**Unpacking Natural Selection and Adaptation from the *Framework***

**Unpacking Document Address: HS-LS4-2, HS-LS4-3, HS-LS4-4, MS-LS4-4, MS-LS4-5**

*Framework Header:* Supporting Phenomena that leads to Natural Selection

*Framework Driving Question:* How does Evolution happen?

**A. PERFORMANCE EXPECTATIONS**

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| **MS-LS4-4.** | **Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.] |
| **MS-LS4-5.** | **Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.** [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.] |

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| **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) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [*Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*] |
| **HS-LS4-3.** | **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [*Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*] |

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| **HS-LS4-4.** | **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.] |

**B. UNPACKING OF FRAMEWORK GRADE BANDS**

**Framework text is in bold.**

Interpretation text below each bolded statement.

**LS4.B: Natural Selection**

***By the end of grade 8*.**

**Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection.**

* There are both genetic and nongenetic variations among individuals in a population.
* Variations relevant to understanding natural selection are those that are genetic, meaning here that the variations are inherited.
* A variation that is selected is one that provides an advantage for survival to the point of being able to reproduce.

**It leads to the predominance of certain traits in a population and the suppression of others.**

* Natural selection changes the proportion of individuals with particular traits over time.
* Over time means across successive generations, though the proportion is likely to shift in a relatively continuous manner, since individuals are being born and reproducing at different times.
* The proportion of individuals with a trait goes up over time if it is selected for. Conversely, if we see the proportion of a certain trait going up over time in a population, one possible explanation (among others) is that it is advantageous and thus being selected for.
* The proportion of individuals with a trait goes down over time if it is disadvantageous. Conversely, if we see the proportion of a certain trait going down over time in a population, one possible explanation (among others) is that it is disadvantageous and thus being selected out.

**In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding.**

* There are two kinds of selection that scientists distinguish, artificial and natural.
* Human action is behind artificial selection, and it focuses on breeding.
  + Note: gene “editing” is an emerging way human action can influence selection of traits artificially.
* In artificial selection, humans create offspring with particular (desired traits) by breeding organisms that have those traits.
* Not all characteristics can be influenced through selective breeding.

**[In artificial selection], one can choose desired parental traits determined by genes, which are then passed on to offspring.**

* Like natural selection, artificial selection depends on heritability of traits.
* Traits are determined by genes.
* Traits of parents are passed on to offspring, “naturally,” even though human beings have influenced the process of reproduction.

***By the end of grade 12*.**

**Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.**

* Certain conditions must be met for natural selection to occur.
* There must be variation in the genetic information between organisms in a population for natural selection to occur.
  + Conversely, if there is no variation, then no natural selection can occur.
    - Scenario idea: No variation in a trait, can selection occur? Why or why not?
  + Implication: If there is no variation, and a trait is disadvantageous, then the population could die out, due to a genetic bottleneck.
* Some genetic information is “expressed,” meaning evident in traits.
  + Some genetic information is not expressed.
* Only when the traits result in difference in survival and reproduction does natural selection occur.
  + Survival and reproduction = “performance” in Framework.

**The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.**

* Some traits are “selected” because they affect the survival of the organism.
  + Survival means “stays alive long enough to reproduce.”
* Natural selection results in a trait becoming more common in a population.
  + “Becoming more common” means the proportion of individuals with the trait in the population becomes more common over time. This is reflected in the PE, which emphasizes shifts over time in the proportion of traits in a population.

**LS4.C: Adaptation**

***By the end of grade 8***

**Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions.**

* Natural selection is cause, and adaptation is effect of selection.
  + This is a tie to a Crosscutting Concept (cause and effect) that could be included in an assessment.
* Species change over time, in terms of the traits in populations of organisms of a particular species.
  + Adaptation is one process by which species change.
  + (Genetic drift is another, but it is not part of the Framework.)
* Changes in environmental conditions drive the process of natural selection.
  + “Conditions” that are relevant are those that affect traits that affect survival.
    - Example could be water temperature in streams affecting salmon survival. Selection could operate if there is individual variation in salmon’s sensitivity to temperature changes.
    - Example could be dams that obstruct salmon’s migrations to spawn.
  + Such changes can come about when organisms stay put, but the environment changes.
  + Such changes can also come about when organisms migrate into a new environment.

**Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common.**

* This statement implies but does not state that natural selection is operating, such that there is variation in traits that affect survival in the first place.
* One indicator of or source of evidence for natural selection is a change in the proportion of organisms with a particular trait.
  + Coupled with evidence of change in environmental conditions, these two pieces of evidence could support an explanation for natural selection occurring in a population.
* “More common” could be rephrased in terms of a change in proportion in the population. Focus here is on proportion of traits in a population, and change over time in them.
  + Link in proportion is to crosscutting concept, “Scale, Proportion, and Quantity.”
* “New environment” here refers to changed conditions that could increase or decrease the probability of an organism surviving in a new environment.
  + The changed conditions could be the result of migration or to changes in the existing environment.

**Thus, the distribution of traits in a population changes.**

* When traits become less common as a result of adaptation, there is a change in distribution of traits.
* This strikes me as an inconsistency across Framework and NGSS to reconcile: for natural selection, the concept of distribution is not introduced until high school.

**In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.**

* Populations can become separated from one another.
* Raises the question of how populations become separated. Migration is one possibility.
* When they remain separated, they can become separate species.
* Raises the question, “What is a species?” “When is a species a new species?”
* Hominids raise this question: Are they really different species, when they could interbreed? Scientists have different views on that.
* A reason implicit here is that natural selection is operating in different ways on the isolated populations, resulting in changes to the distribution of of traits that make it so organisms from the two populations can no longer inter-breed and have fertile offspring.

***By the end of grade 12***

**Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (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.**

* All organisms would have a tendency to produce as many offspring as possible.
  + If resources were unlimited, the population of organisms would therefore increase exponentially.
  + That’s why there is potential for a species to increase in number.
* There are two causes of genetic variation, mutation and sexual reproduction.
* An implied meaning here for “variation” is that it is a transformation that occurs across generations.
* There’s no definition here of mutation, or description of its randomness. Similarly nothing about what happens to genes in reproduction.
* Tie to crosscutting concept: Cause and effect.
* There is also a link here to genetics, to build a more complete understanding of natural selection.
* There is competition in any environment for resources needed to survive and reproduce.
  + Resources are not unlimited, and therefore there can’t be an infinite increase in the number of organisms in an environment (clear tie to LS2, notion of carrying capacity and things that affect it).
  + Competition includes intra-species competition for resources.
  + Competition means some individuals will survive and others will not.
  + The resources an individual needs both for survival and reproduction are necessary to consider.
    - Salmon example here may be relevant: Salmon could survive, but if conditions change for spawning to limit reproduction, then limited resources could result in elimination of those salmon not able to make it through the fish ladders.
* Those organisms with particular traits that allow them to survive and reproduce will increase in number.
  + Question students might have could be: Can their number increase indefinitely? Does natural selection stop at that point, or continue? On the same basis, or different?

**Natural selection leads to adaptation—that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment.**

* Note: Focus is on organisms that survive, not on the distribution of traits here, in contrast to text related to natural selection.
* Natural selection is the cause, adaptation is the effect.
  + Tie to crosscutting concept: Cause and effect.
* Organisms that can have survival advantage due to different kinds of variation.
  + They might have anatomical features that allow them to survive better.
  + They might engage in behaviors that allow them to survive better.
  + They might have physiological (e.g., pertaining to regulation and homeostasis) traits that allow them to survive better.
* Characteristics that are an advantage to survival and reproduction in one environment may not be advantageous in another.
  + Asking students to predict whether organisms with particular characteristics and that dominate one environment would do as well in another could be a good scenario, something akin to an invasive species. (Another LS2 connection here)

**That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait 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.**

* There are connections here to natural selection, focusing on the changes to proportions of individuals over time with organisms with different traits.
* Focus is on proportion: Tie to crosscutting concept: Rate, proportion, and scale.
* Emphasis is both on the increase in proportion of individuals with traits that are advantageous and decreased in organisms without the trait.
* Here, over time is operationalized as being over successive generations.

**Adaptation also means that the distribution of traits in a population can change when conditions change.**

* Conditions changing are one thing that can change what is selected for.
* A change in what traits are selected for results in different adaptations.
* That change also shifts the relative distribution of traits in a population.

**C. WHAT IS THE DIFFERENCE BETWEEN 8TH AND 12TH GRADE FOR THESE DCIs?**

There is a differentiation of “traits” between middle school and high school, so that high schoolers would be expected to recognize that what could be selected for is anatomical, behavioral, or physiological.

**D. ASSESSMENT (TASK/ACTIVITY) DESIGN**

*What are some characteristics of problem contexts or phenomena that should be presented to students to fully assess this PE, based on the above analysis of the DCIs?*

*Task template tool:* [*http://researchandpractice.org/ngsstaskformats/*](http://researchandpractice.org/ngsstaskformats/)

HS-LS4-4 (Explanation)

***Construct an explanation based on evidence for how natural selection leads to adaptation of populations.***

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| **Complete Student Understanding** | **Possible Scenarios Related to DCI Components**  (Scenarios should elicit student responses, and whatever is to be modeled or explained must have the claim in answer) | **Task Requirements for Students**  Task requirements must adhere to one of our task templates for practices | **Evidence**  (Write an example student answer, justify how it supports an inference about the assessment claim) |
| A complete model begins with the idea of initial variation in traits in a population. The traits could be physiological, behavioral, physical. There’s variation that matters for survival and reproduction in a changed environment. The trait becomes more common in the population through the mechanisms of mutation and sexual reproduction. Adaptation is the result, a population well suited to survive and reproduce in the new environment. | Brook trout prefer clear water and are very sensitive to pollution. They can survive in temperatures from 34 to 72 °F, with some trout being able to survive in slightly warmer temperatures than that.  Removal of trees from a riparian corridor takes place, removing shade near rivers where a population of brook trout swim, causing an increase in the water temperature in the summer such that temperature ranges from 70-80 degrees F in a given week. Trout population numbers stay the same, despite the change in conditions. | What physiological trait is likely related to survival of the trout in the new conditions?  Draw a picture showing the distribution of this trait in the trout population as it might be after the removal of the trees, given the picture on the left showing the initial distribution?  Why did the distribution change?  How could the population have stayed the same, if most trout would die when the temperature went above 72 degrees? | Part 1: “The temperatures they can survive in.”  Part 2: Students draw a picture that shows the trait of surviving in temperatures between 10-20 degrees above range to be shifted in distribution to be more of those.  Part 3: “The distribution changed because the trait of tolerance of warmer temperatures was more advantageous for survival and reproduction”  Part 4: “The population just shifted its distribution, and those that did passed on this trait through reproducing and surviving to reproduce again” |