Natural Selection
Teacher Handout

Module Overview

Students will be introduced to the concept of variation and natural selection by filling out a worksheet during a class discussion. Then they will break into groups of three to simulate natural selection acting on a population of black and white peppered "moths" in two different environments. To accomplish this, they will have 10 seconds to pick up as many black and white circles as they can from a piece of black construction paper. Then they will count how many of each color they caught (they will most likely pick up more white circles, since those would not have blended in as well against a black background). They will repeat the activity against a white background and see which color moth will increase in frequency.

Curriculum Links
Missouri Science Standards

EC.4.3.C.9-12.a. Describe how variation in characteristics provides populations an advantage for survival

EC.4.3.C.9-12.b. Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits)

EC.4.3.C.9-12.c. Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance)

EC.4.3.C.9-12.d. Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

EC.4.3.C.9-12.e. Given a scenario describing an environmental change, hypothesize why a given species was unable to survive

Next Generation Science Standards

HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. *[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]*

Goals

1. Variation in traits gives populations an advantage for survival
2. Natural selection increases the frequency of traits in a population that improve survival and reproduction
3. Environmental factors can be agents of natural selection

Timing

This module takes about 60-80 minutes to complete

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Kit Materials
Included by the Young Scientist Program

- 10 ziploc bags of black and white hole punched circles
- 20 pieces of construction paper (10 black, 10 white)
- 30 student handouts

The Young Scientist Program - Teaching Kits
http://ysp.wustl.edu
Washington University School of Medicine
Funding provided by The Leon Lowenstein Foundation

YOUNG
SCIENTIST
PROGRAM

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Lesson Design Tool

Course: Teacher:

Week of: Grade Level:

CONTENT AREA:	DIFFERENTIATED INSTRUCTION/CROSS CONTENT INTEGRATION
Goals: Big Idea/Concept	*HOW will you teach the content? (groups, strategies, accommodations, variation, etc.)*
1. Variation in traits gives populations an advantage for survival 2. Natural selection increases the frequency of traits in a population that improve survival and reproduction 3. Environmental factors can be agents of natural selection	-Students will be introduced to the concept of variation and natural selection by filling out a worksheet during a class discussion. -students will break into small groups to simulate natural selection acting on a population of black and white peppered "moths" in two different environments (they will have 10 seconds to pick up as many black and white circles as they can from a piece of black construction paper; then they will count how many of each color they caught) -the class will come together as a large group at the end to discuss the results of the activity
Grade Level Expectation/Objective: *(WHAT are you going to teach?)*	
EC.4.3.C.9-12.a. Describe how variation in characteristics provides populations anv advantage for survival EC.4.3.C.9-12.b. Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) EC.4.3.C.9-12.c. Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance) EC.4.3.C.9-12.d. Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection EC.4.3.C.9-12.e. Given a scenario describing an environmental change, hypothesize why a given species was unable to survive	
Essential Question(s)/DOK: *Higher Order Questions (scaffolded questions to get to Big Idea)*	
Assessment/Performance Task: *How will students SHOW what they have learned?*	**Teacher Reflections/Student Work Analysis**
Responses on handout/discussion questions	

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Vocabulary	Vocabulary Strategies	Reteaching Strategies
natural selection, genetic variability, genetic homogeneity, adaptation, alleles, mutations, genotype, phenotype, evolution		
Technology/Manipulatives		

Background

Natural selection is a nonrandom process that makes biological traits become either more or less common in populations due to how they affect an organism's reproductive success. In other words, organisms with favorable traits survive and reproduce more than organisms without those traits. By reproducing more, they pass those favorable traits on to the next generation, thereby increasing the proportion of individuals with those traits.

There are five steps to Darwin's theory of natural selection, which will be explained in further detail below:

1. There is a struggle for existence (resources are limited).
2. There is variation in traits.
3. There is differential survival and reproduction (individuals with beneficial traits will survive and reproduce more than individuals without those traits).
4. Some of this variation in traits is heritable (the beneficial traits can be passed on across generations).
5. Over time, this process can lead populations to change and evolve.

Charles Darwin first described natural selection in his landmark 1859 book, On the Origin of Species. This type of selection was named "natural" (as opposed to artificial selection), to differentiate it from selective breeding, which was very common at the time.

The effect of natural selection on populations of peppered moths in England was demonstrated nearly a century later by the British geneticist, Bernard Kettlewell. Peppered moths come in two variants: a dark variant and a light variant (both are members of the same species). When lichen covers trees, the light variant blends in well and is camouflaged from predators, while the black variant stands out and is at higher risk of being eaten. When lichen does not cover trees (such as in polluted areas where the lichen cannot grow and the trees are covered in dark soot), the dark variant of moths is better camouflaged. In his 1956 work, Kettlewell showed that the polluted environment surrounding Birmingham selected for the dark-colored variant of moth, whereas the more pristine woodlands near Dorset selected for lighter-colored moths.

Struggle for Existence

Darwin read "An Essay on the Principle of Population," where Reverend Thomas Malthus wrote that while food supply grows arithmetically, an unchecked population grows exponentially.

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Since resources are limited, this leads to a "struggle for existence." Darwin applied this principal to the observations he made of nature, and realized that survival wouldn't just depend on random chance. Organisms with beneficial traits would have a better chance of surviving the struggle for existence than organisms with less favorable traits.

Variation in Traits

Organisms in a population are different from one another. Some are faster, some are stronger, some are better hunters, and so on and so forth. **Genetic variability**, (diversity in the alleles present in a population) is critical for evolution. The opposite of having a lot of genetic variability is having **genetic homogeneity**, where there is no variation for a particular trait in a population. Species without much genetic variability are more at risk of going extinct due to disease or a changing environment. Species that have a lot of genetic variability are more likely to have some individuals in the population with alleles that make them immune to various diseases or help them survive in a new environment.

So, not only is a selective pressure (such as predation on moths by birds) required for a population to evolve, there must also be a variety of phenotypes to be selected. An example would be a case where no moths carry the allele for dark color in an environment that becomes polluted, with only dark-colored trees. In this situation, there are no black moths to be selected for, and it is possible that all the moths will be eaten and go extinct!

Differential Survival and Reproduction

A beneficial trait can be selected because it makes an organism more fit in its environment. A beneficial trait that is acted on by natural selection is called an **adaptation**. Individuals with beneficial traits that allow them to survive well in their environment will tend to live longer than individuals without those beneficial traits. Surviving longer will allow these individuals to reproduce more.

Inheritance

Biological traits are controlled by <u>genes</u>: pieces of genetic material that can be inherited. Genes may occur in several various forms, or **alleles**, such as for light or dark coloration in moths.

New alleles are introduced through **mutations**, which are changes in genes at the molecular level (DNA). A **genotype** is the set of alleles that an individual has for a gene (for example, in humans, a person may have the genotype AB at their blood antigen gene, where they received an A allele from one parent and a B allele from the other parent). A **phenotype** is the trait that gets expressed (a person with the AB genotype will have the phenotype of A and B antigens on the surface of their blood cells).

Time

Natural selection is a key feature of adaptive evolution, or the emergence and propagation of beneficial traits in populations. Over very long periods of time, the beneficial alleles will accumulate in the population. **Evolution** is the change in allele frequencies over time. This can happen due to natural selection (or by other forces such as random genetic drift in small populations, gene flow between different populations, and mutation).

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References and Further Information
1. "Evolution 101: Mechanisms of Evolution."
http://evolution.berkeley.edu/evosite/evo101/IIIMechanisms.shtml (*This gives a brief background on the main forces driving evolution.*)

2. "Natural Selection—Crash Course Biology #14."
http://www.youtube.com/watch?v=aTftyFboC_M (*This 13-minute YouTube video has an animation about peppered moths and explains how natural selection works in this system. It also gives background on Darwin and the Galapagos finches, as well as inbreeding—which went on in Darwin's own family.*)

3. "Natural Selection." http://plato.stanford.edu/entries/natural-selection/ (*This gives a much more in-depth background about natural selection.*)

4. "10 Examples of Natural Selection." http://dsc.discovery.com/tv-shows/curiosity/topics/10-examples-natural-selection.htm (*This lets you flip through 10 different examples of natural selection in: peppered moths, rat snakes, pesticide-resistant insects, Galapagos finches, peacocks, warrior ants, deer mice, nylon-eating bacteria, lizards, and humans.*)

5. "Natural Selection." http://www.neok12.com/Natural-Selection.htm (*This Web site has a list of about 25 video links about natural selection.*)

6. Darwin, Charles, 1859. On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life (1st ed.), London: John Murray. (*This is the citation for Darwin's book on natural selection.*)

7. Kettlewell, 1956. "Further experiments on industrial melanism in Lepidoptera" Heredity, 10: 287-301. (*This is the citation for Kettlewell's experiments on peppered moths.*)

Materials for Each Group of 3 Students
•   1 ziploc bag of black and white circles
•   2 pieces of construction paper (black, white)

Clean-up
Make sure the students put all of the hole punches back into the zip lock bag when they are done with the activity. They should paperclip the bag back to the white and black paper, so it's ready for the next group of students to use.

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Natural Selection Introduction: (Fill in the Blanks!)—ANSWER KEY

Have you ever wondered why giraffes have long necks or why dogs have such a good sense of smell? Animals tend to have traits that are well suited to their natural environments and give them a better chance to **survive** and **reproduce**. The giraffe's **long neck** allows it to reach fruit in tall trees, and having a good nose means the dog can track down **food/prey** from a great distance.

But, how do such favorable traits become common in animal populations? The answer is through **natural selection**! Favorable traits, like having a long neck for a giraffe, make the organism more likely to **survive and reproduce**. Over time, these traits become more common in the population. In other words, the organism's environment *selects* for these **traits**.

A classic example of natural selection is the case of the peppered moth, made famous by the British scientist, Bernard Kettlewell. Peppered moths have two common varieties: dark-colored and light-colored. Kettlewell knew that dark-colored moths were more common in polluted industrial areas than in rural areas. Light-colored moths, however, were more common in the **rural** areas. He **hypothesized** that dark moths were best suited to the polluted environment because they were able to blend in better to the darkened vegetation and avoid **predators**. By contrast, he thought that these dark moths were more likely to be seen by **predators** in the clean, rural environment. To investigate, Kettlewell released a mixed group of light and dark-colored moths into each of these areas. He observed that **light** moths indeed survived best in the rural area and **dark** moths in the polluted area. Kettlewell had demonstrated **natural selection** in action!

For today's activity, you will play the part of the predator by trying to 'eat' as many moths as possible in light and dark environments to simulate Kettlewell's results. You'll take it one more step for the second half of the activity by using chopsticks to prey on mixed colored frogs in a variety of environments to see how an environment selects for certain colors of frogs.

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Concept Check: For each of the environments below, list one trait that would be favored by natural selection and one that would be selected against.

Environment	Traits that would be selected for	Traits that would be selected against
Freshwater Pond	-fins	-lungs
Tundra (very cold, no trees)	-white fur (to blend in with the snow) -thick fur (to stay warm) -small ears (small surface area will cause less heat loss)	-being cold-blooded
Amazon Rainforest	-large ears (to increase heat loss, will help regulate body temperature) -very tall shoots (plants)	-large fat layers (animals)

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Activity: Natural Selection in Action—ANSWER KEY

Peppered Moth Simulation Methods/Protocol:

Set up: Place the black paper in the center of your group. This represents a tree in a polluted environment. Empty all of the black and white circles from the Ziploc bag onto the black paper. The black circles represent the black version of the peppered moth, and the white circles represent the white version of the peppered moth.

Begin: Birds eat peppered moths. In this simulation, you will be the bird. You will have 10 seconds to pick up as many "moths" as you can and put them into a pile in front of you. You may use only your thumb and pointer finger from one hand (to simulate a bird's beak). When time is up, count how many "moths" of each color you got. Record the results from everyone in your group in the table.

<p style="text-align:center;color:red;font-weight:bold;">EXAMPLE OF HOW STUDENTS MIGHT FILL OUT THE TABLE</p>

Peppered Moth Simulation in POLLUTED Environment			
Group Member	White "moths" eaten	Black "moths" eaten	Total "moths" eaten
Name 1: Tierra	26	5	26 + 5 = 31
Name 2: Christian	30	11	30 + 11 = 41
Name 3: Marcus	20	7	20 + 7 = 27
TOTAL NUMBER OF MOTHS EATEN (add up the numbers from each column)	26 + 30 + 20 = 76	5 + 11 + 7 = 23	31 + 41 + 27 = 99
PERCENTAGE OF EACH TYPE OF MOTH EATEN (divide the number eaten of each type by the total number of moths eaten)	76 / 99 = 76.8%	23 / 99 = 23.2%	

Set up: Place the white paper in the center of your group. This represents a tree in a clean environment. Now put all of the black and white circles onto the white paper.

Begin: Repeat what you did last time. You have 10 seconds to collect as many "moths" as you can.

Peppered Moth Simulation in CLEAN Environment			
Group Member	White "moths" eaten	Black "moths" eaten	Total "moths" eaten
Name 1: Tierra	6	30	6 + 30 = 36
Name 2: Christian	9	32	9 + 32 = 41
Name 3: Marcus	15	45	15 + 45 = 60
TOTAL NUMBER OF MOTHS EATEN (add up the numbers from each column)	6+ 9 + 15 = 30	30 + 32 + 45 = 107	31 + 41 + 27 = 137
PERCENTAGE OF EACH TYPE OF MOTH EATEN (divide the number eaten of each type by the total number of moths eaten)	30 / 137 = 21.9%	107 / 137 = 78.1%	

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Peppered Moth Simulation Analysis—ANSWER KEY

1. In the polluted environment (which caused the trees to be black) which color moth survived better in your simulation?
    Black

2. Why do you think that color of moth survived better?
    Because it blended in better. This protected it from being eaten by birds, so black moths survive and reproduce more. Natural selection acts to increase the frequency of black moths in the population.

3. In the clean environment (which caused the trees to be covered in white lichen) which moth survived better?
    White

4. In the clean environment, which color moth will increase in frequency in the next generation due to natural selection?
    White

5. Color in peppered moths is similar to eye color in humans. In humans, the "b" form of the eye color gene causes blue eyes. The "B" form of the gene causes brown eyes. Humans have 2 copies of each gene, one from each parent. If you are "bb" (you got a "b" from mom and a "b" from dad), you have blue eyes. If you are "BB," you have brown eyes. The "B" brown copy is dominant (shown by the capital letter), meaning you only need one to have brown eyes. So if you are "Bb," you have brown eyes.

    In peppered moths, "m" causes white color and "M" causes black color. What color would each of the following individuals be?
    mm: white   MM: black   Mm: black

6. Scientists have researched actual populations of peppered moths. In the 1800s, most peppered moths found in England were white, and lived in forests where trees were covered in white lichen. Over the next hundred years, the black form of the moth became more and more common in the forests near big cities. What do you think might have caused the black form to become more common? (Hint: what do you think was happening to the trees, and why?)
    Cities began to produce a lot more pollution in the 1800s because of the Industrial Revolution. The white lichen on the trees began to die because of the pollution, so the trees looked darker. Now birds could see the white form of moth better (they stood out more on the darker tree background), so more white moths got eaten and more black moths survived and reproduced. This increased the frequency of black moths over time.

7. In the 1950s, a scientist named H.B.D. Kettlewell investigated to see if natural selection was directing this increase in black moths. He put the same number of black and white moths in a polluted forest, and also in a clean forest. He counted the number of each type that got eaten by birds (like you simulated in your experiment). Below are his results:

Kettlewell's Actual Results		
	Number of White form eaten by birds	Number of Black form eaten by birds
Clean woods	26	164
Polluted woods	43	15

a) Is natural selection acting on the color gene? Yes.

b) Does your data support or contradict Kettlewell's data? Supports it.

8. In 1950, 90% of all peppered moths were black. England passed several important laws in the 1950s. In 2010, only 30% of peppered moths were black. What type of laws do you think England passed that might account for the decrease in the black form of peppered moths (and the increase in the white form)?
    England passed anti-pollution laws, which helped clean up the air and the environment. This let the white lichen grow back on the trees, making white moths increase in frequency because they could survive and reproduce better (since they blended in better with the trees).

9. If the "M" allele was lost in the peppered moth population (all individuals were "mm"), what might happen to the population if the environment becomes polluted again?
    If the M allele is lost, all of the moths will be white. If the environment becomes polluted, the population might go extinct because the white moths will not be good at escaping bird predators.

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Natural Selection: Synthesis—ANSWER KEY

10. Describe how variation in traits gives populations an advantage for survival.

Having variation in a population buffers the population against changes in the environment. This is important, because the environment is constantly changing. Populations with more variation have more adaptive potential.

11. Wolves have genes that give them a very powerful sense of smell (much more powerful than humans). This is an adaptation that was favored by natural selection (wolves with a better sense of smell survived longer and reproduced more offspring—who also got the genes for a better sense of smell—thereby increasing the frequency of those genes in the population). Give an example of TWO more adaptations in other organisms that may have resulted from variations that were favored by natural selection. (Think of new examples—not ones we've already talked about today.)

Elephants have big ears that allow them to dissipate more heat (natural selection maybe have acted to increase ear size in elephants because it helped them survive the heat better).

Bats are excellent at using echolocation (natural selection may have acted to improve the use of echolocation in bats because it helped them find their prey at night better).

Humans have opposable thumbs (natural selection may have acted to increase the opposability of thumbs because it helped ancient human ancestors make tools better to survive).

12. Cheetahs are very inbred. Because of this, they have very high levels of genetic homogeneity, to the point where they are almost all genetically identical. Why does this put cheetahs at a very high risk of extinction?

If a disease hits the population, or if the environment changes, there is no variation for natural selection to act on. The species may not be able to adapt, so it would go extinct.

13. There is a population of bears with thick fur and thin fur. In cold weather, bears with thin fur do not survive as long because they freeze. In warm weather, bears with thick fur don't do as well because they overheat.

a) In a very cold climate, which type of bear will natural selection favor: bears with thick fur or thin fur?

Thick fur.

b) Why did you make that prediction?

Thick fur helps keep bears warm, which will let them survive and reproduce more than bears with thin fur that freeze to death.

c) If the climate gets very hot due to global warming, which type of bear will natural selection favor: thick or thin fur?

Thin fur.

d) Why did you make that prediction?

Thin fur prevents the bears from overheating. While the bears with thick fur overheat and die, the bears with thin fur will survive and reproduce better, passing more of their genes to the next generation.

e) A disease kills all of the bears with thin fur in the population. Over the next 50 years, the climate gets significantly hotter due to global warming. The polar bear population goes extinct. Why might this polar bear species have been unable to survive?

When the bears with thin fur went extinct, there was no longer any variation left for fur thickness in the bear population (the population was genetically homogenous). Then when the climate got hotter, the bears all had thick fur, and they overheated and died. There was no variation for selection to act on, so the population went extinct.