Figure 5.1. Integrated Grade Six Storyline

Guiding Concept: Systems within organisms and between them are adapted to Earth's climate systems.

Instructional Segment	**1** A cell, a person, and planet Earth are each a system made up of subsystems.	**2** Weather conditions result from the interactions among different Earth subsystems.	**3** Regional climates strongly influence regional plant and animal structures and behaviors.	**4** Human activities can change the amount of global warming, which impacts plants and animals.
Life Science (LS)	All living things are made of cells. The body is a system made of interacting subsystems.	Blank	Variations of inherited strains arise from genetic differences. Genetic traits and local conditions affect the growth of organisms. Organisms rely on their body structures and behavior to survive long enough to reproduce.	Local conditions affect the growth of organisms. Organisms rely on their body structures and behavior to survive, but these adaptations may not be enough to survive as the climate changes.
Earth and Space Sciences (ESS)	Water cycles among the land, ocean, and atmosphere. Weather and climate involve interactions among Earth's subsystems.	The movement of water and interacting air masses helps determine local weather patterns and conditions. The ocean has a strong influence on weather and climate.	Energy input from the Sun varies with latitude, creating patterns in climate. Energy flow through the atmosphere, hydrosphere, geosphere, and biosphere affects local climate. Density variations drive global patterns of air and ocean currents.	Human changes to Earth's environment can have dramatic impacts on different organisms. Burning fossil fuels is a major cause of global warming. Strategic choices can reduce the amounts and impacts of climate change.
Physical Science (PS)	Blank	Temperature measures the average kinetic energy of the particles that make up matter. Energy transfers from hot materials to cold materials. The type and amount of matter affects how much an object's temperature will change.	The type and amount of matter affects how much an object's temperature will change.	Blank
Engineering, Technology, and Applications to Science (ETS)	Design criteria. Evaluate solutions.	Design criteria. Evaluate solutions. Analyze data. Iteratively test and modify.	Blank	Design criteria. Evaluate solutions. Analyze data.

In IS1, students define systems and system models [CCC-4] and apply these ideas to different Earth science and life science contexts. A key understanding from IS1 is that systems [CCC-4] are made of component parts that interconnect with each other. Moreover each of the component parts is itself a system that is made of component parts. This notion of *systems within systems within systems* (also called nested systems) is particularly apparent in analyzing a "human being system" that is made of components called body systems (e.g., the circulatory system) that are made of organs (e.g., the heart) that are made of tissues that consist of different kinds of cells.

In IS2, students explore California weather from the perspective of the flow of energy and cycling of matter [CCC-5] within a system [CCC-4]. In grade five, students developed models [SEP-2] of how Earth's systems interact (IS1 reviews the systems). They also explored the reservoirs of the water cycle. In IS2 students deepen their understanding by analyzing the processes of the water cycle and the physical science underlying these processes. These Earth science and physical science concepts are then applied to understanding weather in different California regions. Patterns [CCC-1] of temperature and precipitation are causally related [CCC-2] to geographical features such as proximity to the ocean, latitude, altitude, and proximity to mountains. The water cycle is also important conceptually because of its central role in weather phenomena and because it provides an example of a property of a whole system [CCC-4] that is different than the properties of its parts.

Instructional segment 3 extends the students' investigations to the more general level of regional climate in different parts of the planet. At the level of climate, students can correlate the cause and effect [CCC-2] relationships that determine regional climate patterns and the circulation of matter and energy [CCC-5] by the atmosphere and ocean. Students also correlate cause and effect [CCC-2] relationships between the climate of a region and the structures and behaviors of plants and animals that live in that region. Regional climate provides another compelling example of a property of a whole system [CCC-4].

Instructional segment 4 concludes the year by scaling [CCC-3] from the regional climate level to the level of global warming. In previous instructional segments, students had several opportunities to design solutions to problems primarily from engineering and technology perspectives. During IS4, they have opportunities to work on projects related to monitoring an environmental issue and designing solutions [SEP-6] to reduce the impacts related to that issue. Global climate change provides many opportunities to further develop and apply skills relating to the technological and scientific aspects of solving societal problems. Global climate change also provides a real-world context where some of the criteria and constraints can involve social motivations and patterns of behavior that must be considered as part of the design in solving a problem.

IS1

Integrated Grade Six Instructional Segment 1: Systems and Subsystems in Earth and Life Science

The CCC of Systems and System Models [CCC-4] is a useful tool that can help learners to connect ideas both within a topic and across science disciplines. Chapter 1, the overview of this framework, provides a detailed definition of systems [CCC-4] in the CA NGSS. In brief, systems are a just a way of thinking about a small section of the world and the objects and processes that occur within that section. In this instructional segment, students practice defining systems, recognizing their components, and describing how they interact using examples at a range of scales from cells to organisms to the entire planet Earth.

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 1: SYSTEMS AND SUBSYSTEMS IN EARTH AND LIFE SCIENCE

Guiding Questions

- How are living systems and Earth systems similar and different?
- What is the value of creating a systems model?

Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. [Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.] [*Assessment Boundary: Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane. Assessment of the function of the other organelles is limited to their relationship to the whole cell. Assessment does not include the biochemical function of cells or cell parts.*]

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [*Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.*]

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. [*Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.*]

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 1: SYSTEMS AND SUBSYSTEMS IN EARTH AND LIFE SCIENCE

MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.] [*Assessment Boundary: A quantitative understanding of the latent heats of vaporization and fusion is not assessed.*]

MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

The bundle of performance expectations above focuses on the following elements from the NRC document *A Framework for K–12 Science Education*:

Highlighted Science and Engineering Practices	Highlighted Disciplinary Core Ideas	Highlighted Crosscutting Concepts
[SEP-1] Asking Questions and Defining Problems [SEP-2] Developing and Using Models [SEP-3] Planning and Carrying Out Investigations [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.A: Structure and Function LS1.D: Information Processing ESS2.C: The Role of Water in Earth's Surface Processes ESS2.D: Weather and Climate ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions	[CCC-2] Cause and Effect [CCC-3] Scale, Proportion, and Quantity [CCC-4] System and System Models [CCC-5] Energy and Matter: Flows, Cycles and Conservation [CCC-6] Structure and Function

Highlighted California Environmental Principles and Concepts:
Principle II The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies.

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 1: SYSTEMS AND SUBSYSTEMS IN EARTH AND LIFE SCIENCE

Principle III Natural systems proceed through cycles that humans depend upon, benefit from and can alter.

Principle IV The exchange of matter between natural systems and human societies affects the long-term functioning of both.

CA CCSS Math Connections: 6.EE.9

CA CCSS for ELA/Literacy Connections: RST.6–8.1, R.I.6.8, WHST.6–8.1, 7, 8, 9, SL.6.

CA ELD Connections: ELD.PI.6.6a–b,10, 9, 11a

The scientific definition of a system differs from the everyday language definition. Students often equate systems with cycles such as a life cycle or a collection of orbits like the solar system. Rather than learning terminology and definitions first, students begin this instructional segment by exploring a situation that exemplifies the key features of systems. Students **obtained information [SEP-8]** about the massive experiment called *Biosphere 2,* where scientists placed plants, animals, and people in an airtight glass building to see what challenges they faced as they tried to survive together as a system. As an anchoring phenomenon for this unit, students learn about how the project failed when oxygen levels were unsafe and some animals died. After watching a short video that describes some of the events that occurred in the Biosphere experiment, students consider the question, What did the scientists in the Biosphere need to survive and where did they get it? For food, the people ate fish, But what did the fish need to survive and where did they get it? As students draw a system **model [SEP-2]** that traces out the exchange of energy and matter, they grapple with the key features of **systems [CCC-4]**: boundaries, components, interactions, inputs/outputs, and one or more system properties.

Opportunities for ELA/ELD Connections

Have students explore the classroom and find examples of what they predict are systems (e.g., sound, computer, body, ecosystems). Provide students with a graphic organizer that has them write the reasons they consider it a system, using words, phrases or sentences depending on their level of English proficiency. Place students in groups, and using their graphic organizer, have students take turns reporting the information they gathered. Next, have them read an appropriate science text and identify the five features of systems within the text. Using evidence from text and language frames that either confirm or refute it as a system, have them discuss the connections they gathered between their classroom example and textual evidence, including a definition. Ask students in their groups to revisit their classroom examples and reach consensus on whether or not each meets the criteria of a system [CCC-4] based on the five important features: boundaries, components, interactions, inputs/outputs, and one or more system properties.

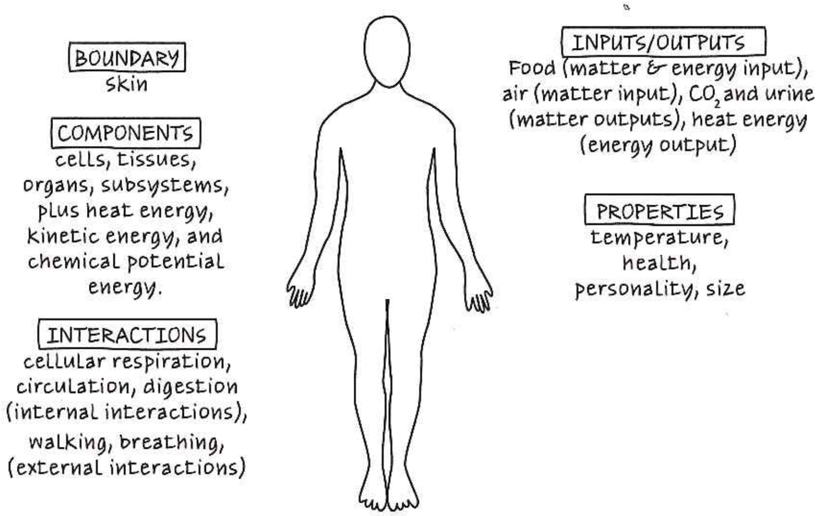
CA CCSS for ELA/Literacy Standards: RST.6–8.1, 2, 4; SL.6–8.1

CA ELD Standards: ELD.PI.6–8.1, 2

Human Body Systems

Next, students focus on their own body system (figure 5.2). Explicitly discussing the features of a system [CCC-4] is just the first step in creating a system model [SEP-2] that can explain different phenomena in a human body. For example, answering the question, Why does my heart race when I get scared? requires that students obtain information [SEP-8] about how different components of the body interact. Students trace the chain of interactions from the energy input to their system (via sense receptors) to low-level interactions in the nervous system to the endocrine system (transfer of energy as electrical impulses). The endocrine system then transfers matter into the circulatory system (adrenaline and other hormones) that stimulates the muscular system to react, enabling a body as a whole to run away from a dangerous situation. The brain also encodes these perceptions as memories to anticipate future problems (MS-LS1-8).

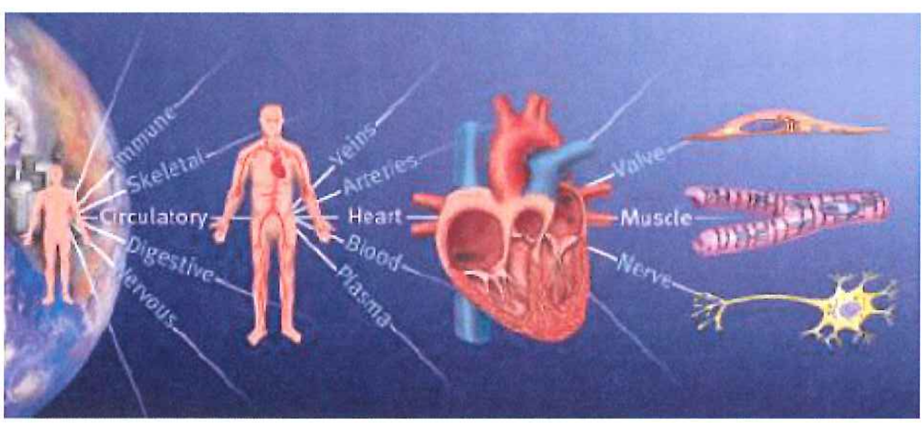
Figure 5.2. Features of a Human Person System



Source: From Making Sense of SCIENCE: Land and Water (WestEd.org/mss) by Folsom and Daehler. Copyright © 2012 WestEd. Adapted with permission.

When tracing out these interactions within the body system, students uncover the middle school understanding: "Systems may interact with other systems; they may have subsystems and be a part of larger more complex systems" (NGSS Lead States 2013). In other words, the components of a system are generally themselves systems that are made of smaller components (figure 5.3). Students must be able to use examples of body phenomena to **support an argument [SEP-7]** that the human body has interacting subsystems (MS-LS3-1).

Figure 5.3. Systems Within Systems Within Systems



Body systems, such as the circulatory system, are examples of systems within systems within systems. *Source:* Sussman 2000

Engineering Connection: Designing a Better Swing

Teaching about organ and tissue donation provides opportunities to connect learning about body systems [CCC-4] with a socially beneficial topic that also has strong connections with engineering and technology. Donate Life California has an informative Web site that includes educator resources, notably an Interactive Body Tour (see Donate Life California at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link2).

Students can work in groups to research and learn about organ and tissue donation related to different body systems and diseases. They can create system diagrams related to the different diseases and transplantation remedies as well as representing the system for soliciting donors, identifying recipients, and getting the organs/tissues to the patients in excellent condition and within the necessary criteria and time constraints.

Students can also evaluate [SEP-8] how well the Web page motivates people to become donors. Without a large pool of potential donors, doctors won't be able to provide transplants to people that need them. Sharing these issues to policy makers and the public are important aspects of communicating science [SEP-8]. Students can also analyze donor recruitment as a system for which they can identify constraints [SEP-1] and propose solutions [SEP-6] to increase the number of people who volunteer to become donors. This kind of system modeling [CCC-4] extends the crosscutting concept beyond physical science and engineering into applications of science to social issues.

Components of subsystems can even be considered systems themselves when viewed at a smaller scale [CCC-3]. Students can focus in on a phenomenon that requires them to understand interactions at the level of an individual cell. For example, What happens to the body when someone gets cancer? Doctors have figured out that cancer occurs when a cell "malfunctions," so students will need to know what a cell is and how it normally functions. Students begin by performing an investigation [SEP-3] to gather evidence that living things are made of cells and nonliving things are not (MS LS1-1). Comparing microscope images of nonliving objects and different types of cells, students can identify similarities and differences between each of the cells. Then they ask questions [SEP-1] about the role of the parts they see: Why do red blood cells have no large circle in the center? Why is a sperm cell so small and an egg so big? Why do all plant cells have a thick wall around them but animal cells do not? Why do all plant cells have green circles in them but animal cells do not? With scaffolding from the teacher and other resources, they use their observations to develop a model [SEP-2] of what several parts of the cell do: the nucleus, mitochondria, chloroplasts, cell wall, and cell membrane. The clarification statement of MS-LS1-2 specifies this limited set of parts so that students can focus on the key structures that facilitate energy and reproduction, and the details of other organelles will not be assessed in the middle grades (students will expand their model in high school as part of the developmental progression of the CA NGSS). Students **obtain information [SEP-8]** from books or media about how **energy and matter [CCC-5]** flow into, out of, and within the cell system. Rather than the traditional assessment of having students label parts of the cell, students could use a cell diagram as a template for making a system **model [SEP-2]** with arrows and labels indicating **energy and matter flows [CCC-5]**. Students can return to the original phenomena of cancer in the context of their model of the cell, identifying the location where the cell malfunctions (the nucleus).

Students should not only be able to represent the system model of the cell, they should be able to use it to explain more complicated phenomena such as why people get thirsty when they eat salty foods. As with all systems, student can identify salt as the input of matter and then trace the cycling of the matter between the different components of the system (parts of the body). Using their knowledge of body systems, students can probably trace the flow of salt from their food to their blood, but they need to **ask questions [SEP-1]** about the possible **causes [CCC-2]** of the thirst sensation (e.g., Do you actually need to drink, or does the salt just trigger your nervous system into thinking that you need to drink?). As students discuss each possible cause, they use evidence to rule some of these ideas out. They then propose investigations that could test the remaining ideas. Students can **conduct an investigation [SEP-3]** to observe how cells react to water with different concentrations of salt (using plant cells rather than animals due to safety and logistical concerns). By thinking of the cell as a system, students can explain the shrinking of a plant cell in saltwater by the flow of matter out of the system.

The assessment boundary for MS-LS1-2 emphasizes that students should be able to explain the role the cell wall/membrane plays as the boundary of the cell system, and how its **structure supports this function [CCC-6]**. To refine their **model [SEP-2]** of cell boundary behavior, students use DCIs from physical science about how matter is made of particles (5-PS1-1). They can represent saltwater as a mixture of particles including water particles and "salt particles." Which flows across the cell wall (or membrane) more easily, water particles or salt particles? Even though a model with salt as a single particle is an oversimplification, it is consistent with what students know and have observed. For that reason, one could argue that applying this "incorrect'" model is more scientifically accurate in that it exemplifies the tentative nature of scientific models built on observable evidence. Students will revise this model of saltwater later in high school when they find that a single "salt" particle cannot explain the electrical conductivity of saltwater.

Earth Systems

The salt tolerance of plants is a topic for agriculture and also motivates a transition to looking at a larger system of systems, the planet Earth. What happens to plants near the coast when rising sea level brings salty water into the soil? Students can **obtain information [SEP-8]** about saltwater intrusion in coastal aquifers as an entry point into thinking about the entire planet Earth as a system of interacting subsystems. In grade five students learned that planet Earth can be thought of as four major systems (table 5.3). Some scientists argue that there should be a fifth sphere called the anthroposphere that highlights the importance of humanity and all its creations.

Table 5.3. Earth Systems

EARTH SYSTEMS	EARTH'S MATERIALS
Geosphere	**Rocks, minerals, and landforms** at Earth's surface and in its interior, including soil, sediment, and molten rocks
Hydrosphere	**Water**, including ocean water, groundwater, glaciers and ice caps, rivers, lakes, etc.
Atmosphere	**Gases** surrounding the Earth (i.e., our air)
Biosphere	**Living organisms**, including humans

While in grade five, students focused on the functioning of each individual system. In the grade six they progress to understanding the Earth as a singular system where each of the Earth systems they learned about in grade five is now viewed as a component or subsystem of the larger scale planet system. Learners of all ages generally expect that definitions, especially those in science, should be precise and either/or. For example, the geosphere is *either* its own system or a component of a larger system, but not both at the same time. Older students of science often advance beyond rigid either/or thinking toward both/and nuances and complexity. In the case of saltwater intrusion, rising temperature in the atmosphere exchanges energy with water in the hydrosphere causing it to warm and expand. That water ultimately infiltrates into soil in the geosphere, where it becomes a part of groundwater. There, plant roots bring it into the biosphere. When thinking about Earth systems, water is commonly exchanged as output from one subsystem and input to a different one, but water is also considered a subsystem of its own (the hydrosphere). This ambiguity highlights how system boundaries can often be challenging to define. The person modeling the system (scientist, teacher, student) has the freedom to choose the boundaries of the system based upon the goal of the modeling. Table 5.4 indicates the boundaries that different people might choose when studying water on Earth based on different goals of their investigations. Students also gain insight into system boundaries by explicitly comparing the boundaries in body and cell systems to boundaries in the Earth system. Students can practice identifying the appropriate boundaries for investigating phenomena from other domains explored in earlier grades (e.g., What causes an egg to break when it drops? [PS2.A] Why do animals move into the city during a drought? [LS2.C] Why is gold so expensive? [ESS3.A]).

Table 5.4. Different System Boundaries for Investigating Water on Earth

INVESTIGATION TOPIC	SYSTEM BOUNDARY	MATTER INPUT/OUTPUT
Forecasting changes in the water cycle due to global warming	Planet Earth and all its subsystems	Very little water enters or leaves the planet
Predicting changes in sea level for known global warming scenarios	All Earth's oceans and ice	Rainfall and streamflow in, evaporation out
Tracking down the source of pollution in a creek	An entire watershed, including surface and groundwater	Rainfall enters, pollution enters, water flows out to the ocean and evaporates
Getting freshwater for a farm	Groundwater aquifer	Water soaking in from the surface, pumping out
Surfing at the beginning and end of the day	A local beach, including seafloor shape	Tidewater in/out (energy in from waves, out from crashing)
Cleaning a city's sewage before it drains into the ocean	City sewage treatment facility	Sewage in, clean water and waste out

Table by Dr. Art Sussman, courtesy of WestEd

Just as the boundaries between systems can be difficult to define, the boundary between IS1 and IS2 is also nebulous. The goal of IS1 is to deepen student understanding of systems and system models and therefore includes systems from several disciplines. Instructional segment 2 then goes into the details of system models of the water cycle and weather systems.