Content Connections

Natural Selection

Introduction

The STeLLA program intentionally places student thinking at the foreground of student learning. The purpose of this document is to support and further your own understanding about your students' possible ideas about natural selection and ways these ideas may influence their ability to develop a conceptual understanding about how populations of organisms change over time. You can use it to develop your knowledge and skill in anticipating and responding to student ideas and confidently guiding student learning.

The content is written with you, the teacher, in mind. It presents subject matter knowledge that is tied to the lessons you will be teaching in the STeLLA program. It provides a rationale for sequencing and structuring student learning experiences to address shortcomings in typical instruction that have been shown to lead students to miss some important con+ceptual links between their understanding of natural selection and how populations of organism change over time. Common student ideas are described throughout this document. Although these common student ideas are scientifically inaccurate, these ideas, when surfaced and made explicit to students, can be used as building blocks to a more meaningful and scientifically accurate understanding of the science content.

Getting Started: Structuring learning experiences that support conceptual understanding

The *Natural Selection* lesson sequence is a series of six lessons that focus on how populations of organisms change over time through the process of natural selection. The lessons start with an introduction to the phenomena students will be studying throughout the first five lessons—changes that occurred in a population of stickleback. Darwin's idea of natural selection and Lamarck's idea of acquired characteristics are introduced in Lessons 1 and 2 and are used as a lens by which students begin to think about how the changes within the stickleback population occurred. The goal is not to reinforce Lamarckian ideas; rather, the introduction of acquired characteristics provides the opportunity to directly surface student ideas that relate to Lamarckian ideas and challenge them accordingly. Even in high school, students may hold on to ideas that individuals within a population need or want to change based on environmental demands. During the first two lessons, students then develop a body of evidence to support a Darwinian perspective of natural selection over Lamarckian ideas. However, it is important to note that students' Lamarckian conceptions are tenacious and persist even as students are confronted with a strong body of evidence that supports Darwin. Throughout the remaining four lessons, the teacher needs to provide opportunities to surface and challenge students' Lamarckian ideas. These lessons provide ample opportunity for teachers to use the STeLLA Student Thinking and Science Content Storyline Lenses to support students as they wrestle with and make sense of science ideas and construct a coherent understanding of natural selection.

Lessons 3, 4, and 5 serve to deepen and enhance students' understanding of natural selection. In Lesson 3, students explore Darwin's ideas further with the introduction of the four factors of natural selection. Students begin thinking about how these factors could have caused the changes in the stickleback population by examining data and looking for evidence that supports or refutes the four factors. In doing so, students develop a deeper understanding of natural selection and how it can change a population of organisms over time. In Lesson 4, students refine their understanding of natural selection

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by using a computer simulation to model and test the interactions among the four factors. The goal is for students to determine if the four factors can fully account of the changes that occurred in the stickleback population. In Lesson 5, students use what they have learned in previous lessons and generate an evidence-based explanation concerning how the changes to the stickleback population occurred. This explanation includes evidence they developed from previous lessons and the science ideas they learned. In Lesson 6, students apply their knowledge and understanding of natural selection to a different phenomenon. The phenomenon they will explain concerns the changes that occurred to the medium ground finch population after a severe drought in 1977 on the Galápagos island of Daphne Major. They engage in argumentation by developing a series of claims supported by evidence concerning the medium ground finch population. They then critique these claims based on the strength of the evidence and the reasoning they use to justify their claims.

To ensure the *Natural Selection* lessons build toward a conceptual understanding of natural selection, the lessons were developed with and are closely aligned to the *Next Generation Science Standards* (NGSS). Table 1 shows the Performance Expectation (PE), Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs) and the Crosscutting Concept (CCC) upon which the lessons are based and were used to guide the development process. Additionally, the table highlights the Main Learning Goals for each of the lessons.

As you teach the *Natural Selection* lessons, look for opportunities to make science ideas embodied in the DCIs, the CCC of cause and effect and the SEPs explicit to students. Although you will find only SEP 6: Constructing explanations called out in the Table 1, there are numerous places throughout the lesson were students are engaged in aspects of additional SEPs, which serve to support students evolving knowledge and use of the practice and deepen their conceptual understanding of natural selection. Likewise, the crosscutting concept of cause and effect is highlighted within this lesson sequence. There are places in the lessons where students are asked to apply ideas of cause and effect to the changes that occurred in the stickleback and ground finch populations. Allow students the time and space needed to wrestle with cause and effect ideas as they apply these conceptions to the phenomena they are explaining.

The narrative that follows provides insight into common ideas that students may have concerning how changes occur within populations of organisms over time. These common student ideas are strongly grounded in Lamarckian views of how populations change. The intent is for you to understand what the common student idea is and how the scientifically accurate idea is different. As you read though the list of nine common student ideas, you will encounter STOP AND THINK sections. The purpose of these sections is to help you connect the information you are reading about to your teaching of the *Natural Selection* lessons. You may find it helpful to use these STOP AND THINK sections as an opportunity to examine how the STeLLA lenses and strategies support and enhance student learning of the natural selection science content. Happy Reading!

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Table 1: NGSS Alignment of *Natural Selection* Lessons

<table>
<tr><td colspan="3">HS-LS4 Biological Evolution: Unity and Diversity</td></tr>
<tr><td colspan="3">Performance Expectation HS-LS4-2
Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) organisms have what they need to survive and reproduce, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment</td></tr>
<tr><td colspan="3">Crosscutting Concept(s)
Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td></tr>
<tr><th>Student Learning Goals</th><th>Disciplinary Core Ideas</th><th>Science Practices</th></tr>
<tr><td>Lesson 1: Populations of organisms change over time (evolve) and there have been competing explanations of what causes populations to change.

Lesson 2: Living populations change over time as organisms with traits that are well suited to the environment are better able to survive and reproduce. This leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

Lesson 3: The four factors of natural selection are supported by evidence and can be used to explain the changes in the Loberg Lake stickleback population.

Lesson 4: The interaction of four factors of natural selection influences the changes that occur in populations of organisms.

Lesson 5: A change in population is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) variations in traits inherited from organisms' parents, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

Lesson 6: The factors of natural selection that explain the changes in one population are generalizable and can be used to explain changes in other populations.</td><td>LS4.B: Natural Selection: The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.

LS4.B: Natural Selection: Natural selection occurs only if there is both (1) variation between organisms in a population and (2) trait variation—that leads to differences in performance among individuals.

LS4.C: Adaptation: Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a population, (3) individuals have what they need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.</td><td>Constructing Explanations and Designing Solutions
Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</td></tr>
</table>

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Common Student Idea #1

Populations change because individuals adapt deliberately or through nonheritable processes because they *need* a given trait.

Students may have ideas that individuals can change their traits simply because they "want to" or "need to." This idea of individuals deliberately adapting because of want or need is rooted in the Lamarckian notion of acquired characteristics. Paramount to this view is the conception that individual organisms can change a characteristic or trait if it helps to improve the organism's overall fitness. (The term fitness refers to the reproductive success of a genotype. This is measured by the number of offspring that are produced by individuals within a population who possess a certain gene variation or set of variations.) The new version of the trait that was changed can then be passed down to the next generation of offspring.

Students may also use genes in their Lamarckian descriptions. For example, some students may think that because moths do not want to be eaten by birds, they change the genes that control their wing coloration. This, as we know, is not the case. Instead, moths, like many organisms, show variation in the trait for wing color. During the industrial revolution, pollution led to tree trunks becoming darker. Lighter colored moths then stood out against the trunks and could be seen more easily by birds. This led to a selective pressure that gave dark-colored moths an advantage because they blended in to the tree trunks better. This meant they had more opportunity to live long enough to reproduce, at which point they may pass on their trait of being dark colored. After several generations, the average color of the moth population was darker. This moth example exemplifies Darwinian ideas of how populations change over time due to natural selection. Individuals have different versions of the same trait. Because of these variations, some individuals may be better suited to survive than other individuals from the same population. Those individuals that are better able to survive are more likely to reproduce and pass their favorable trait variations on to their own offspring.

Due the pervasive and somewhat commonsense nature of Lamarckian views, *Natural Selection* Lesson 1 has students examine both Lamarckian and Darwinian views of how populations of organisms change over time. Students read and then apply these two views to the changes that occurred in saltwater stickleback populations as they became trapped in freshwater lakes. In Lesson 2, students look for evidence that supports Darwin's and/or Lamarck's ideas. As students complete the lesson, the evidence they compile strongly supports a Darwinian view of how populations of organisms change over time. Doing so, directly challenges the common student idea that populations change because individuals adapt deliberately or through non-heritable processes because they need a given trait

Common Student Idea #2

An individual's traits change throughout her or his lifetime based on use or disuse. These acquired changes are passed on to the offspring.

Natural selection and acquired characteristics are similar in some ways. Both concepts assume that an individual organism can pass his or her traits on to offspring. Likewise, both assert that it's the individual

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organism's ability to survive and reproduce that determines the traits that get passed on to the next generation. Although these two ideas seem similar, they deviate in an important way. Lamarck's theory of acquired characteristics is based on the idea that the traits that make up an individual organism are mutable and can change based on use or disuse. Whereas natural selection is based on the idea that an organism's traits are fixed and these traits cannot be changed within an individual's lifetime. It may seem absurd that students in a high school biology class would espouse Lamarckian ideas. However, the following paragraph describes a real example where high school students used Lamarckian thinking to explain the disappearance of a vestigial structure within the orca (killer whale) lineage.

An ancestor to the modern orca was the Basilosaurus (figure 1). Dated fossils of this organism tell scientists that it lived 35 to 45 million years ago in vast ocean environments. Upon comparison, Basilosaurus and the orca look somewhat similar and have certain morphological features (i.e.; dorsal and pectoral fins, sleek and streamlined body, huge pointy teeth) in common (figure 1). However, when skeletons are compared (figure 2), Basilosaurus has a small, bony, appendage-like structure toward the end of its body. This rear appendage is attached to the vertebral column of the Basilosarus. In modern orcas, this bony appendage is absent. High school students were asked how a biologist would explain *how* the lineage that led to orcas changed over time—from an ancestral group that had rear appendages to the modern group that does not have rear appendages. To the astonishment of the teacher, many students responded that the small, bony appendage evident in the Basilosaurus skeleton was not needed, so over time ancestors to the modern orca lost the appendage due to disuse. When pressed for additional information, some students believed that the appendage would just vanish, while others believed that, over time, the appendage would become smaller and smaller and eventually just be another bone in the vertebral column.

The scientific answer to this orca ancestor question aligns with a Darwinian view of change and goes beyond natural selection to encompass an evolutionary process. The answer includes the following components: variation, inheritance, origin of variation, fitness, and evolutionary change in a population.

- Variation: Within the population of the ancestral group of whales, some had longer rear appendages than others.
- Inheritance: The differences in the length of the rear appendage have a genetic component and can be inherited.
- Origin of variation: The differences in rear appendage length that have a genetic component came about through mutation.
- Fitness: More offspring are born than survive. The environment favored shorter rear appendages. So, individuals that had shorter rear appendages had a survial advantage over indivduals who had longer appendages. This resulted in individuals who had shorter rear appendages having more offspring, on average, than those with longer appendages.
- Evolutionary change: The frequency of individuals with shorter and shorter rear appendages increased over time. Over millions of years, this process resulted in a lineage that did not have a rear appendage.

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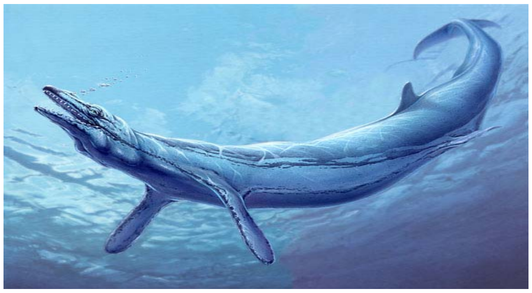
Figure 1

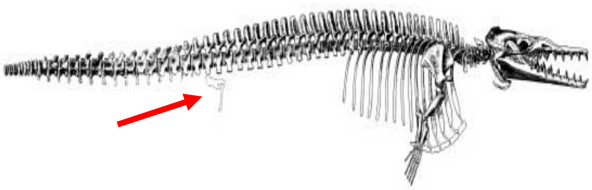
Basilosaurus



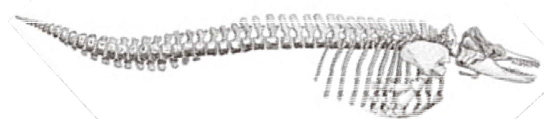
Orca

Figure 2

Basilosaurus Skeleton



Orca Skeleton



STOP AND THINK

Common Student Idea #2, like Common Student Idea #1, is directly challenged in Lessons 1 and 2 of the *Natural Selection* lessons. This occurs when students are asked to apply Lamarckian and Darwinian perspectives to the stickleback fish scenario. However, Lamarckian ideas of change within populations can be very tenacious and may need to be surfaced and challenged in Lessons 3 and 4 when the lesson focus shifts to the four factors that comprise natural selection. Likewise, teachers need to carefully consider the questions: What Lamarckian ideas do you think your students possess? Will just the act of surfacing these ideas be enough to challenge these ideas? What do you do in your own classroom when these common student ideas continually show up in class and small-group discussions?

Common Student Idea #3

Change occurs in inherited traits of a population because individuals observe the traits of other, successful individuals and model their appearance or habits.

This common student idea implies that traits are malleable and can change. However, an individual's traits are fixed and changes in the traits of a population depend on those traits being inherited by future

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generations. This means that the trait must be one that is coded for in DNA, the material in cells that provides all of biological instructions that make species unique. If an individual simply observes the traits of another and mimics those traits, they are not coded in DNA and thus would not be inherited by any offspring.

As you might have already inferred, this common student idea, like the first two, is rooted in Lamarckian thinking. Aspects of this common student idea are pervasive and used, unknowingly at times, by high school students to explain how changes can occur to a population of organisms over time. This is evidenced in the student statement below. In this example, a small group of students is engaged in a discussion about how Lamarck would explain the changes that occurred to a black bear population that resulted in a proportion of individuals having large front claws. All the students agreed with how Lamarck would explain the changes, but they argue against the Lamarckian perspective that continued use makes for stronger and larger claws and that this large claw trait would then be passed down to offspring. However, during a brief pause in the conversation, one student offers an alternative idea.

"I think that if bears use their claws more, maybe they can teach their kids to do that. So then that thing or knowing how to do something better can get passed down. It wouldn't be passed down like a physical trait but something like a behavioral one. Maybe?"

What does this student think about changes that occur in populations over time? Without more detailed information it is difficult to answer this question. Does the student think that a trait controlling certain innate behaviors can be changed during an individual's life and then passed down to offspring? Or, does the student believe that using claws more or in a different way is a learned behavior that can be taught to offspring, who in turn teach this behavior to their own offspring. Without the use of probe questions, we may never find out what a student is actually thinking.

STOP and THINK

What probe questions could you ask to surface student ideas about Lamarck's notion of how populations of organisms change over time? What challenge questions could you ask that would challenge Lamarckian ideas of population change? When during the lessons would you ask these questions?

Common Student Idea #4

Changes in a population occur because there are gradual changes in all individuals.

Changes that occur to a population over time are due to natural selection working through trait variations that individual organisms within a population possess. The individual organism either has a certain trait variation or not. The environment may then favor a certain trait variation, meaning the trait can help the organism that possesses it to better survive and reproduce. If the environmental pressure remains the same and the trait variation continues to enhance the fitness of organisms who have it, the trait will, over generations, increase in frequency.

This idea that changes in a population occur because there are gradual changes in all individuals has, yet again, a basis in and draws upon Lamarckian ideas. Lamarck's notion of acquired characteristics asserts that individual organisms can change their traits based on need or want. This can manifest through use

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or disuse of a certain physiological or behavioral feature or characteristic. Since all organisms within a population are living in the same environment and are subject to the same biotic and abiotic factors, these changes can occur to all or most individuals within a population, depending on whether an individual uses, or not, the feature that helps to increase survival. Many students use what they have learned previously about genetics and assert genes that control traits can undergo subtle changes. Students will often refer to this changes as a mutation. However, this is not a scientifically accurate idea as mutations are random events and only rarely improve an organism's chance of surviving and reproducing. Nonetheless, students will assert that these subtle genetic changes do occur and can help an organism respond to environmental challenges. These subtle trait variations are then passed on to offspring, who in turn build on the changes that were initiated within the parental generation.

STOP AND THINK

This common student idea can be somewhat difficult to surface and challenge if students are using a genetic basis to rationalize and explain their thinking. Without the use of probe questions, teachers may not fully understand what students actually think is occurring to the genes of individuals. Students may indicate that changes occurring to populations can happen when certain genes and accompanying traits within individuals are favored by the environment over time. This response is accurate but incomplete. Without the use of questions that probe for a deeper understanding, students who respond in this manner could also believe that these genetic changes occur gradually within the genes of all individuals within a population. What questions could you ask to elicit student thinking concerning this common student idea? What probe questions could you ask? Where in the lessons would it be appropriate to ask these questions?

Common Student Idea #5

Changes in the environment cannot lead to changes in the traits of populations living in that environment.

Individuals who are better adapted for the environmental conditions are more likely to survive long enough to reproduce. It can be said that these traits are then selected for or favored by the environment. The traits that made them well suited for the environment can be passed on to offspring. Assuming that the environmental conditions stay the same, the offspring that inherit the specific traits are also more likely to survive long enough to reproduce. This selection of traits means that some individuals inherit and pass on traits that confer advantages. This can cause changes to a population over time as individuals who do not carry traits that are a selective advantage may not survive to pass their traits on to the next generation. So, the environment does provide the selective pressure that leads to change in a population over time.

Invasive species can be used to exemplify the idea of how the environment can favor or select certain traits over others. For example, the Russian Olive (*Elaeagnus angustifoili)* is a tree that is native to Europe and Asia, grows up to 30 feet tall, has silvery-green foliage, and produces little, olive-shaped fruits (figure 3). This tree can reproduce via seed dispersal or by underground rhizomes. Seed dispersal is wide spread and aided by birds that use the fruits as a food source. This plant has traits that make it both heat and shade tolerant and extremely good at exploiting available water sources and also give it the ability to fix-nitrogen within its roots. As a result, the Russian Olive grows extremely well in riparian

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waterways located in arid regions of the Rocky Mountain West. Due to the environmental factors that make up Front Range riparian areas and the traits that make the Russian Olive well suited for this environment, this invasive plant can aggressively out-compete native species that grow in these habitats and easily overtake areas once dominated by native plant populations.

Figure 3
Russian Olive

Be aware that as students begin to see the important role the environment plays in natural selection, they may overemphasize the idea that nature actively selects certain trait variations. This idea of actively selecting certain traits that are beneficial to one organism over another can lead to the idea that natural selection leads to perfection (Common Student Conception #8). Help students to understand that the environment or nature does not select a trait variation. Rather, there is a set of environmental conditions where populations of organisms reside. These environmental conditions can be quite static or change based on shifting abiotic and biotic factors. An individual's traits may help it to be better suited to certain environmental changes and allow the organism to survive, reproduce, and pass on these well-suited traits to offspring. However, the opposite could also be true. The environment could change, where a certain trait variation is either a detriment to survival or has neither positive nor negative consequences, resulting in a neutral effect.

Common Student Idea #6

All individuals within a population are the same. Any differences are trivial and unimportant.

AND

Common Student Idea #7
Every difference has a purpose.

Both of these common student ideas are different sides of the same coin and, therefore, will be discussed together. Both concern ideas surrounding cause and effect. As you read the section below, think about ideas you have heard students in your classroom say that relate to either Common Student Idea #6 or Common Student Idea #7. What experiences do students need to challenge these ideas? Are these ideas difficult or easy to contend with?

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For some species, variation within a trait may be hard to distinguish, making it look like all individuals within a population are the same and have no genetic variation. This may lead students to believe that all individuals within a population are the same and any difference is trivial and unimportant. Take kidney beans for example; beans have small differences in size and shape. If you took one kidney bean out of a group of 100 beans and examined it, could you easily and quickly find that same exact bean again once it is placed back in the group? Because it's so difficult to observe outward differences in the beans, it would be virtually impossible to pick up that exact bean within a short amount of time. However, there is genetic variation within the bean seeds that allows for variations within traits. Although these trait variations may not affect the outward appearance of the bean, they do influence the molecular biochemistry of individuls that are not inconsequential. These trait variations can be favored by certain environmental conditions which allow some beans to be better suited to sprout, grow, and reproduce. Addtionally, in animals there are variations in behavior among individuals within a population. Although these differences might seem to be unimportant and trivial, they could confer an advantage that allows some individuals to survive and reproduce better than others.

STOP AND THINK

What does the crosscutting concept of cause and effect mean to you? How would your students think about cause and effect as it relates to explaining natural phenomena? How does Common Student Idea #7, Every difference has a purpose, overextend ideas of cause and effect?

A goal of teaching the crosscutting concept of cause and effect is to foster within students the habit of mind to see natural events as having understandable causes and to distinguish between scientific causal claims and nonscientific ones. In doing so, students need to know the differences between causation and correlation. Oftentimes, students conflate correlation and causation. These words do not have the same meaning. Correlation refers to the extent to which two variables fluctuate together. A direct correlation means the two variables increase and decrease together or in parallel. An indirect or inverse correlation means that as one variable increases, the other decreases. Causation, on the other hand, is the action of causing something. It's the relationship between a cause and an effect. A correlation *does not* infer causation. For example, take a fictitious population of beetles. Let's just say there is a variation in carapace (shell) color—dark brown or tan. Just because the frequency of tan-colored beetles increased during a hot summer spell does not mean that the tan color keeps the beetles cooler and thus makes them better able to survive. The warmer temperature may not be the actual cause of the increased number of tan-colored beetles. There may be a strong correlation between rising temperatures and increases in tan beetles, but this does not automatically infer causation. What are your students' ideas concerning correlation and causation? How can the *Natural Selection* lesson be an opportunity to teach students the difference between the two ideas?

Common Student Idea #8
Natural selection leads to perfection.

This common student idea stems from the assumption that since the environment selects only favorable traits, over time the accumulation of these traits leads to a population of organisms that is perfectly suited to live and survive in that environment. Be aware that some of the language that is often used related to natural selection, or even evolution, can be misleading. For example, "this species was better

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adapted and survived" or "evolved into a new species" may cause students to think that the species that survive are perfect. However, species adapt to the present conditions in an environment. Those conditions change over time, so adaptations that helped an organism survive in one environment may no longer be helpful when the conditions change.

Likewise, it is important for students to recognize and understand that if a certain trait variation is favored over another, the favored trait is not necessarily stronger or better than the trait that is not favored. That particular trait variation helped the individual to better survive within a certain set of environmental conditions that were present at a certain place in a particular time. Students may have an incorrect notion that the environment favors only the best traits. Therefore, over time, populations become better or stronger as the environment weeds out the weakest traits, resulting in a super fit population of organisms. This is certainly not the case. If we return to our stickleback fish population, one can see that trait variations that are advantageous in one type of environment are not necessarily advantageous in another different type of environment. Complete armor and long spines were advantageous in the open ocean. Large fish had difficulty swallowing these fish, thus the long-spined variation was favored over short spines. However, as saltwater populations got trapped in freshwater lakes, long spines were a disadvantage as dragonfly nymphs could catch long-spined sticklebacks easier than stickleback with short or no spines.

STOP and THINK

How often have you heard the phrase "only the strongest survive" mentioned with Darwin's idea of natural selection? The chance to explicitly surface this idea can happen throughout the *Natural Selection* lessons, but the idea can be appropriately challenged as students work through Lessons 3 and 4. During Lessons 1 and 2, the primary focus is an examination of Lamarckian and Darwinian ideas, ending with students coming to the conclusion that Darwin's ideas better take into account the changes that occur in populations over time. In Lessons 3 and 4, students delve further into natural selection and learn about the four factors that comprise Darwin's ideas. It is during these lessons where students are making sense of the four factors and applying them to a natural phenomenon that a teacher can effectively challenge the notion that the environment favors only the "best traits", leading, over time, to perfection. Read through the *Natural Selection* lesson sequence. Why might Lessons 3 and 4 be a better place to challenge this common student idea rather than in Lessons 1 and 2?

Common Student Idea #9
Natural selection and evolution are equivalent terms.

Evolution occurs due to changes in genetic information and traits across generations of a population or species due to the processes of mutation, natural selection, migration, or genetic drift. These processes are mechanisms of evolution. While natural selection is one of the most powerful and well-documented mechanisms, it is not the only one. The narrative below explains each of these mechanisms, in random order, that can lead to evolution. This section will not discuss natural selection as it is covered in numerous other sections of this document, but it will describe sexual selection, which is a special case of natural selection.

A genetic mutation is an alteration in a DNA sequence that makes up a gene. This alteration in DNA's nulcleotide sequence may produce a protein that functions differently (or not at all) than the originally

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coded protein. This change in the nucleotide sequence then may cause a variation in a trait. If this new trait variation improves the overall fitness of an organism, the individual who possesses it will have a better chance of surviving and passing this new version of the trait on to its offspring. If this trait variation continues to improve the fitness of individuals who possess it, the gene for the trait variation may become prevalent within a population's gene pool over successive generations. Please see the Genetics Content Connections document for more information on how mutations in the nucleotide sequence of DNA could cause variations in traits.

Migration of individuals into (immigration) and out of a population (emigration) is a mechanism for evolution. As organisms from one population migrate to another population, they bring their genes with them. This has the possibility of incorporating new trait variations into an existing population's gene pool. Take this simplified example. Perhaps there are two populations of white-tailed deer that are separated geographically by a large river. Although each population had a brown coat color, one population had a trait variation that made their coat just a little darker. This darker color was much more difficult to see by predators. Perhaps, a small group of dark-coated deer was forced to swim across the large river and mixed with the light-coat population. Since the dark-coated deer were harder for predators to see than the light-coated deer, more of the dark-coated deer were able to escape predation and reproduce. If this trend consistently occurred for successive generations, the result would be the majority of deer within the population having a dark coat.

Genetic drift occurs primarily when the frequency of certain genes and their traits dramatically changes within a population. This is different from natural selection. With natural selection, environmental factors may make certain trait variations advantageous over others. With genetic drift, changes in gene frequency occur due to random chance events. For example, genetic drift can occur during natural disasters like a wildfire or volcano eruption where a portion of the population is killed off and with it all of its genetic information. The population of organisms that is left has reduced variability within its gene pool and, therefore, has a reduction in the number of trait variations that can be passed on to offspring. This is known as the bottleneck effect. However, there is another type of genetic drift called the founder effect. This occurs when a small group of interbreeding individuals from a larger population becomes geographically isolated. This small group of individuals has reduced genetic variation when compared to the original population. Due to its decreased genetic variability and geographic isolation, this small population can, over time, become genetically different from the original parent population from which it came.

Lastly, sexual selection, a special case of natural selection, can also lead to evolution. With natural selection, the environment may select or favor one trait variation over another, with this trait variation helping the organism survive and reproduce. Sexual selection, however, acts on an organism's ability to attract and copulate with a mate. For example, males from various bird of paradise species have a vast assortment of interesting and colorful plumages (figure 4). Males use these feathery displays to attract females. Females prefer to mate with males who have grand displays. Selecting only males who have the grandest displays, over time, resulted in male birds of paradise having these colorful plumages.

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Figure 4
Bird of Paradise

STOP AND THINK

Students may think that natural selection, over time, leads to evolution. However, this is not always the case as natural selection can also exist without evolution. This can occur because abiotic and biotic factors within the envornment can change very rapidly. Consequently, traits that are selected in one generation may not be favored by a rapidly changing environment and are not inherited by the next generation. An example of this occurred within brown anole (*Anolis sagrei)* populations. This ground-dwelling lizard can be found on certain Bahamian islands. As a ground-dwelling lizard, longer legs for running were an advantage over shorter legs. However, when a longer limbed terrestrial predator was introduced, the northern curly tailed lizard (*Leiocephalus carinatus*), the brown anole took to living in the trees where shorter legs were favored. This change in selective pressure occurred within as little as one generation.

How will you surface and then challenge these ideas concerning natural selection and evolution? Review the lessons; where might be an appropriate place to surface these ideas? When might it be an appropriate time to challenge these ideas?

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