. This climate also has frequent fog in the summer.

Arid low-latitude desert: This climate is extremely dry most of the year. Temperatures can become very high, especially during the summer.

Arid mid-latitude desert: This climate is extremely dry most of the year. Temperatures are lower than in low-latitude desert.

Mediterranean/hot summer: Mediterranean climates have mild temperatures and seasonal rains. In this climate, summers are hot and winters are cool. It rarely freezes. Most of the precipitation falls in the wintertime. Summers are very dry.

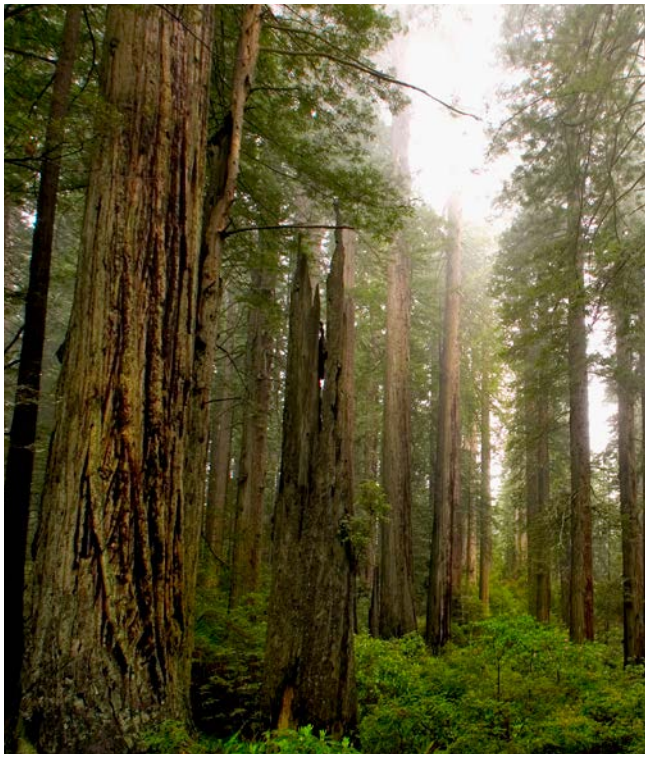
Mediterranean/cool summer: Mediterranean climates have mild temperatures and seasonal rains. In this climate, summers are cool and winters are cool. It rarely freezes. Most of the precipitation falls in the winter. Summers are very dry.

Mediterranean/summer fog: Mediterranean climates have mild temperatures and seasonal rains. In this climate, summers are cool and winters are cool. It rarely freezes. Most of the precipitation falls in the wintertime. Summers are very dry. This climate also has frequent summer fog.

Cool continental/dry summer: This climate features cold winters and cool summers. It gets moderate amounts of rain and snow, though most of the precipitation falls in the winter.

Cold winter/dry summer: This climate features cold winters and cool summers. Summers are also very short. It gets moderate amounts of rain and snow, though most of the precipitation falls in the winter.

Highland/Timberline: This climate is influenced by very high altitude. It features cold winters and cool, short summers. Most of the precipitation falls in the winter.



Redwoods

The Coastal Redwood
(*Sequoia sempervirens*)

The coastal redwood is the tallest species in the world, reaching heights of over 300 feet. This tree requires a year-round supply of water, either from the soil or from the air. One unique feature of this tree is that it can absorb water from fog through its needles. Scientists estimate that the coastal redwood gets 30–40% of its water from fog. It requires rich soil to survive, and cannot tolerate salt spray from the ocean. It also does not grow at altitudes much higher than 2,000 feet.

Giant sequoia

The Giant Sequoia
(Sequoiadendron giganteum)

As its name suggests, the giant sequoia is one of the largest tree species in the world. These trees are also known for their age. Many trees alive today are 2,000 to 3,000 years old. Giant sequoias require moderate amounts of water to survive. They can survive in cold temperatures, down to about -12° F (-24° C). Above 9,000 feet, temperatures become too extreme for the trees. They also cannot survive at elevations lower than 2,700 feet, as these lower areas tend to have less water for the trees. Large giant sequoias have thick bark that allows them to survive fires that occur in dry summers. In fact, these trees need fires as a means to remove other trees that make shade. Young giant sequoias need lots of direct sunlight to grow and cannot survive in the shade.

McDonald's rockcress

McDonald's Rockcress
(*Arabis Macdonaldiana)*

McDonald's rockcress is a plant with vibrant-colored flowers. It grows in soils rich in serpentine, which is California's state rock. This rock is formed when tectonic plates meet, as they do in the mountains of central and northern California. Serpentine rock is a metamorphic rock that contains high amounts of metals. McDonald's rockcress has a high tolerance for these metals, which few plants can tolerate. This plant survives well in a mild, cool climate and can tolerate dry summers. It also needs a moderate amount of water to survive.

Pitkin's marsh lily

Pitkin's Marsh Lily
(Lilium pardalinum ssp. pitkinense)

Pitkin's marsh lily is known for its beautiful flowers. Petals are red on the outside, yellow near the center, and covered with small deep maroon dots. This lily grows in moist, sandy soils in freshwater marshes. It gets its water from the soil near marshes, so it can survive dry summers, provided that the marsh does not disappear. These flowers survive best in mild climates where it can avoid extremes of temperature (too cold or too hot). It grows only at low altitudes in the range of 115–197 feet (35−60m) above sea level. (The "*ssp.*" in the flower's scientific name stands for "subspecies"—a group within a species that appears or behaves differently from other groups within that same species.)

Blunt-nosed leopard lizard

Blunt-nosed Leopard Lizard
(*Gambelia sila*)

The blunt-nosed leopard lizard comes in a variety of colors, depending on the kind of soil or plants it lives on. These lizards have very specific temperature needs, and are rarely active when it gets colder than 70° F (21° C). By autumn, blunt-nosed leopard lizards enter burrows to keep warm, and there they hibernate until spring. They cannot tolerate extremely hot temperatures. They cannot live in places with lots of plants, though they do use some plants to help them hide from predators. Too much water puts them at risk of drowning in floods.

American pika

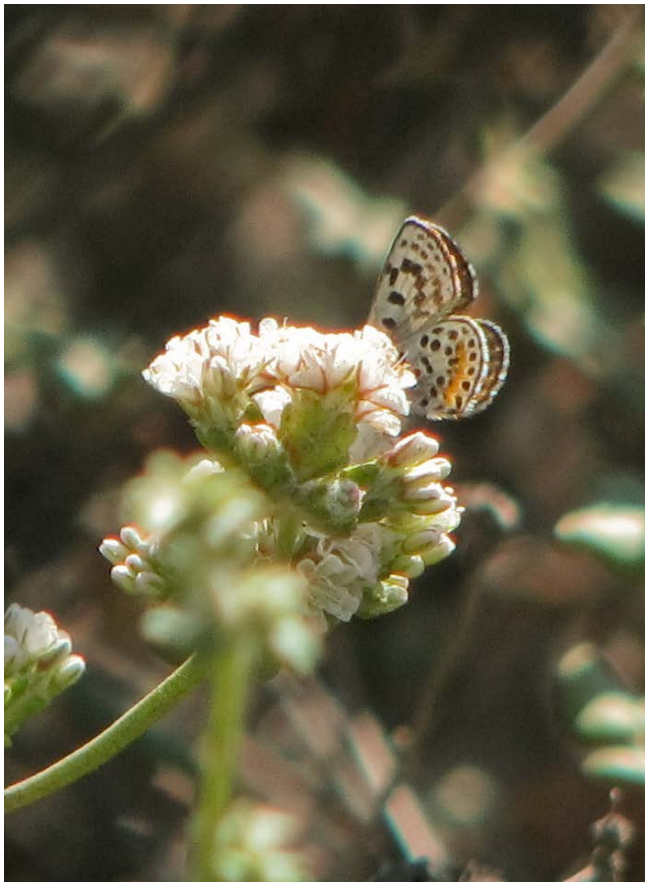
American Pika
(*Ochotona princeps*)

The American pika is a tiny, round mammal with some similarities to a rabbit. It weighs less than one-half pound. The pika has a dense fur coat that allows it to survive in cold, moist climates. It spends short summers collecting grasses and wildflowers to eat during long winters. The pika dries the plants, then stores the food in “hay piles” deep beneath the rocks. It spends winters beneath the rocks, though it does not hibernate. The pika has the lowest tolerance for heat of any mammal. If temperatures reach about 77° F, the animal will die if it does not reach a cool space under a rock. Pikas cannot live if summers are hot, because they are not able to go out in the heat to find food that they would need to survive the winter. Pikas live at elevations of 8,000 to 13,000 feet, where the temperatures are more likely to stay cool.

Desert kangaroo rat

Desert Kangaroo Rat
(Dipodomys deserti)

The desert kangaroo rat is a small rodent. It has several adaptations to help it survive in a hot climate with extremely limited water supplies. This rat collects dry seeds to eat, but it also can extract water out of the seeds to quench its thirst. It also has special kidneys that remove waste from its body without using much liquid. To save water, the rat does not sweat or pant. It stays in burrows during the heat of the day to stay cool. The desert kangaroo rat only comes out at night when the temperature is cool. All of these traits allow this rodent to live in a very hot environment where there is little water.



El Segundo blue butterfly

El Segundo Blue Butterfly
(*Euphilotes battoides allyni)*

The El Segundo blue butterfly is a tiny insect about one inch across. It lives its entire life on one kind of plant called coastal buckwheat, which grows in the sand dunes of beaches. The butterfly's life cycle matches that of the buckwheat. When the warm, dry summer arrives, coastal buckwheat begins to flower. That is when the El Segundo blue butterfly emerges from its cocoon. It lives for only a few days as a butterfly, just long enough to lay eggs on the coastal buckwheat. About a week later, caterpillars emerge from the eggs. They feast on the coastal buckwheat for a month, then form cocoons. Here the El Segundo blue butterfly remains until the next summer, when the buckwheat flowers again. The coastal buckwheat, which does not require much water itself, provides the butterfly with all the moisture it needs to survive. Mild temperatures are needed for both the butterfly and the coastal buckwheat.

Greater Prairie Chicken

The greater prairie chicken was once very common in North America. These prairie chickens are not the same as chickens that people raise for food. They are a wild species that live in the tall grasses of the prairies. Male birds have distinctive golden pouches on the sides of their necks. They inflate these pouches to attract females. The population of prairie chickens has disappeared in Canada and dropped significantly in the United States over the past 100 years.

Tall grass prairies used to cover 400,000 square miles of land in the United States. This is equivalent to 15% of the land in the lower 48 states. Since the 19th century, farmers have cleared these prairies to create farms. Only 5% of the tall grass prairies still exist in the United States.

As tall grass prairies have disappeared, so have prairie chickens. Lack of habitat has forced birds into smaller geographic areas. Small populations of these birds still exist, though they are isolated from one another. One study of prairie chickens in Illinois highlights this. In 1933, 25,000 prairie chickens lived in Illinois. By 1962, 2,000 birds lived in one of three groups. By 1994, fewer than 50 birds remained. All of the offspring in present-day populations have come from those remaining 50 birds. With so few birds reproducing, there is a smaller variety of genes to be passed on. As a result, offspring have very similar traits.

Having such a small gene pool has posed a problem for this bird species. If a harmful gene exists in one bird, it often exists in others, because all of the birds are genetically similar. Two mating birds can both pass on copies of this harmful gene to offspring. Inheriting the harmful gene from both parents can prevent eggs from hatching. This causes populations of prairie chickens to have lower hatch rates. (A hatch rate is the percentage of eggs that hatch successfully.) In 1990, the hatch rate in the prairie chicken populations was only 38%. Looking at it another way, 62% of the eggs that the birds laid had harmful combinations of genes and could not survive.

Scientists predicted that the prairie chickens in Illinois could not survive without introducing a greater variety of genes into the gene pool. They brought birds from Kansas and Minnesota to add to the three groups in Illinois. After this intervention, the hatch rate increased. The population of prairie chickens in Illinois has started to grow again.

Greater prairie chicken

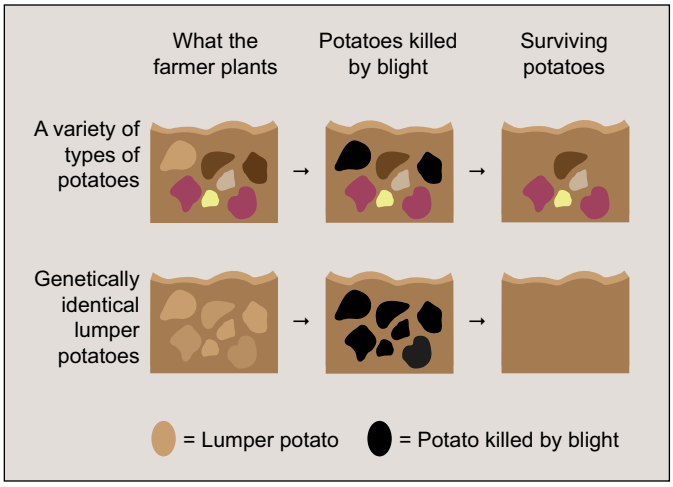
Lumper Potatoes

In the early 1800s, Ireland's population grew rapidly. In order to feed increasing numbers of people, farmers began to change the way they farmed. A type of potato known as the "lumper" became very popular. While this potato was one of the worst-tasting potatoes around, it was very fertile. An entire family could feed itself for a year on just a small plot of lumpers. The poor people of Ireland did not have much land for farming. They used the little land they did have to grow lumper potatoes. For millions of people in Ireland, the lumper potato became the main source of food. Before 1800, many kinds of potatoes, as well as grains and vegetables, were grown in Ireland for everyone. By 1800, 90% of Ireland's people lived almost entirely off of lumper potatoes.

In the wild, hundreds of different kinds of potatoes grow together. Bumblebees carry pollen from one potato plant to another to help them reproduce. But farmers grow potatoes differently. Farmers take a potato and cut out a small section. They then plant this section to grow a new potato plant. This produces potatoes that are genetically identical to their parents. The new potatoes are actually clones of the ones they grew from. By 1845, identical lumper potatoes filled the fields of Ireland.

In 1845, a fungus from North America called "late blight" accidentally arrived in Ireland. This fungus grew on the lumper potatoes. Farmers dug the potatoes out of the ground, and within a few days, the potatoes turned into a slimy, black mess. Other varieties of potatoes have genes that resist blight. Because the lumper potatoes were genetically identical to one another, none of them had the genes to resist the fungus. Mutation would still provide some genetic variation in the potato population; however, in 1845, 40% of the potato crop failed, and by 1846, blight destroyed 100% of the lumper crop. In Ireland, this period of time is known as "The Great Hunger." An estimated 1.5 million people died of starvation and disease because of the blight. This represented one out of every eight people in Ireland.

Other countries experienced blight, too. In the United States, Canada, and in other parts of Europe, blight killed lumper potato crops. These places did not experience severe starvation, because farmers there grew other potato species. Other species survived because they still had enough genetic variation, including some potatoes with a genetic trait that could resist blight.



Susceptibility to blight

Northern Elephant Seal

The northern elephant seal lives in the North Pacific Ocean, from Baja, Mexico, to the Gulf of Alaska. This seal is the second largest seal in the world. Adult males can grow to over 13 feet long and weigh up to 4,500 pounds. These seals spend their breeding season on a few remote beaches and islands in California and Mexico. During the rest of the year, they live in the open ocean.

In the 1700s and 1800s, hunters killed thousands of elephant seals. They mainly used their blubber, or fat, as lamp oil. By 1892, there were only 20 to 100 elephant seals left in the world. These seals had bred on just one island off the coast of Mexico. The Mexican and United States governments began to protect these seals. Those few seals that were left reproduced. The population of elephant seals grew rapidly.

There are now over 150,000 elephant seals. All of these seals came from those few ancestors who were protected—the 20 to 100 seals that lived in 1892. This means that the current population of seals have very little genetic variation, because they all came from such a small number of parents. Even though there are many seals alive today, some scientists are concerned that they could become extinct. With the small amount of genetic variability in the gene pool that random mutations provide, these seals do not have as many potential adaptations available. Scientists worry that a change in the environment, such as a new disease, could kill all the seals. If one seal does not have the genes to fight a new disease, other seals are also unlikely to have them.

Northern elephant seals

Sweet Vernal Grass

Sweet vernal grass has a vanilla-like smell when it is cut. Because of this pleasant scent, many people like to plant it. This grass originally grew in Europe and Asia, but now has spread throughout the Americas and Africa. Sweet vernal grass can be found in many counties in California. Scientists have studied this grass because it seems to survive in a wide variety of environments.

In the 1800s, miners in the United Kingdom mined lead and zinc at the Trelogan mine. In the process, miners left piles of mine tailings. Tailings are a byproduct of mining; they are the materials that remain after miners have finished processing the metals they take out of the ground. These tailings are still around today, and as a result, the soil near the mine has high levels of zinc and lead. Farther away from the mine, the soil does not have these metals. Sweet vernal grasses grow in both of these places.

Sweet vernal grass

Scientists have studied the sweet vernal grass that grows at the Trelogan mine, as well as at other mines. They have discovered some amazing differences in the grasses. The grasses that grow on the tailings have a high tolerance for metals. These grasses actually die when they are grown in soil without metals. In contrast, the grasses that grow away from the tailings cannot tolerate metals in the soil.

These two populations of grasses have changed over time in another way. They produce flowers at different times of the year. Pollen from grasses is spread by the wind. Pollen blows from the flowers of one plant to the flowers of another in order to reproduce. Now that the two populations of grasses develop flowers at different times of the year, pollen cannot spread between the type that lives near the mines and the type that lives far away. This means the two types of grasses can no longer reproduce together. Reproducing at different times might be a favorable adaptation for the grass. Because each population can only survive well in its own kind of soil, breeding with the other population would bring the genes into the population that would prevent offspring from surviving. Over time, these populations of grasses may evolve into two separate species.

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