SB6. Obtain, evaluate, and communicate information to assess the theory of evolution.

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<tr><th>Science & Engineering Practices</th><th>Core Ideas</th><th>Crosscutting Concepts</th></tr>
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<td>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
● Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
● Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
● Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
● Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
● Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td>
<td>● Evolution is a series of changes, some gradual and some sporadic, that accounts for the present form and function of organisms. The general idea of evolution is that the present arises from materials and forms of the past. Although the term can also describe changes in the universe, evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors.</td>
<td>Patterns: Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
● Empirical evidence is needed to identify patterns.
● Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.
● Mathematical representations are needed to identify some patterns.
Cause & Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
● Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
● Changes in systems may have various causes that may not have equal effects.</td>
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a. Construct an explanation of how new understandings of Earth's history, the emergence of new species from pre-existing species, and our understanding of genetics have influenced our understanding of biology.

Science & Engineering Practices	Core Ideas	Crosscutting Concepts
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. ● Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. ● Construct and revise 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. ● Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. ● Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**Earth's History** ● The geologic time scale interpreted from rock strata and the fossil record indicates that the Earth is more than 4 billion years old. ● While the Earth's environment has changed dramatically throughout its history, the Earth processes we see today, driven by plate tectonics, are similar to those that occurred in the past. ● Evolution is shaped by Earth's varying geological conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. ● The evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere. **Emergence of Species** ● The fossil record demonstrated that species changed over time and that ancient species existed which no longer exist. ● Modern ideas about evolution and heredity provide a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. **Understanding of Genetics** ● Many of an organism's traits—which may be observed as structural, behavioral, or biochemical characteristics—are heritable. ● New variation in these traits, resulting from changes in DNA in germ cells, occur spontaneously at low rates. ● These heritable characteristics influence how likely an organism is to survive and reproduce.	**Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ● Empirical evidence is needed to identify patterns. ● Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. ● Mathematical representations are needed to identify some patterns.

SB6b. Analyze and interpret data to explain patterns in biodiversity that result from speciation.

Science & Engineering Practices	Core Ideas	Crosscutting Concepts
Analyzing and interpreting data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ● Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. ● Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. ● Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. ● Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.	● The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms. ● Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). ● Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. ● Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. ● This results in a branching pattern of evolution, in which all species are related by descent from common ancestors, but not all branches extend to the present day.	**Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ● Empirical evidence is needed to identify patterns. ● Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. ● Mathematical representations are needed to identify some patterns. **Cause & Effect:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ● Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ● Changes in systems may have various causes that may not have equal effects.

c. Construct an argument using valid and reliable sources to support the claim that evidence from comparative morphology (analogous vs. homologous structures), embryology, biochemistry (protein sequence) and genetics support the theory that all living organisms are related by way of common descent.

Science & Engineering Practices	Core Ideas	Crosscutting Concepts
Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ● Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. ● Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. ● Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. ● Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. ● Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.	● Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. ● Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. ● Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in RNA and amino acid sequences.	**Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ● Empirical evidence is needed to identify patterns. ● Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. ● Mathematical representations are needed to identify some patterns.

d. Develop and use mathematical models to support explanations of how undirected genetic changes in natural selection and genetic drift have led to changes in populations of organisms. *(Clarification statement: Element is intended to focus on basic statistical and graphic analysis. Hardy Weinberg would be an optional application to address this element.)*

e. Develop a model to explain the role natural selection plays in causing biological resistance (e.g., pesticides, antibiotic resistance, and influenza vaccines).

Science & Engineering Practices	Core Ideas	Crosscutting Concepts
Developing and using models in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). ● Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. ● Design a test of a model to ascertain its reliability. ● Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. ● Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. ● Use a model to provide mechanistic accounts of phenomena. ● Develop a complex model that allows for manipulation and testing of a proposed process or system. ● Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Mathematical and computational thinking** in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ● Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success. ● Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. ● Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. ● Apply techniques of algebra and functions to represent and solve scientific and engineering problems. ● Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. ● Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).	● Natural selection occurs only if there is heritable variation in traits within a population that leads to differences in performance among individuals. ● The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. ● 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 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. ● 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. 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. ● Adaptation also means that the distribution of traits in a population can change when conditions change. ● Chance alone can also result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism.	**Cause & Effect:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ● Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ● Changes in systems may have various causes that may not have equal effects.