



# Bundling Guide for Biology 1

## Purpose and Use

This document is intended to be a guide to provide examples of ways Performance Expectations (PEs) could be bundled. For this purpose, a bundle as defined by Pruitt (2014), is, “a set of PEs that provide students with coherent connections among concepts within and across disciplines.” This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. The bundles presented in this guide are not ordered for instruction. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

The bundles in this document do not represent the only way the PEs can be bundled. PEs bundled together may change depending upon the selected anchoring phenomenon that students are working to explain. The bundles presented in this guide were developed using an iterative process informed by the work of Krajick and colleagues (2014). This process is summarized in the steps below:

1. Review bundles that already exist.
2. Build bundles around an anchoring phenomenon.
  - a. The “Example anchoring phenomena to support 3D instruction” provided in this resource is just that, an example. There are myriad phenomena to support 3D instruction, and different phenomena may be more appropriate for different learning contexts.
3. Explore and look for unexpected relationships among the PEs, including bundling across disciplines (Earth and Space Science, Life Science, Physical Science) when appropriate. This can include identification of PEs that are only partially met in the bundle.
  - a. PEs within a bundle marked with an asterisk (\*) share an authentic connection with the bundle but may not fully met.
  - b. PEs from additional high school content areas with a close connection to the bundle are listed. This is not intended to add to the instructional demand, but instead to provide teachers with additional content to build upon and/or support student sensemaking.
4. Make sure each PE in the grade/course is found in at least one bundle.

## Structure and Function of Life

Photosynthesis is a process where plants convert light energy into chemical energy stored in sugars, while releasing oxygen as a byproduct. These sugars contain carbon, hydrogen, and oxygen, which are essential for building other molecules needed for life, such as amino acids and DNA. Living systems continuously rearrange chemical elements as matter and energy flow through them. For example, cellular respiration is a chemical process where food molecules and oxygen are broken down to produce new compounds, releasing energy that cells use for work. Proteins are vital for living organisms because they serve multiple functions. They provide structure, act as messengers for cell communication, regulate cell processes, and facilitate chemical reactions as enzymes.

### ***PEs aligned to this bundle:***

- B-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.\*
- B-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.\*
- B-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and other large carbon-based molecules necessary for essential life processes.\*
- B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.\*

### ***Connected PEs from additional content areas:***

- C-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at a bulk scale to infer the strength of various forces between particles.
- C-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- C-PS2-6. Communicate scientific and technical information about why the molecular structure determines the functioning of designed materials.
- P-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- P-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- E-ESS2-5. Investigate the ways that water (given its unique physical and chemical properties) impacts various Earth systems.



***Example anchoring phenomena to support 3D instruction:***

- How do we know what the “paleo diet” is?
- How to build an artificial leaf?
- Macromolecule synthesis

## Matter and Energy in Ecosystems

Photosynthesis and cellular respiration are important parts of the carbon cycle, which involves the movement of carbon among living organisms, the atmosphere, oceans, and the Earth's crust through various processes. During photosynthesis, plants use light energy to convert carbon dioxide from the air and water from the soil into sugars, releasing oxygen as a byproduct. These sugars store energy that plants and other organisms can use for growth and other life processes. In living systems, matter and energy constantly move and interact, leading to the formation of different products through chemical reactions. Energy is transferred between molecules during these processes. Cellular respiration is a chemical process in which cells break down sugars and oxygen to release energy in the form of ATP, which is used for cell work. This process also releases carbon dioxide and water as byproducts. Anaerobic cellular respiration is a less efficient process that occurs in the absence of oxygen. It provides energy to cells but produces less ATP compared to aerobic respiration.

### ***PEs aligned to this bundle:***

- B-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- B-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.\*
- B-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and other large carbon-based molecules necessary for essential life processes.\*
- B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.\*

### ***Connected PEs from additional content areas:***

- C-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at a bulk scale to infer the strength of various forces between particles.
- C-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- C-PS2-6. Communicate scientific and technical information about why the molecular structure determines the functioning of designed materials.
- P-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- P-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

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- E-ESS2-6. Develop a quantitative model to describe the cycling of carbon through the hydrosphere, atmosphere, geosphere, and biosphere.

***Example anchoring phenomena to support 3D instruction:***

- Sustainable forestry
- Air plants
- Algae for food and fuel?

## **Ecosystem Interactions and Dynamics**

Ecosystems have limits to the number of organisms and populations they can support, known as carrying capacities. These limits are influenced by factors like the availability of resources such as food, water, and space, as well as challenges like predation, competition, and disease. If resources were unlimited, organisms could potentially reproduce and grow their populations without restraint. However, the finite nature of environments and resources creates a balance that determines the abundance of species in an ecosystem. Human activities, such as habitat destruction, pollution, over-harvesting, introduction of invasive species, and climate change, can disrupt ecosystems and threaten the survival of species. This is concerning because humans rely on biodiversity for resources like food, medicine, and ecosystem services. These anthropogenic changes have adverse impacts on biodiversity, leading to declines in species diversity and potentially harmful consequences for humans and other organisms. Maintaining biodiversity is crucial for sustaining ecosystem functioning, productivity, and resilience. Therefore, it's important to take action to sustain biodiversity and ensure the well-being of both humans and the environment.

### ***PEs aligned to this bundle:***

- B-LS2-1. Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales.
- B-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.

### ***Connected PEs from additional content areas:***

- B-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- B-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions but changing conditions may result in a new ecosystem.
- E-ESS2-7. Communicate scientific information that illustrates how Earth's systems and life on Earth change and influence each other over time.
- E-ESS3-3. Use computational representation to illustrate the relationships among the management of Earth's resources, the sustainability of human populations, and biodiversity.

### ***Example anchoring phenomena to support 3D instruction:***

- Pika mammals and climate change
- Isle Royale populations
- Beach nourishment

## **Inheritance and Variation of Traits**

In multicellular organisms, cells grow and divide through a process called the cell cycle, which allows the organism to grow and repair itself. It all starts with a single fertilized egg cell, which undergoes repeated divisions to produce many cells. During division, each parent cell passes on identical genetic material, consisting of two versions of each chromosome pair, to its daughter cells. Genes, made of sequences of nucleotides, contain instructions for building proteins. DNA controls protein production by first being transcribed into messenger RNA, which is then translated into proteins by cellular machinery. Cell division and specialization lead to the development and maintenance of complex organisms composed of tissues and organs that work together. During sexual reproduction, chromosomes can exchange sections during a process called meiosis, resulting in new genetic combinations and increasing genetic variation. While DNA replication is usually accurate, mutations can occur, introducing additional genetic variation. Environmental factors can also cause mutations, and viable mutations can be passed on to offspring. Environmental factors also influence how traits are expressed, affecting the likelihood of certain traits appearing in a population. Therefore, the variation and distribution of observed traits result from both genetic and environmental influences.

### ***PEs aligned to this bundle:***

- B-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
- B-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- B-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- B-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.\*

### ***Connected PEs from additional content areas:***

- B-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

### ***Example anchoring phenomena to support 3D instruction:***

- CRISPR
- Chimerism
- Double-muscling cattle

## Changes in Populations Over Time

Evolution is shaped by four key factors: (1) species have the potential to increase in numbers over time, (2) genetic variation exists among individuals within a species due to mutations and sexual reproduction, (3) competition for limited resources in the environment drives natural selection, favoring individuals with advantageous traits, and (4) those individuals with beneficial traits are more likely to survive and reproduce, leading to the proliferation of those traits in subsequent generations. Natural selection occurs when there is genetic and trait variation within a population, resulting in differences in survival and reproduction rates. Over time, this process leads to adaptation, where populations become better suited to their environment in terms of anatomy, behavior, and physiology. Changes in the environment, whether caused naturally or by human activity, can influence the evolution of species. Some species may thrive and expand, while others may decline or even face extinction if they cannot adapt quickly enough to environmental changes. In essence, evolution is driven by the interaction of these factors, resulting in the diversification of life and the adaptation of species to their changing environments.

### ***PEs aligned to this bundle:***

- B-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.\*
- B-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.\*
- B-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species..\*
- B-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.\*
- B-LS2-1. Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales.\*
- B-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.\*



***Connected PEs from additional content areas:***

- B-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.
- E-ESS2-7. Communicate scientific information that illustrates how Earth's systems and life on Earth change and influence each other over time.
- E-ESS2-4. Use a model to describe how causes of short and long-term variations in the flow of energy into and out of Earth's systems result in changes to climate.

***Example anchoring phenomena to support 3D instruction:***

- Prevalence of tusklessness in African elephants
- Antibiotic resistance
- Preserved dental plaque DNA sequencing for starch processing genes

## Common Ancestry and Speciation

Genetic information, much like the fossil record, offers evidence of evolution. While DNA sequences differ among species, there are also similarities. By comparing these sequences, scientists can infer the ongoing branching of evolutionary lines. Additionally, similarities and differences in amino acid sequences, as well as anatomical and embryological evidence, further support our understanding of how species are related. Evolution is shaped by four key factors: (1) species have the potential to increase in numbers over time, (2) genetic variation exists among individuals within a species due to mutations and sexual reproduction, (3) competition for limited resources in the environment drives natural selection, favoring individuals with advantageous traits, and (4) those individuals with beneficial traits are more likely to survive and reproduce, leading to the proliferation of those traits in subsequent generations. Natural selection results in adaptation, where populations become better suited to their environment. This occurs because individuals with traits that enhance survival and reproduction are favored. Over time, changes in the physical environment, whether natural or human-induced, can lead to the expansion of some species, the emergence of new species, and the decline or extinction of others.

### ***PEs aligned to this bundle:***

- B-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- B-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.\*
- B-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.\*
- B-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.\*
- B-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.\*
- B-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.\*

***Connected PEs from additional content areas:***

- B-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.
- E-ESS2-7. Communicate scientific information that illustrates how Earth's systems and life on Earth change and influence each other over time.
- E-ESS2-4. Use a model to describe how causes of short and long-term variations in the flow of energy into and out of Earth's systems result in changes to climate.

***Example anchoring phenomena to support 3D instruction:***

- Are guinea pigs and rabbits rodents?
- Hox genes
- Snapping shrimp mutation rates and the Isthmus of Panama

## References

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