

Unit Summary
<p align="center"><i>How do the structures of organisms enable life's functions?</i></p> <p>Students formulate an answer to the question “<i>How do the structures of organisms enable life's functions?</i>” Students investigate explanations for the structure and functions of cells as the basic unit of life, of hierarchical organization of interacting organ systems, and of the role of specialized cells for maintenance and growth. The crosscutting concepts of <i>structure and function</i>, <i>matter and energy</i>, and <i>systems and system models</i> are called out as organizing concepts for the disciplinary core ideas. Students use <i>critical reading</i>, <i>modeling</i>, and <i>conducting investigations</i>. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.</p>
Student Learning Objectives
<p>Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. <i>[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]</i> (LS1.A)</p>
<p>Create representations that explain how genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein. (LS1.A)</p>
<p>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. <i>[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]</i> (HS-LS1-1)</p>
<p>Construct models that explain the movement of molecules across membranes with membrane structure and function. <i>[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]</i> (LS1.A)</p>
<p>Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. <i>[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]</i> (HS-LS1-2)</p>
<p>Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)</p>
<p>Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. <i>[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]</i> (HS-LS1-3)</p>
<p>Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. <i>[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]</i> (HS-LS1-4)</p>

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Unit Sequence	
Part A: <i>How does the structure of DNA determine the structure of proteins, and what is the function of proteins?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> Systems of specialized cells within organisms help them perform the essential functions of life. 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. Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal their functions and/or solve a problem. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. Construct an explanation, based on 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, for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. Conduct a detailed examination of the structure and function of DNA.

Unit Sequence	
Part B: <i>What do you mean they say that people are made of a system of systems?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Develop and use a model based on evidence to illustrate hierarchical organization of interacting systems that provide specific functions within multicellular organism. Develop and use a model based on evidence to illustrate the interaction of functions at the organism system level. Develop and use a model based on evidence to illustrate the flow of matter

	and energy within and between systems of an organism at different scales.
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Unit Sequence	
Part C: How do feedback mechanisms maintain homeostasis?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. Feedback mechanisms maintain a living system's internal conditions within certain limits, and they mediate behaviors, allowing the system to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. Feedback (negative or positive) can stabilize or destabilize a system. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Plan and conduct an investigation individually and collaboratively to produce evidence that feedback mechanisms (negative and positive) maintain homeostasis. In the planning of the investigation, decide on the types, amount, and accuracy of the data needed to produce reliable measurements, consider limitations on the precision of the data, and refine the design accordingly.

Unit Sequence	
Part D: Why aren't all elephants the same size?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. Models (e.g., physical, mathematical, and computer models) can be used to simulate systems and interactions, including energy, matter, and information flows, within and between systems at different scales. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Use a model based on evidence to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. Use a model to illustrate the role of cellular division and differentiation in terms of energy, matter, and information flows within and between systems of cells/organisms.

What It Looks Like in the Classroom

Students must learn that systems of specialized cells within organisms help the organisms perform the essential functions of life. All cells contain genetic information in the form of DNA molecules. Genes are regions of DNA that contain the instructions that code (transcription and translation) for the formation of proteins, which carry out most of the work of cells. Students should conduct a detailed examination of the structure and function of DNA by building a model of DNA to demonstrate their knowledge of Chargaff's Rule. Models can also be used to illustrate the processes of transcription and translation to clarify the function of DNA in terms of protein synthesis. Students should also draw and cite evidence from informational texts to support an explanation for how the structure of DNA determines the structure of proteins.

Multicellular organisms have a hierarchical structural organization in which one system is made of numerous parts and is itself a component of the next level. Models (e.g. physical, mathematical, and computer models) could be used by students to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Students should also examine matter and energy transfers within and between systems of an organism at different scales. Students might create presentations, using digital media, to enhance their understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Students should develop an understanding of how systems of cells, tissues, and organs work together to meet the needs of the whole organism. Students should use models and oral presentations to simulate maintenance and development within complex organisms by mitosis and cell differentiation. For example, students might develop models of kidney function using dialysis tubing to illustrate the filtration of particular solutes. The same materials can be used to connect the specialized cells of the kidney to the rest of the organ, organ system, and organism in relation to excretion. Other system models that represent the hierarchical levels of organization that perform necessary life functions maintaining homeostasis could be used. Some examples include gas exchange, secretion, absorption, transport, and communication.

Students need an understanding of how external conditions affect the internal conditions of an organism. Feedback mechanisms maintain the internal conditions of living systems within a limited range, in part due to mediated behaviors such as basking, use of shade, mud baths, and burrowing. These feedback mechanisms can encourage or discourage physiological responses in living systems. Students can investigate sugar, oxygen, and temperature regulations, individually and collaboratively, to produce evidence that feedback mechanisms maintain homeostasis. Because feedback can stabilize or destabilize a system, the planning of investigations should address decisions about the type, quantity, accuracy, reliability, and limitations of the data. Design of investigations should be adjusted accordingly. In planning their investigations, students should conduct research and synthesize information from multiple reliable sources to support claims about how feedback mechanisms maintain homeostasis.

Students should investigate and model the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. In multicellular organisms, individual cells grow and then divide in the process called mitosis. At the earliest stage of life, a single cell, or zygote, divides successively to produce many cells (stem cells). These cells pass identical genetic material (two variants of each chromosome pair) in the form of homologous chromosome pairs to both daughter cells. Complex multicellular organisms maintain themselves by growing and developing through cellular divisions (mitosis) and differentiation of cells. Students should identify important quantities in the role of cellular division and differentiation and use mathematical models to illustrate how these processes produce and maintain complex organisms. Models might include data showing numbers of cells at different stages of development. Data could be collected from observing the different stages of mitosis using a microscope or virtual/computer simulation. Graphs and functions could be used to show growth rate in terms of cell division.

Connecting with English Language Arts/Literacy and Mathematics*English Language Arts/Literacy*

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and differentiation in producing and maintaining complex organisms and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Graph functions expressed symbolically showing the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

Preliminary research indicates that it may be easier for students to understand that the cell is the basic unit of structure (which they can observe) than that the cell is the basic unit of function (which has to be inferred from experiments). Research also shows that high-school students may hold various misconceptions about cells after traditional instruction ([NSDL, 2015](#)).

Prior Learning

By the end of Grade 8, students understand that:

Life science

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and

organs that are specialized for particular body functions.

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.
- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.
- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.
- Genetic factors as well as local conditions affect the growth of the adult plant.
- Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.

Connections to Other Units

- Each chromosome consists of a single, very long DNA molecule, and each gene on a 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 known function.

Sample of Open Education Resources

Membrane Channels Simulation: Students begin by asking questions that arise from demonstrations with aromatic sprays and they will articulate the movement of particles from areas of high concentrations to lower concentrations. The students will then ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. Students will develop, revise, and /or use a model based on evidence to illustrate and/or predict the relationship between systems or between components of a system using a computer simulation. Students will then communicate scientific and/or technical information or ideas in multiple formats (including orally, graphically, and textually).

Membrane Diffusion: Collaboratively, students will analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution. Students can then work either collaboratively or independently to use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Appendix A: NGSS and Foundations for the Unit
<p>Explain the connection between the sequence and the subcomponents of a biomolecule and its properties. <i>[Clarification Statement: Emphasis is on the general structural properties that define molecules. Examples include r-groups of amino acids, protein shapes, the nucleotide monomers of DNA and RNA, hydrophilic and hydrophobic regions.] [Assessment Boundary: Assessment does not include identification or the molecular sequence and structure of specific molecules]</i> (LS1.A)</p>
<p>Create representations that explain how genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a protein. (LS1.A)</p>
<p>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. <i>[Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]</i> (HS-LS1-1)</p>
<p>Construct models that explain the movement of molecules across membranes with membrane structure and function. <i>[Clarification Statement: Emphasis is on the structure of cell membranes, which results in selective permeability; the movement of molecules across them via osmosis, diffusion and active transport maintains dynamic homeostasis.]</i> (LS1.A)</p>
<p>Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. <i>[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]</i> (HS-LS1-2)</p>
<p>Provide examples and explain how organisms use feedback systems to maintain their internal environments. (LS1.A)</p>
<p>Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. <i>[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]</i> (HS-LS1-3)</p>
<p>Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. <i>[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]</i> (HS-LS1-4)</p>

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Construct 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. (HS-LS1-1) <p>Developing and Using Models</p> <ul style="list-style-type: none"> Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2) <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3) 	<p>LS1.A: Structure and Function</p> <ul style="list-style-type: none"> 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-LS1-2) 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 (negative feedback) what is going on inside the living system. (HS-LS1-3) Regions of DNA called genes determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells. The sequence of genes contains instructions that code for proteins. (LS1.A) Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism. (LS1.A) 	<p>Systems and System Models</p> <ul style="list-style-type: none"> Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-2) <p>Stability and Change</p> <ul style="list-style-type: none"> Feedback (negative or positive) can stabilize or destabilize a system. (HS-LS1-3)

English Language Arts	Mathematics
<p>Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. WHST.9-12.7 (HS-LS1-3)</p> <p>Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. WHST.11-12.8 (HS-LS1-3)</p> <p>Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. SL.11-12.5 (HS-LS1-2)</p>	<p>N/A</p>