LESSON 3
Patterns of Natural Selection

VOCABULARY

**DIRECTIONAL SELECTION:** natural selection in which an extreme phenotype (i.e., phenotype either greater or lesser than the population mean) is favored over other phenotypes, causing the allele frequency to shift over time in the direction of that phenotype

**STABILIZING SELECTION:** natural selection in which intermediate forms of a trait are favored and the extremes are selected against

**DISRUPTIVE SELECTION:** natural selection in which extreme forms of a trait are favored over intermediate values. Variance of the trait increases and the population is divided into two distinct groups. Over time, disruptive selection can lead to two new species

LESSON SUMMARY

In this one-day lesson students will first learn about three types of natural selection: directional, stabilizing and disruptive selection. Next, students complete a practice set with different population scenarios and predict what kind of natural selection the population will undergo. As a conclusion to the lesson, students work in groups to identify how a real population of organisms might respond to climate change induced changes in their environments. Each group draws a graph and writes predictions on a white board. The group information is presented to the entire class and the students fill in a graphic organizer listing problems created by climate change and possible adaptations in response to those problems.

STUDENT LEARNING OBJECTIVES

• SWBAT differentiate between direction, stabilizing, and disruptive selection
• SWBAT predict what kind of selection might occur in a species in response to changes in the environment due to climate change

MATERIALS:

• Student Page: Patterns of Natural Selection
• Student Page: Guided Notes Outline
• Student Page: Natural Selection in the Face of Climate Change – Species Fact Sheets
• 6 White Boards and Markers (one for each group)

BACKGROUND INFORMATION:

See first page of student worksheet.

ADVANCE PREPARATION:

• Print Student Page: Patterns of Natural Selection - ONE copy per student
• Student Page: Guided Notes Outline- ONE copy per student
• Student Page: Natural Selection in the Face of Climate Change — Species Fact Sheets (consider laminating for future use) — ONE set (each group of 2-4 students will get ONE sheet)
PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES

1. (10-12 MINUTES) Pass out the Part I Student Worksheet. Review the key features of natural selection from the activity “What Can Cold Flies Teach Us About Evolution.” Discuss the three types of natural selection on the first page with the class. Have students complete the four practice problems.

2. (10-15 MINUTES) Pass out one whiteboard, markers and ONE Student Page: Natural Selection in the Face of Climate Change-Species Fact Sheets to each group. Instruct students to create a graph on their whiteboard showing the frequency of one trait of the species on their card that might be affected by climate change. Students should draw one line representing the current trait frequencies and then add a second line showing how that trait might be acted upon by evolution to help the species survive the challenges posed by climate change (see teacher answer key for examples). Students should also write a 1-2 sentence summary of how the climate change issue on the card could result in the pattern of natural selection depicted in their graph. Inform students that they will have 10 minutes to create their graph and prepare a summary of the species information and climate change challenge to the entire class.

3. (20-25 MINUTES) Pass out ONE student-guided note sheet to EACH student. Fill out the definition of climate change together as a class. Groups should take turns showing the graphs they created and explain how climate change is affecting their species and how their species could potentially evolve to become better suited to future environmental conditions created by climate change. Then each group of students should add one statement to the “climate change challenge” box and one statement to the “As a result of Climate Change Natural selection would favor...” box.

4. (5-10 MINUTES) Conclude the class with a discussion on the limits of evolutionary adaptability. Make sure to emphasize that many species will NOT be able to evolve in response to climate change and face serious risk of extinction.

ASSESSMENT SUGGESTIONS:

• Collect either/both Student Page(s)
Patterns of Natural Selection

**DIRECTIONAL SELECTION:** Natural selection in which an extreme phenotype is favored over other phenotypes, causing the alleles causing that phenotype to be favored and shift over time in the direction of that phenotype.

Example: Prior to the industrial revolution in England the peppered moth had light coloration and lived on trees covered with light colored lichen. This provided camouflage against predatory birds. There were a few dark individuals in the population, but they were usually eaten by birds. However, once the industrial revolution began the light-colored lichens covering the trees were killed by sulfur dioxide emissions from the new factories. Without the light background of the trees, the light moths were more visible to birds and now the dark moths had a camouflage advantage. In 1848, the dark moths comprised 1% of the population and by 1959 they represented ~90% of the population.

**STABILIZING SELECTION:** Natural selection in which intermediate forms of a trait are favored and more extreme values are selected against.

Example: Human birth weight has undergone stabilizing selection. Babies of low weight lose heat more quickly and get ill from infectious diseases more easily, whereas babies of large body weight are more difficult to deliver through the pelvis. Infants of a more medium weight have the greatest survival.

**DISRUPTIVE SELECTION:** Natural selection in which extreme forms of a trait are favored over intermediate values. Variance of the trait increases and the population becomes divided phenotypically into two distinct groups. Over time, disruptive selection can lead to formation of two new species (speciation).

Example: A population of mice lives in a desert habitat with both sand and black volcanic rocks. The mice with black fur are able to hide from predators amongst the black rocks, and the mice with lighter fur are able to hide from predators in the sand. The mice with intermediate fur, however, stand out in all areas of the habitat, and thereby suffer greater predation. Natural selection would favor both light and dark colored mice, but select against mice of intermediate color.
PRACTICE PROBLEMS

INSTRUCTIONS: For each of the following scenarios assume each population has continuous variation in the traits described below, the traits are genetically inherited and there is a great deal of genetic diversity in the populations. Initially assume the distribution of trait values in the population starts out in a normal distribution. Predict which pattern of natural selection would be most likely to occur based on the information provided. Draw the new populations in a different color on the graphs provided. Label both axes.

1. Fantail Warblers are birds that live in subtropical regions of Africa. The parasitic weaver (a lice like organism) is a specialist parasite of Fantail Warblers. However, parasite populations are declining due to climate change. Previously the birds with thicker feathers (which required more energy to produce) were more resistant to the parasitic weaver. As the effects of climate change increase what type of pattern of natural selection would we expect to see in the fantail warbler population with respect to feather thickness?

Type of Selection

![Graph](image)

2. A large population of southern yellow tailed hornbills is living in the Kalahari Desert. There are small amounts of rainfall and the summer temperature is very high. Yellow-billed hornbills are monogamous and will live in breeding pairs or small family groups. When they begin their courtship the male will feed the female for up to a month by bringing her small bits of food in his mouth. Females are attracted to males with richly pigmented feathers and less likely to choose a male with dull colored feathers. However, if the males have richer pigment they have trouble regulating their body temperature in warmer temperatures and often don’t survive to adulthood. As the effects of climate change increase what type of pattern of natural selection could we expect to see in the southern yellowtail hornbill population with respect to amount of pigment in males?

Type of Selection

![Graph](image)
3. Fingered Poison Frogs are endemic to Trinidad. Females deposit small clutches of eggs in terrestrial nests. After hatching in July, one of the parents transports the tadpoles to a small water body, where they complete their development to metamorphosis. Suppose that due to changing climate conditions small bodies of water are only readily available during certain months of the year. Fingered Poison Frogs in southern Trinidad begin to only produce offspring during the spring months (April and May) and Fingered Poison Frogs in Northern Trinidad only produce offspring during the fall (September-October). What type of pattern of natural selection would we expect to see Trinidad’s Fingered Poison Frogs population with respect to time of reproduction?

Type of Selection

4. A study was conducted on *Pocillopora damicornis*, a coral widely distributed in the Indo-Pacific. The study measured changes in reproductive timing associated with increased seawater temperature. In this study, the effect of increased seawater temperature on the timing of planula (free swimming coral larvae) release was examined during the lunar cycles of March and June 2012. Twelve brooding corals were removed from Hobihu reef in Nanwan Bay, southern Taiwan and placed in 23°C and 28°C controlled temperature treatment tanks. For both temperatures, the timing of planulation was found to be plastic, with the high temperature treatment resulting in significantly earlier peaks of planula release compared to the low temperature treatment. This suggests that temperature alone can influence the timing of larval release in *pocillopora damicornis* in Nanwan Bay. What pattern of natural selection would we expect to see in the *pocillopora damicornis* population if ocean temperatures continue to increases?

Type of Selection
CLIMATE CHANGE:

<table>
<thead>
<tr>
<th>Problems Created By Climate Change</th>
<th>As a Result of Climate Change Natural Selection Would Favor</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Carbon Dioxide Molecule" /></td>
<td><img src="image" alt="Evolutionary adaptations" /></td>
</tr>
</tbody>
</table>

Limitations to Evolutionary Adaptability:

1) 

2)
Species Information
Snowshoe hares are forest-dwellers that prefer the thick cover of brushy undergrowth. They are primarily a northern species that inhabit boreal forests and can range as far north as the shores of the Arctic Ocean. Hares are a bit larger than rabbits, and they typically have taller hind legs and longer ears. Snowshoe hares have especially large, furry feet that help them to move atop snow in the winter.

Snowshoe hares feed on plants such as, grass, ferns and leaves. Their main predators include lynx, foxes, coyotes, raptors and birds of prey. Young hares are frequently eaten by red squirrels. Most hares live less than a year because of predators.

One defense against predators is that snowshoe hares have a snow-white winter coat that turns brown when the snow melts each spring. It takes about ten weeks for the coat to completely change color. Hares switch color in the spring and fall in response to light, when the days get longer or shorter. However, if the snow comes late, the result is white hare on brown ground. Unfortunately the hares still think they are camouflaged and act like predators can’t see them and are usually eaten.

Climate Change Challenge
Hares are consistently molting (changing color) at the same time, year after year. However, due to climate change the snowfall comes later and melts earlier resulting more and more times when hares are mismatched with the environment.

A white snowshoe hare against a brown background makes the animal easy prey.

LESSON 3 | SPECIES 2

Species: *Icterus galbula* (Baltimore Orioles)

**SPECIES INFORMATION**

Baltimore Orioles spend summer and winter in entirely different geographic ranges. From early April to late May, flocks arrive in eastern and central North America to breed. These breeding grounds range from Louisiana (31°N) to Canada (50°N) where they prefer open woodland, forest edges, river banks, and small groves of trees. They will also forage for insects and fruits in brush and shrubbery during this time. Post breeding season they begin to migrate to wintering grounds ranging from Florida (25°N) to the Caribbean (15°N). This migration season can begin as soon as July, where they will remain until the next breeding season.

**CLIMATE CHANGE CHALLENGE**

Due to climate change the Baltimore Orioles limited North American summer breeding range may shrink. Warming will likely harm vegetation that birds rely on for nesting and food in the southern part of the breeding grounds.

LESSON 3 | SPECIES 3

Species: Spheniscus magellanicus (Magellanic penguin)

SPECIES INFORMATION
The Magellanic penguin is a South American penguin, breeding in coastal Argentina, Chile and the Falkland Islands. Magellanic penguins feed in the water, preying on cuttlefish, squid, krill, and other crustaceans.

Magellanic penguins mate with the same partner year after year. The male reclaims his burrow from the previous year and waits to reconnect with his female partner. The females are able to recognize their mates through their call alone. Both the male and female penguins care for their young, taking turns incubating the eggs and feeding their chicks.

CLIMATE CHANGE CHALLENGE
Weather records show that there is more rainfall and more severe storms occurring in Magellanic penguin breeding grounds. Warmer air temperatures mean not only hotter weather, but also more evaporation from the Atlantic, which puts more moisture in the air and thus creates wetter storms. Juvenile penguins are dying of hypothermia after heavy rain. Chicks are covered in down. Their juvenile plumage doesn’t come in to protect them at all until they are older than 40 days.

Magellanic penguins strut their stuff on the rocky shoreline of Argentina’s Punta Tombo, home to the largest colony of the birds in the world.

Species: Pacific Northwest Shellfish

SPECIES INFORMATION
In North America we eat a few different varieties of bivalves including clams, mussels, oysters, and scallops.

Oysters are filter feeders, drawing water in over their gills through the beating of cilia. Suspended plankton and particles are trapped in the mucus of a gill, and from there are transported to the mouth, where they are eaten, digested, and expelled. Oysters usually reach maturity in one year. They are protandric meaning during their first year they spawn as males by releasing sperm into the water. However, as they grow over the next two or three years and develop greater energy reserves, they spawn as females by releasing eggs.

Scallops are found in all of the world’s oceans and are primarily “free-living”. Many species are capable of rapidly swimming short distances and even of migrating across the ocean floor. The scallop family is unusual in that some members of the family are dioecious (males and females are separate), while others are simultaneous hermaphrodites (both sexes in the same individual), and a few are protoandrous hermaphrodites (males when young then switching to female).

CLIMATE CHANGE CHALLENGE
As levels of CO₂ continue to rise some of the CO₂ is absorbed by the ocean. When CO₂ combines with water it produces carbonic acid and results in ocean acidification. The Vancouver Aquarium has recorded a steady decrease in water pH in the Pacific Northwest waters, from an average of around 8.1 until 1974 to levels as low as 7.2 in recent years. Acidic waters make it harder for oyster and scallop larvae to form their hard shells. Thinner, more fragile shells make them vulnerable to predators and diseases.

Species: *Rana cascadae* (Cascades Frog)

**SPECIES INFORMATION**

Cascades frogs (aka the “chuckle frog”) live in the mountains of the Northwest and thrive in alpine wetlands fed by melting snow. Cascades frogs spend most of the year beneath dozens of feet of snow. But for a few months in the summer, the frogs come to warm sunny ponds produced from snowmelt to feed and mate. Females can only breed once a year. A single female will lay up to 425 eggs at a time, but very few tadpoles will live past their first year. The eggs hatch within eight to 20 days, which immediately begins the “larval period.” Their larval period lasts 80 to 95 days.

Most frogs reach their full size after three years, after which they become fertile and can begin mating. Adults appear to use the same breeding sites for several years. Larvae are thought to be primarily benthic feeders (organisms who obtain energy from the consumption of sedimentary material) and adults are thought to consume a variety of invertebrate prey and will occasionally consume other frogs and tadpoles.

**CLIMATE CHANGE CHALLENGE**

The Pacific Northwest has lost about 50 percent of its snowpack over the last 50 years. With less snowpack and hotter summers, more egg sacks and tadpoles (aka the larval stage) are stranded out of water and die.

STUDENT PAGE

LESSON 3 | SPECIES 6

Species: *Calidris canutus* (Red Knot)

**SPECIES INFORMATION**
Red Knots make one of the longest yearly migrations of any bird, flying more than 9,300 miles from south to north every spring; they repeat the trip in reverse every autumn. Red Knots concentrate in huge numbers at traditional staging grounds during migration. Delaware Bay is an important staging area during spring migration, where the Red Knots feed on the eggs of spawning horseshoe crabs. It is estimated that nearly 90 percent of the entire population of the Red Knot subspecies *C. rufa* can be present on the bay in a single day.

**CLIMATE CHANGE CHALLENGE**
The horseshoe crabs and the birds have to arrive at the same time if the Red Knots are going to make it to the Arctic to nest. This timing is critical since the birds need the energy from consuming the horseshoe crab’s eggs to finish the migration. Warming water temperatures could prompt the crabs to lay eggs before the birds arrive. Climate change could throw this critical meeting out of sync. In addition, rising seas and bigger storms are washing away the beaches where the horseshoe crabs come to mate.

At high tide thousands of mating horseshoe crabs gather along the water’s edge. Migrating red knots roughly double their body weight in 10 days of gorging on the crabs’ fatty eggs.

Patterns of Natural Selection

**DIRECTIONAL SELECTION:** Natural selection in which an extreme phenotype is favored over other phenotypes, causing the alleles causing that phenotype to be favored and shift over time in the direction of that phenotype.

**Example:** Prior to the industrial revolution in England the peppered moth had light coloration and lived on trees covered with light colored lichen. This provided camouflage against predatory birds. There were a few dark individuals in the population, but they were usually eaten by birds. However, once the industrial revolution began the light-colored lichens covering the trees were killed by sulfur dioxide emissions from the new factories. Without the light background of the trees, the light moths were more visible to birds and now the dark moths had a camouflage advantage. In 1848, the dark moths comprised 1% of the population and by 1959 they represented ~90% of the population.

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**Example:** A population of mice lives in a desert habitat with both sand and black volcanic rocks. The mice with black fur are able to hide from predators amongst the black rocks, and the mice with lighter fur are able to hide from predators in the sand. The mice with intermediate fur, however, stand out in all areas of the habitat, and thereby suffer greater predation. Natural selection would favor both light and dark colored mice, but select against mice of intermediate color.
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Type of Selection  Directional

2. A large population of southern yellow tailed hornbills is living in the Kalahari Desert. There are small amounts of rainfall and the summer temperature is very high. Yellow-billed hornbills are monogamous and will live in breeding pairs or small family groups. When they begin their courtship the male will feed the female for up to a month by bringing her small bits of food in his mouth. Females are attracted to males with richly pigmented feathers and less likely to choose a male with dull colored feathers. However, if the males have richer pigment they have trouble regulating their body temperature in warmer temperatures and often don’t survive to adulthood. As the effects of climate change increase what type of pattern of natural selection could we expect to see in the southern yellowtail hornbill population with respect to amount of pigment in males?

Type of Selection  Stabilizing
3. Fingered Poison Frogs are endemic to Trinidad. Females deposit small clutches of eggs in terrestrial nests. After hatching in July, one of the parents transports the tadpoles to a small water body, where they complete their development to metamorphosis. Suppose that due to changing climate conditions small bodies of water are only readily available during certain months of the year. Fingered Poison Frogs in southern Trinidad begin to only produce offspring during the spring months (April and May) and Fingered Poison Frogs in Northern Trinidad only produce offspring during the fall (September – October). What type of pattern of natural selection would we expect to see Trinidad’s Fingered Poison Frogs population with respect to time of reproduction?

Type of Selection  **Disruptive**

4. A study was conducted on *pocillopora damicornis*, a coral widely distributed in the Indo-Pacific. The study measured changes in reproductive timing associated with increased seawater temperature. In this study, the effect of increased seawater temperature on the timing of planula (free swimming coral larvae) release was examined during the lunar cycles of March and June 2012. Twelve brooding corals were removed from Hobihu reef in Nanwan Bay, southern Taiwan and placed in 23°C and 28°C controlled temperature treatment tanks. For both temperatures, the timing of planulation was found to be plastic, with the high temperature treatment resulting in significantly earlier peaks of planula release compared to the low temperature treatment. This suggests that temperature alone can influence the timing of larval release in *pocillopora damicornis* in Nanwan Bay. What pattern of natural selection would we expect to see in the *pocillopora damicornis* population if ocean temperatures continue to increases?

Type of Selection  **Directional**
CLIMATE CHANGE: a change in global or regional climate patterns; attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

<table>
<thead>
<tr>
<th>Problems Created By Climate Change</th>
<th>As a Result of Climate Change Natural Selection Would Favor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acclimation strategies become out of sync with changing seasons</td>
<td>1. Snowshoe hares that turn white later in the winter and/or turn brown earlier in the spring</td>
</tr>
<tr>
<td>2. Breeding ranges may shrink</td>
<td>2. Baltimore Orioles that expand their range to higher latitude during the breeding season</td>
</tr>
<tr>
<td>3. More rainfall and severe storms due to increased evaporation from warmer temperatures</td>
<td>3. Juvenile Magellanic Penguins with more fat (to avoid hypothermia) and/or that develop adult feathers earlier in life</td>
</tr>
<tr>
<td>4. Ocean acidification occurs when CO2 is absorbed by the ocean and creates carbonic acid</td>
<td>4. Shellfish with thicker shells</td>
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<tr>
<td>5. Loss of snowpack in mountainous regions</td>
<td>5. Cascades tadpoles with a shorter larval period and/or are more resistant to desiccation</td>
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<tr>
<td>6. Food sources may be out of sync with migration patterns</td>
<td>6. Red knots that can find other food sources and/or arrive earlier in Delaware so arrival is synced with horseshoe crab egg laying</td>
</tr>
</tbody>
</table>

Limitations to Evolutionary Adaptability:

1) There may not be enough (or any) genetic variation in the population for a given trait

2) A population may not be able to evolve fast enough (especially organisms with longer generation times) to keep up with the pace of climate change **, ***

*Teacher’s Note: Point out to students that these are all examples of directional selection.

**Teacher’s Note: Point out to students that if an organism cannot adapt to a changing environment it is in danger of extinction.

*** Teacher’s Note: This would also be a good place to remind students that evolution is NOT goal oriented and does NOT produce “perfect” organisms.
Natural Selection in the Face of Climate Change — Key

*** Please note students may come up with different traits that natural selection may act on. These are just possible answers. ***

**SPECIES 1 – SNOW SHOE HARE**

Climate Change Issue

Snow doesn’t come until later in the winter. Snowshoe hares that turn white later in the winter and/or turn brown earlier in the spring are camouflaged more effectively because they don’t stand out to predators.

**SPECIES 2 – BALTIMORE ORIOLES**

Climate Change Issue

Baltimore Orioles that shift their summer range north so they can find enough food and the correct habit for breeding as temperature rises and deciduous trees move north.
**SPECIES 3 – MAGELLANIC PENGUIN**

Climate Change Issue

More rainfall and severe storms due to increased evaporation from warmer temperatures select for juvenile penguins that are protected by adult plumage earlier.

![Graph showing number of individuals vs. day on which plumage provides protection to juvenile penguins.](image)

**SPECIES 4 – PACIFIC NORTHWEST SHELLFISH**

Climate Change Issue

Ocean acidification selects for shellfish that can form successful shells by despite low pH. (The issue with ocean acidification is with mollusks not being able to sequester the calcium carbonate to form shell material when they are growing.)

![Graph showing current and predicted future populations of shellfish vs. shell weight.](image)
**SPECIES 5 – CASECADES FROG**

Climate Change Issue

*Since there is less snowpack and therefore water is available for a shorter time, Cascades tadpoles with a shorter larval period would be selected for.*

![Graph showing number of days spent in larval stage vs. number of individuals.](image)

**SPECIES 6 – RED KNOT**

Climate Change Issue

*Horseshoe crabs may begin to lay eggs, an important food source for red knots, earlier in the year. Natural selection may select for red knots that arrive earlier in Delaware so arrival is synced with horseshoe crab egg laying.*

![Graph showing month red knots arrive in Delaware Bay vs. number of individuals.](image)
Notes: