

Indiana Science

# **Disciplinary Core Ideas: Grades 9, 10, 11, 12**

Adopted 2022

## Life Science

### 1. From Molecules to Organisms: Structures and Processes **LS.1**

- LS1-1.** Systems of specialized cells within organisms help them perform the essential functions of life. **HS.LS1-1**
- LS1-2.** All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. **HS.LS1-2**
- LS1-3.** Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. **HS.LS1-3**
- LS1-4.** Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage. **HS.LS1-4**
- LS1-5.** In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. **HS.LS1-5**
- LS1-6.** The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. **HS.LS1-6**
- LS1-7.** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. **HS.LS1-7**
- LS1-8.** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. **HS.LS1-8**
- LS1-9.** As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another and releases energy to the surrounding environment and to maintain body temperature. Cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. **HS.LS1-9**

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## 2. Ecosystems: Interactions, Energy, and Dynamics LS.2

- LS2-1.** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. [HS.LS2-1](#)
- LS2-2.** Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. [HS.LS2-2](#)
- LS2-3.** Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. [HS.LS2-3](#)
- LS2-4.** Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. [HS.LS2-4](#)
- LS2-5.** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. [HS.LS2-5](#)
- LS2-6.** Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. [HS.LS2-6](#)
- LS2-7.** Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. [HS.LS2-7](#)

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### 3. Heredity: Inheritance and Variation of Traits LS.3

- LS3-1.** Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. HS.LS3-1
- LS3-2.** In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. HS.LS3-2
- LS3-3.** Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. HS.LS3-3

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#### 4. Biological Evolution: Unity and Diversity LS.4

- LS4-1.** 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 amino acid sequences and from anatomical and embryological evidence. HS.LS4-1
- LS4-2.** 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. HS.LS4-2
- LS4-3.** The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. HS.LS4-3
- LS4-4.** 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. HS.LS4-4
- LS4-5.** 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. HS.LS4-5
- LS4-6.** Adaptation also means that the distribution of traits in a population can change when conditions change. HS.LS4-6
- LS4-7.** 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. HS.LS4-7
- LS4-8.** 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. HS.LS4-8
- LS4-9.** Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). HS.LS4-9
- LS4-10.** Humans depend on the living world for the resources and other benefits provided by having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and

enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [HS.LS4-10](#)

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## Earth and Space Science

### 1. Earth's Place in the Universe [ESS.1](#)

- ESS1-1.** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. [HS.ESS1-1](#)
- ESS1-2.** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. [HS.ESS1-2](#)
- ESS1-3.** The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gasses, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. [HS.ESS1-3](#)
- ESS1-4.** Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. [HS.ESS1-4](#)
- ESS1-5.** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. [HS.ESS1-5](#)
- ESS1-6.** Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. [HS.ESS1-6](#)
- ESS1-7.** Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. [HS.ESS1-7](#)
- ESS1-8.** Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. [HS.ESS1-8](#)

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## 2. Earth's Systems **ESS.2**

- ESS2-1.** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **HS.ESS2-1**
- ESS2-2.** Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. **HS.ESS2-2**
- ESS2-3.** The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. **HS.ESS2-3**
- ESS2-4.** The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. **HS.ESS2-4**
- ESS2-5.** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. **HS.ESS2-5**
- ESS2-6.** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. **HS.ESS2-6**
- ESS2-7.** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. **HS.ESS2-7**
- ESS2-8.** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **HS.ESS2-8**
- ESS2-9.** Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. **HS.ESS2-9**
- ESS2-10.** Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gasses added to the atmosphere each year and by the ways in which these gasses are absorbed by the ocean and biosphere. **HS.ESS2-10**

**ESS2-11.** The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. [HS.ESS2-11](#)

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**3. Earth and Human Activity** [ESS.3](#)

**ESS3-1.** Resource availability has guided the development of human society. [HS.ESS3-1](#)

**ESS3-2.** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. [HS.ESS3-2](#)

**ESS3-3.** Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. [HS.ESS3-3](#)

**ESS3-4.** The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. [HS.ESS3-4](#)

**ESS3-5.** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. [HS.ESS3-5](#)

**ESS3-6.** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. [HS.ESS3-6](#)

**ESS3-7.** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. [HS.ESS3-7](#)

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## Physical Science

### 1. Matter and Its Interactions PS.1

- PS1-1.** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. HS.PS1-1
- PS1-2.** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. HS.PS1-2
- PS1-3.** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. HS.PS1-3
- PS1-4.** Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. HS.PS1-4
- PS1-5.** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. HS.PS1-5
- PS1-6.** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. HS.PS1-6
- PS1-7.** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. HS.PS1-7
- PS1-8.** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. HS.PS1-8
- PS1-9.** Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. HS.PS1-9

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## 2. Motion and Stability: Forces and Interactions PS.2

- PS2-1. Newton's second law accurately predicts changes in the motion of macroscopic objects. HS.PS2-1
- PS2-2. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. HS.PS2-2
- PS2-3. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. HS.PS2-3
- PS2-4. Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. HS.PS2-4
- PS2-5. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. HS.PS2-5
- PS2-6. Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. HS.PS2-6
- PS2-7. ...and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. HS.PS2-7

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### 3. Energy PS.3

- PS3-1.** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. [HS.PS3-1](#)
- PS3-2.** At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. [HS.PS3-2](#)
- PS3-3.** These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. [HS.PS3-3](#)
- PS3-4.** Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. [HS.PS3-4](#)
- PS3-5.** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. [HS.PS3-5](#)
- PS3-6.** Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. [HS.PS3-6](#)
- PS3-7.** The availability of energy limits what can occur in any system. [HS.PS3-7](#)
- PS3-8.** Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). [HS.PS3-8](#)
- PS3-9.** When two objects interacting through a field change relative position, the energy stored in the field is changed. [HS.PS3-9](#)
- PS3-10.** Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. [HS.PS3-10](#)
- PS3-11.** Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. [HS.PS3-11](#)
- PS3-12.** The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. [HS.PS3-12](#)
- PS3-13.** Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. [HS.PS3-13](#)

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#### 4. Waves and Their Applications in Technologies for Information Transfer PS.4

- PS4-1.** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. HS.PS4-1
- PS4-2.** Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. HS.PS4-2
- PS4-3.** Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) HS.PS4-3
- PS4-4.** Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. HS.PS4-4
- PS4-5.** Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. HS.PS4-5
- PS4-6.** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.(HS-PS4-4) HS.PS4-6
- PS4-7.** Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. HS.PS4-7
- PS4-8.** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. HS.PS4-8
- PS4-9.** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. HS.PS4-9
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## Engineering, Technology, and the Application of Science

### 1. Matter and Its Interactions **EPS.1**

- EPS1-1.** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. **HS.EPS1-1**
- EPS1-2.** Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. **HS.EPS1-2**
- EPS1-3.** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. **HS.EPS1-3**
- EPS1-4.** Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. **HS.EPS1-4**
- EPS1-5.** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade offs) may be needed. **HS.EPS1-5**