High School Conceptual Progressions Model Course II – Bundle 4
Stability in Body Systems

This is the fourth bundle of the High School Conceptual Progressions Model Course II. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 4 Question: This bundle is assembled to address the question "how do organisms maintain stability, even under different conditions?"

Summary

The bundle organizes performance expectations around helping students understand the various levels of organization and maintenance in body systems. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

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 (LS1.A as in HS-LS1-2). This concept connects to the idea that these systems are formed when individual cells grow and then divide via a process called mitosis. 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 (LS1.B as in HS-LS1-4). Both of these ideas connect to the concept that complexity is supported by various feedback mechanisms that 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 (LS1.A as in HS-LS1-3).

The engineering design concept that humanity faces major global challenges today, such as the need for clean water and food or for energy sources that minimize pollution, which can be addressed through engineering (ETS1.A as in HS-ETS1-1) could be applied to many different science ideas, including to the idea that feedback mechanisms maintain a living system's internal conditions within certain limits even as external conditions change within some range (LS1.A as in HS-LS1-3). Connections could be made through an engineering design task such as obtaining and evaluating information about human tolerance levels for water contaminants to define criteria for public water systems, or analyzing data on the conditions needed to maintain healthy plants to define criteria for large-scale agriculture.

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (HS-ETS1-1), developing and using models (HS-LS1-2 and HS-LS1-4), and planning and carrying out investigations (HS-LS1-3). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Systems and System Models (HS-LS1-4) and Stability and Change (HS-LS1-3). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	**HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** [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.] **HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.** [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.] **HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.] **HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
Example Phenomena	When I get cold, I shiver. When I get a cut, a scab grows and my skin heals itself.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. Students could *ask questions that arise from examining models to seek additional information* [about how] ***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-LS1-4 **Developing and Using Models** • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. Students could *use multiple types of models to provide mechanistic accounts* [of how] ***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***. HS-LS1-3 **Planning and Carrying Out Investigations** • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. Students could *make directional hypotheses that specify what happens to* [one part of a body] ***system*** *when* [another part of the body] ***system changes***. HS-LS1-3

Additional Practices Building to the PEs (Continued)	**Analyzing and Interpreting Data** • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Students could *analyze data to make valid and reliable scientific claims* [about the idea that] ***feedback mechanisms can encourage or discourage what is going on inside the living system***. HS-LS1-3 **Using Mathematical and Computational Thinking** • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Students could use mathematical representations to support claims [that] ***the systems in multicellular organisms are hierarchical***. HS-LS1-2 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Students could apply scientific ideas and evidence to provide an explanation [for how] ***systems of tissues and organs work together to meet the needs of the whole organism***. HS-LS1-4 **Engaging in Argument from Evidence** • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). Students could evaluate competing design solutions [for how artificial systems could mimic] ***feedback mechanisms in maintaining a living system's internal conditions within certain limits***. HS-LS1-3 **Obtaining, Evaluating, and Communicating Information** • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). Students could communicate scientific information in multiple formats [about how] ***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***. HS-LS1-3
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Students could identify *different patterns at each of the scales of an organism's* [body] *system and provide evidence for causality* [for] ***feedback mechanisms*** [between the] ***systems***. HS-LS1-2 and HS-LS1-3

Additional Crosscutting Concepts Building to the PEs (Continued)	**Cause and Effect** • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Students could *suggest and predict cause and effect relationships by examining what is known about smaller scale mechanisms* [for how] ***feedback mechanisms maintain a living system's internal conditions***. HS-LS1-3 **Structure and Function** • 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 its function and/or solve a problem. Students could *examine the structures of different* ***system*** *components* [when] *investigating* [whether] ***multicellular organisms have a hierarchical structural organization***. HS-LS1-2
Additional Connections to Nature of Science	**Scientific Knowledge is Based on Empirical Evidence (SEP):** • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. Students could construct an argument for how *science disciplines share common rules of evidence used to evaluate explanations,* [using as an example the explanation that] ***feedback mechanisms maintain a living system's internal conditions within certain limits***. HS-LS1-3 **Science Addresses Questions About the Natural and Material World (CCC):** • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. Students could construct an argument for how s*cience and technology may raise ethical issues for which science, by itself, does not provide answers and solutions* [about how] ***feedback mechanisms maintain a living system's internal conditions within certain limits as external conditions change,*** [but only] ***within*** [certain] ***ranges***. HS-LS1-3

HS-LS1-2

Students who demonstrate understanding can:

HS-LS1-2. **Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.** [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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.	**LS1.A: Structure and Function** • 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.	**Systems and System Models** • 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.

Observable features of the student performance by the end of the course:		
1	Components of the model	
	a	Students develop a model in which they identify and describe* the relevant parts (e.g., organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms.
2	Relationships	
	a	In the model, students describe* the relationships between components, including:
		i. The functions of at least two major body systems in terms of contributions to overall function of an organism;
		ii. Ways the functions of two different systems affect one another; and
		iii. A system's function and how that relates both to the system's parts and to the overall function of the organism.
3	Connections	
	a	Students use the model to illustrate how the interaction between systems provides specific functions in multicellular organisms.
	b	Students make a distinction between the accuracy of the model and actual body systems and functions it represents.

HS-LS1-3

Students who demonstrate understanding can:

HS-LS1-3. **Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.** [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.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • 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. - ***Connections to Nature of Science*** **Scientific Investigations Use a Variety of Methods** • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.	**LS1.A: Structure and Function** • 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.	**Stability and Change** • Feedback (negative or positive) can stabilize or destabilize a system.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon under investigation		
	a	Students describe* the phenomenon under investigation, which includes the following idea: that feedback mechanisms maintain homeostasis.	
2	Identifying the evidence to answer this question		
	a	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including:	
		i.	Changes within a chosen range in the external environment of a living system; and
		ii.	Responses of a living system that would stabilize and maintain the system's internal conditions (homeostasis), even though external conditions change, thus establishing the positive or negative feedback mechanism.
	b	Students describe* why the data will provide information relevant to the purpose of the investigation.	
3	Planning for the investigation		
	a	In the investigation plan, students describe*:	
		i.	How the change in the external environment is to be measured or identified;
		ii.	How the response of the living system will be measured or identified;

		iii.	How the stabilization or destabilization of the system's internal conditions will be measured or determined;
		iv.	The experimental procedure, the minimum number of different systems (and the factors that affect them) that would allow generalization of results, the evidence derived from the data, and identification of limitations on the precision of data to include types and amounts; and
		v.	Whether the investigation will be conducted individually or collaboratively.
4	Collecting the data		
	a	Students collect and record changes in the external environment and organism responses as a function of time.	
5	Refining the design		
	a	Students evaluate their investigation, including:	
		i.	Assessment of the accuracy and precision of the data, as well as limitations (e.g., cost, risk, time) of the investigation, and make suggestions for refinement; and
		ii.	Assessment of the ability of the data to provide the evidence required.
	b	If necessary, students refine the investigation plan to produce more generalizable data.	

HS-LS1-4

Students who demonstrate understanding can:

HS-LS1-4. **Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.** [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- 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.

Crosscutting Concepts

Systems and System Models

- 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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From the given model, students identify and describe* the components of the model relevant for illustrating the role of mitosis and differentiation in producing and maintaining complex organisms, including:	
		i.	Genetic material containing two variants of each chromosome pair, one from each parent;
		ii.	Parent and daughter cells (i.e., inputs and outputs of mitosis); and
		iii.	A multi-cellular organism as a collection of differentiated cells.
2	Relationships		
	a	Students identify and describe* the relationships between components of the given model, including:	
		i.	Daughter cells receive identical genetic information from a parent cell or a fertilized egg.
		ii.	Mitotic cell division produces two genetically identical daughter cells from one parent cell.
		iii.	Differences between different cell types within a multicellular organism are due to gene expression — not different genetic material within that organism.
3	Connections		
	a	Students use the given model to illustrate that mitotic cell division results in more cells that:	
		i.	Allow growth of the organism;
		ii.	Can then differentiate to create different cell types; and
		iii.	Can replace dead cells to maintain a complex organism.
	b	Students make a distinction between the accuracy of the model and the actual process of cellular division.	

HS-ETS1-1

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Analyze complex real-world problems by specifying criteria and constraints for successful solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** • 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. • 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.	- ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering, and Technology on Society and the Natural World** • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Observable features of the student performance by the end of the course:			
1	Identifying the problem to be solved		
	a	Students analyze a major global problem. In their analysis, students:	
		i.	Describe* the challenge with a rationale for why it is a major global challenge;
		ii.	Describe*, qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
		iii.	Document background research on the problem from two or more sources, including research journals.
2	Defining the process or system boundaries, and the components of the process or system		
	a	In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.	
	b	In their analysis, students describe* societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).	
3	Defining the criteria and constraints		
	a	Students specify qualitative and quantitative criteria and constraints for acceptable solutions to the problem.	