Big Idea 1: The process of evolution drives the diversity and unity of life.

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<tr>
<th>Essential knowledge</th>
<th>Chapters/sections</th>
<th>Illustrative examples covered</th>
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</thead>
</table>
| 1.a.1 Natural selection is a major mechanism of evolution                          | 22.2, 23.1        | • Graphical analysis of allele frequencies in a population  
• Application of the Hardy-Weinberg equilibrium equation |
| 1.a.2 Natural selection acts on phenotypic variations in populations               | 23.2, 23.4        | • Flowering time in relation to global climate change  
• Peppered moth  
• Sickle cell Anemia  
• DDT resistance in insects  
• Artificial selection  
• Loss of genetic diversity within a crop species  
• Overuse of antibiotics |
| 1.A.3: Evolutionary change is also driven by random Processes                      | 23.3              | No illustrative examples listed in Curriculum Framework.                                                                                                    |
| 1.a.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics. | 22.3, 26.2        | • Graphical analyses of allele frequencies in a population  
• Analysis of sequence data sets  
• Analysis of phylogenetic trees  
• Construction of phylogenetic trees based on Sequence data |
| 1.b.1 Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. | 26.1, 26.3, 26.4, 26.5 | • Cytoskeleton (a network of structural proteins that facilitate cell movement, morphological integrity and organelle transport)  
• Membrane-bound organelles (mitochondria and/or chloroplasts)  
• Linear chromosomes  
• Endomembrane systems, including the nuclear Envelope |
| 1.b.2 Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested. | 25.1, 25.2, 25.3  | • Number of heart chambers in animals  
• Oppposable thumbs  
• Absence of legs in some sea mammals |
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</table>
| 1.c.1 Speciation and extinction have occurred throughout the Earth’s history. | 24.2, 24.3, 26.2 | • Five major extinctions  
• Human impact on ecosystems and species extinction rates |
| 1.c.2 Speciation may occur when two populations become reproductively isolated from each other. | 24.1 | *No illustrative examples listed in Curriculum Framework.* |
| 1.c.3 Populations of organisms continue to evolve. | 24.2 | • Chemical resistance (mutations for resistance to antibiotics, pesticides, herbicides or chemotherapy drugs occur in the absence of the chemical)  
• Emergent diseases  
• Observed directional phenotypic change in a Population (Grants’ observations of Darwin’s finches in the Galapagos)  
• A eukaryotic example that describes evolution of a structure or process such as heart chambers, limbs, the brain and the immune system |
| 1.d.1 There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence. | 4.1, 26.1, 26.3, 26.4, 26.5 | *No illustrative examples listed in Curriculum Framework.* |
| 1.d.2 Scientific evidence from many different disciplines supports models of the origin of life. | 26.6 | *No illustrative examples listed in Curriculum Framework.* |
Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

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</table>
| 2.a.1 All living systems require constant input of free energy. | 8.1, 8.2, 8.3, 9.1-9.5, 10.1, 10.2, 10.3, 40.1-40.5, 51.3, 52.3, 52.4, 53.2, 54.1, 54.3 | • Krebs cycle  
• Glycolysis  
• Calvin cycle  
• Fermentation  
• Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures)  
• Ectothermy (the use of external thermal energy to help regulate and maintain body temperature)  
• Seasonal reproduction in animals and plants  
• Life-history strategy (biennial plants and reproductive diapause)  
• Change in the producer level can affect the number and size of other trophic levels  
• Change in energy resources levels such as sunlight can affect the number and size of the trophic levels |
| 2.a.2 Organisms capture and store free energy for use in biological processes. | 9.1-9.5, 10.1, 10.2, 10.3 | • NADP+ in photosynthesis  
• Oxygen in cellular respiration |
| 2.a.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization. | 3.1, 3.2, 3.3, 4.1, 4.2, 6.2 | • Cohesion  
• Adhesion  
• High specific heat capacity  
• Universal solvent supports reactions  
• Heat of vaporization  
• Heat of fusion  
• Water’s thermal conductivity  
• Root hairs  
• Cells of the alveoli  
• Cells of the villi  
• Microvilli |
<p>| 2.b.1 Cell membranes are selectively permeable due to their structure. | 7.1, 7.2 | No illustrative examples listed in Curriculum Framework. |</p>
<table>
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</thead>
<tbody>
<tr>
<td>2.b.2 Growth and dynamic homeostasis are maintained by the constant movement of</td>
<td>7.3, 7.4, 7.5</td>
<td>• Glucose transport</td>
</tr>
<tr>
<td>molecules across membranes.</td>
<td></td>
<td>• Na+/K+ transport</td>
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<tr>
<td>2.b.3 Eukaryotic cells maintain internal membranes that partition the cell into</td>
<td>6.2, 6.3, 6.4, 6.5</td>
<td>• Endoplasmic reticulum</td>
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<td>specialized regions.</td>
<td></td>
<td>• Mitochondria</td>
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<td></td>
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<td>• Chloroplasts</td>
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<td></td>
<td></td>
<td>• Golgi</td>
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<td></td>
<td></td>
<td>• Nuclear envelope</td>
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<tr>
<td>2.c.1 Organisms use feedback mechanisms to maintain their internal environments and</td>
<td>40.2, 40.4, 40.5</td>
<td>• Operons in gene regulation</td>
</tr>
<tr>
<td>respond to external environmental changes.</td>
<td></td>
<td>• Temperature regulation in animals</td>
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<td></td>
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<td>• Plant responses to water limitations</td>
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<tr>
<td></td>
<td></td>
<td>• Lactation in mammals</td>
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<tr>
<td></td>
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<td>• Onset of labor in childbirth</td>
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<td></td>
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<td>• Ripening of fruit</td>
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<td></td>
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<td>• Diabetes mellitus in response to decreased insulin</td>
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<td>• Dehydration in response to decreased antidiuretic hormone (ADH)</td>
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<td></td>
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<td>• Graves’ disease (hyperthyroidism)</td>
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<td></td>
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<td>• Blood clotting</td>
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<td>2.C.2 Organisms respond to changes in their external environments.</td>
<td>40.5</td>
<td>• Photoperiodism and phototropism in plants</td>
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<td></td>
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<td>• Hibernation and migration in animals</td>
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<td>• Taxis and kinesis in animals</td>
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<td></td>
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<td>• Chemotaxis in bacteria, sexual reproduction in fungi</td>
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<td></td>
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<td>• Nocturnal and diurnal activity: circadian rhythms</td>
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<td>• Shivering and sweating in humans</td>
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<tr>
<td>2.d.1 All biological systems from cells and organisms to populations, communities,</td>
<td>50.2, 52.1, 52.2, 52.3, 53.1, 53.2, 53.3, 53.4, 53.5, 54.1, 54.2, 54.3, 54.4</td>
<td>• Cell density</td>
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<td>and ecosystems are affected by complex biotic and abiotic interactions involving</td>
<td></td>
<td>• Biofilms</td>
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<td>exchange of matter and free energy</td>
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<td>• Temperature</td>
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<td></td>
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<td>• Water availability</td>
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<td></td>
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<td>• Sunlight</td>
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<td></td>
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<td>• Symbiosis (mutualism, commensalism, and parasitism)</td>
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<td></td>
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<td>• Predator–prey relationships</td>
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<td>• Water and nutrient availability, temperature, salinity, and pH</td>
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<td>Illustrative examples covered</td>
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</table>
| 2.d.2 Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments. | 40.4, 40.5, 55.1  | • Gas exchange in aquatic and terrestrial plants  
• Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, and one-way digestive systems  
• Respiratory systems of aquatic and terrestrial animals  
• Nitrogenous waste production and elimination in aquatic and terrestrial animals  
• Excretory systems in flatworms, earthworms, and vertebrates  
• Osmoregulation in bacteria, fish and protists  
• Osmoregulation in aquatic and terrestrial plants  
• Circulatory systems in fish, amphibians and mammals  
• Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms) |
| 2.d.3 Biological systems are affected by disruptions to their dynamic homeostasis. | 40.4, 40.5, 55.1  | • Physiological responses to toxic substances  
• Dehydration  
• Immunological responses to pathogens, toxins, and allergens  
• Invasive and/or eruptive species  
• Human impact  
• Hurricanes, floods, earthquakes, volcanoes, and fires  
• Water limitation  
• Salination |
| 2.d.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis. | 39.5, 43.1, 43.2, 43.3, 43.4, 43.5 | • Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses  
• Plant defenses against pathogens include molecular recognition systems with systemic responses; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects  
• Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens |
<table>
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</table>
| 2.e.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms. | 19.2, 21.2, 38.1, 38.2 | • Morphogenesis of fingers and toes  
• Immune function  
• *C. elegans* development  
• Flower Development |
| 2.e.2 Timing and coordination of physiological events are regulated by multiple mechanisms. | 38.1, 38.2, 39.2, 39.3, 24.1, 11.1 | • Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues  
• Diurnal/nocturnal and sleep/awake cycles  
• Jet lag in humans  
• Seasonal responses, such as hibernation, estivation, and migration  
• Release and reaction to pheromones  
• Visual displays in the reproductive cycle  
• Fruiting body formation in fungi, slime molds, and certain types of bacteria  
• Quorum sensing in bacteria |
| 2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection. | 51.1, 51.2, 39.2, 39.3, 51.2, 53.1 | • Availability of resources leading to fruiting body formation in fungi and certain types of bacteria  
• Niche and resource partitioning  
• Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae)  
• Biology of pollination  
• Hibernation  
• Estivation  
• Migration  
• Courtship |
Big Idea 3: Living systems store, retrieve, transmit and respond to information essential to life processes.

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</table>
| 3.A.1: DNA, and in some cases RNA, is the primary source of heritable information. | 5.5, 27.1, 16.1, 16.2, 17.1, 17.2, 17.3, 17.4, 18.1, 20.1, 20.2, 20.3 | • Addition of a poly-A tail  
• Addition of a GTP cap  
• Excision of introns  
• Enzymatic reactions  
• Transport by proteins  
• Synthesis  
• Degradation  
• Electrophoresis  
• Plasmid-based transformation  
• Restriction enzyme analysis of DNA  
• Polymerase Chain Reaction (PCR)  
• Genetically modified foods  
• Transgenic animals  
• Cloned animals  
• Pharmaceuticals, such as human insulin or factor X |
| 3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization. | 12.1, 12.2, 12.3, 13.1, 13.2, 13.3 | • Mitosis-promoting factor (MPF)  
• Action of platelet-derived growth factor (PDGF)  
• Cancer results from disruptions in cell cycle control |
| 3.A.3 The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring | 14.1, 14.2, 14.3, 14.4 | • Sickle cell anemia  
• Tay-Sachs disease  
• Huntington’s disease  
• X-linked color blindness  
• Trisomy 21/Down syndrome  
• Klinefelter’s syndrome  
• Reproduction issues  
• Civic issues such as ownership of genetic information, privacy, historical contexts, etc. |
| 3.A.4 The inheritance pattern of many traits cannot be explained by simple Mendelian genetics. | 15.1, 15.2, 15.3, 15.5 | • Sex-linked genes reside on sex chromosomes (X in humans)  
• In mammals and flies, the Y chromosome is very small and carries few genes  
• In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits |
<table>
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<tbody>
<tr>
<td>Are always expressed in males</td>
<td></td>
<td>• Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males</td>
</tr>
</tbody>
</table>
| 3.B.1 Gene regulation results in differential gene expression, leading to cell specialization. | 18.4, 19.2 | • Promoters  
• Terminators  
• Enhancers |
| 3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression. | 11.1, 11.4, 18.4, 19.2, 21.2 | • Cytokines regulate gene expression to allow for cell replication and division  
• Mating pheromones in yeast trigger mating gene expression  
• Levels of cAMP regulate metabolic gene expression in bacteria  
• Expression of the SRY gene triggers the male sexual development pathway in animals  
• Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen  
• Seed germination and gibberellin  
• Mating pheromones in yeast trigger mating genes expression and sexual reproduction  
• Morphogens stimulate cell differentiation and development  
• Changes in p53 activity can result in cancer  
• HOX genes and their role in development |
| 3.C.1 Changes in genotype can result in changes in phenotype. | 15.4, 16.2, 17.7, 23.4 | • Antibiotic resistance mutations  
• Pesticide resistance mutations  
• Sickle cell disorder and heterozygote advantage |
| 3.C.2 Biological systems have multiple processes that increase genetic variation. | 18.3, 13.4 | No illustrative examples listed in Curriculum Framework. |
| 3.C.3 Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts. | 18.1 | • Transduction in bacteria  
• Transposons present in incoming DNA |
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</table>
| 3.D.1  Cell communication processes share common features that reflect a shared evolutionary history. | 11.1, 11.2       | • Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing)  
  • Use of pheromones to trigger reproduction and developmental pathways  
  • Response to external signals by bacteria that influences cell movement  
  • Epinephrine stimulation of glycogen breakdown in mammals  
  • Temperature determination of sex in some vertebrate organisms  
  • DNA repair mechanisms                                                                                                                                 |
| 3.D.2  Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling. | 11.1, 11.2       | • Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells, and killer T-cells. [See also 2.D.4]  
  • Plasmodesmata between plant cells that allow material to be transported from cell to cell  
  • Neurotransmitters  
  • Plant immune response  
  • Quorum sensing in bacteria  
  • Morphogens in embryonic development  
  • Insulin  
  • Human growth hormone  
  • Thyroid hormones  
  • Testosterone  
  • Estrogen                                                                                                                                 |
  • Ligand-gated ion channels  
  • Receptor tyrosine kinases  
  • Ligand-gated ion channels  
  • Second messengers, such as cyclic GMP, cyclic AMP, calcium ions (Ca²⁺), and inositol triphosphate (IP₃)                                                                                                                                 |
| 3.D.4.  Changes in signal transduction pathways can alter cellular response.      | 11.4             | • Diabetes, heart disease, neurological disease, autoimmune disease, cancer, and cholera  
  • Effects of neurotoxins, poisons, and pesticides  
  • Drugs (Hypertensives, Anesthetics, Antihistamines, and Birth Control Drugs)                                                                                                                                 |
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</table>
| 3.E.1. Individuals can act on information and communicate it to others.            | 51.2, 51.3        | - Fight or flight response  
- Predator warnings  
- Protection of young  
- Plant-plant interactions due to herbivory  
- Avoidance responses  
- Herivory responses  
- Territorial marking in mammals  
- Coloration in flowers  
- Bee dances  
- Birds songs  
- Territorial marking in mammals  
- Pack behavior in animals  
- Herd, flock, and schooling behavior in animals  
- Predator warning  
- Colony and swarming behavior in insects  
- Coloration  
- Parent and offspring interactions  
- Migration patterns  
- Courtship and mating behaviors  
- Foraging in bees and other animals  
- Avoidance behavior to electric fences, poisons, or traps |
| 3.E.2. Animals have nervous systems that detect external and internal signals,     | 48.1, 48.2, 48.3, 48.4, 48.5 | - Acetylcholine  
- Epinephrine  
- Norepinephrine  
- Dopamine  
- Serotonin  
- GABA  
- Vision  
- Hearing  
- Muscle movement  
- Abstract thought and emotions  
- Neuro-hormone production  
- Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum)  
- Right and left cerebral hemispheres in humans |
Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

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<tbody>
<tr>
<td>4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.</td>
<td>5.1, 5.2, 5.3, 5.4, 5.5</td>
<td>No illustrative examples listed in Curriculum Framework.</td>
</tr>
<tr>
<td>4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.</td>
<td>6.2, 6.3, 6.4, 6.5</td>
<td>No illustrative examples listed in Curriculum Framework.</td>
</tr>
</tbody>
</table>
| 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts. | 48.4 (refer to illustrative examples for more) | • Stomach and small intestines  
• Kidney and bladder  
• Root, stem and leaf  
• Respiratory and circulatory  
• Nervous and muscular  
• Plant vascular and leaf |
| 4.A.5: Communities are composed of populations of organisms that interact in complex ways. | 52.1, 52.3, 52.4, 52.5, 52.6  
53.1, 53.2 | • Predator/prey relationships spreadsheet model  
• Symbiotic relationship  
• Graphical representation of field data  
• Introduction of species  
• Global climate change models |
| 4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy. | 53.2  
54.1, 54.2, 54.3, 54.4, 55.4 | No illustrative examples listed in Curriculum Framework. |
| 4.B.1: Interactions between molecules affect their structure and function. | 5.4  
8.4, 8.5 | No illustrative examples listed in Curriculum Framework. |
<table>
<thead>
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</thead>
</table>
| 4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter. | 6.4, 40.1, 40.2 (refer to illustrative examples) | • Exchange of gases  
• Circulation of fluids  
• Digestion of food  
• Excretion of wastes  
• Bacterial community in the rumen of animals  
• Bacterial community in and around deep sea vents |
| 4.B.3: Interactions between and within populations influence patterns of species distribution and abundance. | 53.1              | • Loss of keystone species  
• Kudzu  
• Dutch elm disease                                                                                                                                         |
| 4.B.4: Distribution of local and global ecosystems changes over time.               | 25.4, 54.5        | • Dutch elm disease  
• Potato blight  
• Small pox [historic example for Native Americans]  
• El Nino  
• Continental drift  
• Meteor impact on dinosaurs                                                                                                                                  |
| 4.C.1: Variation in molecular units provides cells with a wider range of functions. | 5.1, 5.2, 5.3, 5.4, 5.5, 19.5 | • Different types of phospholipids in cell membranes  
• Different types of hemoglobin  
• MHC proteins  
• Chlorophylls  
• Molecular diversity of antibodies in response to an antigen  
• The antifreeze gene in fish                                                                                                                                    |
| 4.C.2: Environmental factors influence the expression of the genotype in an organism. | 14.3              | • Height and weight in humans  
• Flower color based on soil pH  
• Seasonal fur color in arctic animals  
• Sex determination in reptiles  
• Density of plant hairs as a function of herbivory  
• Effect of adding lactose to a Lac + bacterial culture  
• Effect of increased UV on melanin production in animals  
• Presence of the opposite mating type on pheromones production in yeast and other fungi  
• Darker fur in cooler regions of the body in certain mammal species  
• Alterations in timing of flowering due to climate changes |
### Essential knowledge

**4.C.3:** The level of variation in a population affects population dynamics.

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</table>
| 23.1, 23.2, 23.3  | *Campbell Biology* offers many examples for this area, such as:  
• California condors  
• Black-footed ferrets  
• Prairie chickens  
• Potato blight causing the potato famine  
• Corn rust affects on agricultural crops  
• Tasmanian devils and infectious cancer  
• Not all animals in a population stampede  
• Not all individuals in a population in a disease outbreak are equally affected; some may not show symptoms, some may have mild symptoms, or some may be naturally immune and resistant to the disease |

**4.C.4:** The diversity of species within an ecosystem may influence the stability of the ecosystem.

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| 14.3  
23.1  
53.2  
55.1 | *No illustrative examples listed in Curriculum Framework.* |

Sections that are not covered will depend on which illustrative examples the teacher chooses. Visit [http://www.pearsonschool.com/APCampbellBiology](http://www.pearsonschool.com/APCampbellBiology) (“AP Bio Exam Redesign” section) to see which Concepts in *Campbell BIOLOGY AP* Edition, 9th Edition are included in the Essential Knowledge and Objective outlined in the Curriculum Framework.