Enduring Understanding 2.A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter.

**Essential Knowledge 2.A.3:** Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

a. **Molecules and atoms from the environment are necessary to build new molecules.**

1. Carbon moves from the environment to organisms where it is used to build carbohydrates, proteins, lipids or nucleic acids. Carbon is used in storage compounds and cell formation in all organisms.

2. Nitrogen moves from the environment to organisms where it is used in building proteins and nucleic acids. Phosphorus moves from the environment to organisms where it is used in nucleic acids and certain lipids.

Enduring Understanding 2.D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system’s environment.

**Essential Knowledge 2.D.1:** All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.

a. **Cell activities are affected by interactions with biotic and abiotic factors.**

   - Cell density
   - Biofilms
   - Temperature
   - Water availability
   - Sunlight

b. **Organism activities are affected by interactions with biotic and abiotic factors.**

   - Symbiosis (mutualism, commensalism, parasitism)
   - Predator-prey relationships
   - Water and nutrient availability, temperature, salinity, pH

c. **The stability of populations, communities and ecosystems is affected by interactions with biotic and abiotic factors.**

   - Water and nutrient availability
   - Availability of nesting materials and sites
   - Food chains and food webs
   - Species diversity
   - Population density
   - Algal blooms
Essential Knowledge 2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis.

b. Disruptions to ecosystems impact the dynamic homeostasis or balance of the ecosystem.
   - Invasive and/or eruptive species
   - Human impact
   - Hurricanes, floods, earthquakes, volcanoes, fire
   - Water limitation
   - Salination

Enduring Understanding 4.A: Interactions within biological systems lead to complex properties.

Essential Knowledge 4.A.5: Communities are composed of populations of organisms that interact in complex ways.

a. The structure of a community is measured and described in terms of species composition and species diversity.

b. Mathematical or computer models are used to illustrate and investigate population interactions within and environmental impacts on a community.
   - Predator/prey relationships spreadsheet model
   - Symbiotic relationship
   - Graphical representation of field data
   - Introduction of species
   - Global climate change models

c. Mathematical models and graphical representations are used to illustrate population growth patterns and interactions.

   1. Reproduction without constraints results in the exponential growth of a population.

   2. A population can produce a density of individuals that exceeds the system’s resource availability.

   3. As limits to growth due to density-dependent and density-independent factors are imposed, a logistic growth model generally ensues.

   4. Demographics of data with respect to age distributions and fecundity can be used to study human populations.

Essential Knowledge 4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.

a. Energy flows, but matter is recycled.

b. Changes in regional and global climates and in atmospheric composition influence patterns of primary productivity.

c. Organisms within food webs and food chains interact.
d. Food webs and food chains are dependent on primary productivity.

e. Models allow the prediction of the impact of change in biotic and abiotic factors.

1. Competition for resources and other factors limits growth and can be described by the logistic model.

2. Competition for resources, territoriality, health, predation, accumulation of wastes and other factors contribute to density-dependent population regulation.

f. Human activities impact ecosystems on local, regional and global scales.

1. As human populations have increased in numbers, their impact on habitats for other species have been magnified.

2. In turn, this has often reduced the population size of the affected species and resulted in the habitat destruction and, in some cases, the extinction of species.

g. Many adaptations of organisms are related to obtaining and using energy and matter in a particular environment.

Enduring Understanding 4.B: Competition and cooperation are important aspects of biological systems.

Essential Knowledge 4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter.

a. Organisms have areas or compartments that perform a subset of functions related to energy and matter, and these parts contribute to the whole.

3. Interactions among cells of a population of unicellular organisms can be similar to those of multicellular organisms, and these interactions lead to increased efficiency and utilization of energy and matter.
   - Bacterial community in the rumen of animals
   - Bacterial community in and around deep sea vents


a. Interactions between populations affect the distributions and abundance of populations.

1. Competition, parasitism, predation, mutualism and commensalism can affect population dynamics.

2. Relationships among interacting populations can be characterized by positive and negative effects, and can be modeled mathematically (predator/prey, epidemiological models, invasive species).
3. Many complex symbiotic relationships exist in an ecosystem, and feedback control systems play a role in the functioning of these ecosystems.

b. A population of organisms has properties that are different from those of the individuals that make up the population. The cooperation and competition between individuals contributes to these different properties.

c. Species-specific and environmental catastrophes, geological events, the sudden influx/depletion of abiotic resources or increased human activities affect species distribution and abundance.
   - Loss of a keystone species
   - Kudzu
   - Dutch elm disease

Essential Knowledge 4.B.4: Distribution of local and global ecosystems changes over time.

a. Human impact accelerates change at local and global levels.
   - Logging, slash and burn agriculture, urbanization, monocropping, infrastructure development (dams, transmission lines, roads), and global climate change threaten ecosystems and life on Earth.
   - An introduced species can exploit a new niche free from predators or competitors, thus exploiting new resources.
   - Introduction of new diseases can devastate native species.
     - Dutch elm disease
     - Potato blight
     - Small pox

b. Geological and meteorological events impact ecosystem distribution.

1. Biogeographical studies illustrate these changes.
   - El Niño
   - Continental drift
   - Meteor impact on dinosaurs

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

a. Natural and artificial ecosystems with fewer component parts and with little diversity among the parts are often less resilient to changes in the environment.

b. Keystone species, producers, and essential abiotic and biotic factors contribute to maintaining the diversity of an ecosystem. The effects of keystone species on the ecosystem are disproportionate relative to their abundance in the ecosystem, and when they are removed from the ecosystem, the ecosystem often collapses.