all the rest of Earth's crust. Atoms of these eight elements combine to form the vast majority of Earth's rocks and minerals. Throughout all the physical and chemical interactions, none of these atoms are lost or destroyed. Even as the appearance and behavior of the rocks change [CCC-7], their overall composition remains relatively stable [CCC-7].

IS3 Integrated Grade Seven Instructional Segment 3: Natural Processes and Human Activities Shape Earth's Resources and Ecosystems

When students look out on a landscape, they might see trees in some places but not others and a gold mine on one hill but not another. In this instructional segment, students focus on explaining why things are located where they are, including organisms within an ecosystem and resources and hazards on the planet. In both cases, interactions within and between different Earth systems determine these distributions. Humans both depend on these distributions and can dramatically alter them. The goal of integrating these topics is that the questions students learn to ask about the distribution of resources on the planet can serve as a template for understanding the relationships between organisms in an ecosystem, and vice versa.

INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 3: NATURAL PROCESSES AND HUMAN ACTIVITIES SHAPE EARTH'S RESOURCES AND ECOSYSTEMS

Guiding Questions

- How can we use interactions between individual rocks or individual organisms to understand systems as big as the whole geosphere or whole ecosystem?
- How can we use patterns in geosphere interactions to predict the location of resources?
- How can we use patterns in ecosystem interactions to predict how organisms compete and share resources?

Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 3: NATURAL PROCESSES AND HUMAN ACTIVITIES SHAPE EARTH'S RESOURCES AND ECOSYSTEMS

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [*Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.*]

MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*] (Revisited from IS1, but not assessed until IS4)

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms that represent atoms.] [*Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.*]

INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 3: NATURAL PROCESSES AND HUMAN ACTIVITIES SHAPE EARTH'S RESOURCES AND ECOSYSTEMS

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-2] Developing and Using Models [SEP-4] Analyzing and Interpreting Data [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-8] Obtaining, Evaluating, and Communicating Information	LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycles of Matter and Energy Transfer in Ecosystems ESS1.C: The History of Planet Earth ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS3.A: Natural Resources PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions	[CCC-1] Patterns [CCC-2] Cause and Effect: Mechanism and Explanation [CCC-5] Energy and Matter: Flows, Cycles, and Conservation [CCC-6] Structure and Function

Highlighted California Environmental Principles and Concepts:

Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.

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

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.

Principle V Decisions affecting resources and natural systems are complex and involve many factors.

CA CCSS Math Connections: 6.EE.6, 9, 6.SP.4, 5, 6.RP.3,7.EE.4, MP.2

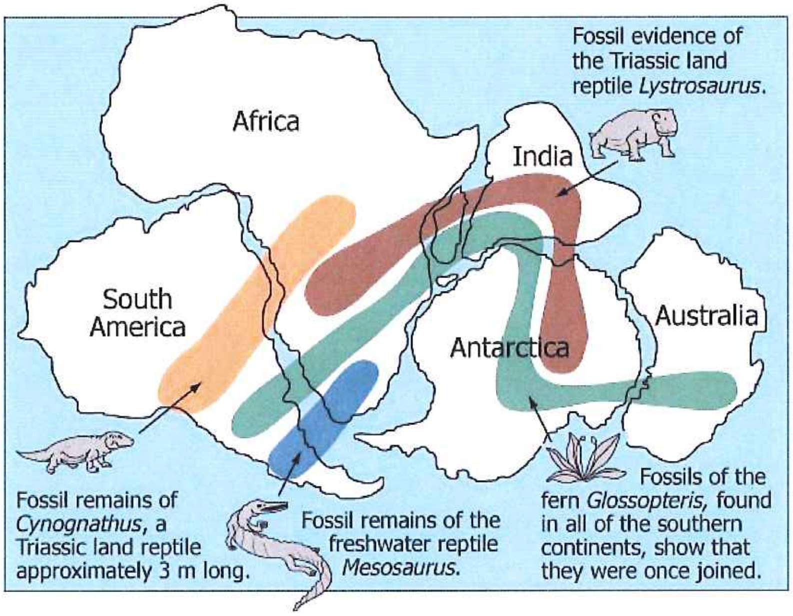
CA CCSS for ELA/Literacy Connections: RST.6–8.1, 2, 7, 9, WHST.6–8.1, 2, 9, SL.7.1, SL.7.4, SL.7.5

CA ELD Connections: ELD.PI.6.1, 5, 6a–b, 9, 10, 11a

Back in Integrated Grade Six, students examined a satellite view of California and explained some of the features they saw (figure 5.4). In grade seven, they return to that image and look for evidence of mountains. California has two main mountain ranges, one along the coast and one on the east side. The anchoring phenomenon the students consider is that both of these mountain ranges run roughly parallel to the coastline. Is the fact that all three of these features are aligned a coincidence? Students engage in a case study of a scientist from the early 1900s named Alfred Wegener, who also began by looking at the locations of mountain ranges and noticed some **patterns [CCC-1]** (MS-ESS2-3). Students begin by reading short geologic descriptions of rocks in the Appalachian Mountains, the Scottish Highlands, South Africa, Brazil, and a few other localities (thrown in for contrast) based on scientific journal articles that Wegener himself read back in the early 1900s. Students identify that the rocks in the Appalachian Mountains have very similar features to those in the Scottish Highlands; rocks from South Africa and Brazil are also similar to one another but different from the other pair. Despite the fact that each pair of rock formations is relatively distinct, each has a matching partner half way around the world. Wegener **asked questions [SEP-1]** about what could possibly explain the large present-day separation, so he considered the idea that all of Earth's continents could have been connected together millions of years ago and subsequently moved to their current locations. He gathered substantial **evidence [SEP-7]** that supported this proposed **explanation [SEP-6]** and he began to refer to the idea as *continental drift*. (An English translation of Wegener's 1912 article outlines the full range of his evidence [Wegener 1912]). Some of this evidence came from using maps to show how well the continents fit together, especially including the submerged continental shelves in aligning the continents, and most obviously with South America and Africa. Students can repeat this jigsaw puzzle activity with paper and scissors and identify specific places where it works well and others where it does not.

Even more persuasive was **evidence [SEP-7]** from fossils. Students can engage in an activity in which they collect samples from around the globe and place them on a map. They discover dozens of different species, but which species support Wegener's claim? Do any of them provide evidence that contradicts his claim? They might end up with a map similar to figure 5.34 that shows continents from the Southern Hemisphere and how they could have been joined together hundreds of millions of years ago. The colored areas correspond to fossils whose specific geographic locations indicate not only that these continents were joined together, but also specifically that the connection points match those predicted by matching the outlines of the continents. The current wide separation of these continents precludes other easy explanations for the locations of these fossils.

Figure 5.34. Fossil Evidence of Continental Drift



A summary of Wegener's fossil evidence that Southern Hemisphere continents were once joined together. *Source:* United States Geological Survey (USGS) 1999

Wegener also traced the past positions and motions of ancient glaciers based on grooves in rocks cut by those glaciers, and also by rock deposits that the glaciers left on different continents. After **obtaining information [SEP-8]** about how to recognize these features, students can **analyze [SEP-4]** pictures of rock outcrops from around the world and decide if they show evidence of ancient glacial activity. Plotting these locations on a map, they can compare them to the locations of present-day glaciers. Like Wegener, they find that locations currently near the equator show evidence of ancient glaciers, an extremely unlikely situation if the continents had not moved. If the continents moved as Wegener hypothesized, those glaciers would have formed much closer to the South Pole.

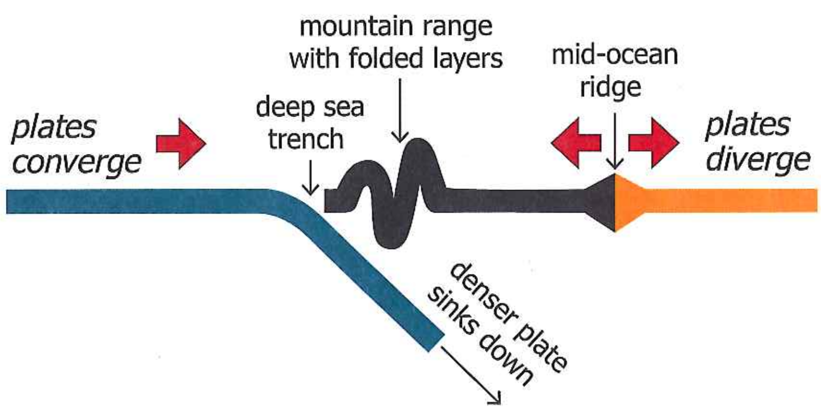
While we often say that Wegener compiled **evidence [SEP-7]**, it is important to note that he built on the work of dozens of scientists of the day. At the time Wegener lived, there was no way to determine the exact age of rocks, but geologists could reconstruct the relative timing of events by correlating sequences of rock layers from one place to another (MS-ESS1-4, as discussed in IS4). Even though Wegener never visited the Andes and the Atlantic coast of South America, other geologists had written that folding of rock layers in the Andes Mountain occurred at the same time as drifting apart of the Atlantic Ocean. Wegener **obtained and evaluated the information [SEP-8]** recorded by other scientists and then connected ideas in ways that nobody else had.

Despite the evidence [SEP-7] that he compiled, Wegener's theory was not accepted and was generally forgotten. While Wegener was using traditional science practices of analyzing data [SEP-4] and constructing explanations [SEP-6] based on evidence [SEP-7], the other geologists were viewing his claims through the lens of the crosscutting concept of cause and effect: mechanism and explanation [CCC-2]. Wegener could not propose any possible mechanism that would cause continents to plow through the ocean over great distances. In the absence of a mechanism to cause the proposed movements of continents, early twentieth-century geologists rejected Wegener's claims. Middle grades students focus first on analyzing [SEP-4] the evidence accumulated since Wegener's time that provides even more definitive evidence that there has been motion of plates (MS-ESS2-3). In high school, they will look in more detail at some of the evidence and finally address the mechanism that drives all this motion (HS-ESS2-1, HS-ESS2-3).

Technological developments approximately 50 years later allowed detailed mapping of the shape of the sea floor, which revealed new information that supported Wegener's claims and also provided the missing mechanism. Students can investigate undersea topography and notice patterns [CCC-1] using a program like Google Earth. They can discover that the largest mountain ranges on the planet actually exist below the water of the ocean. One of the most obvious of these is the Mid-Atlantic Ridge, which rises about 3 kilometers in height above the ocean floor and has a length of about 10,000 kilometers running from a few degrees south of the North Pole down almost all the way to the Antarctic Circle. While basically continuous across a huge part of the planet, it is far from straight. By tracing out the shape of the continental shelves on either side of the Atlantic and the axis of the Mid-Atlantic Ridge, students can notice the ridge roughly parallels the turns of the coastlines. By measuring the distance from the center of the mountain range to the continental shelf, students can notice that the highest point of the mountains lies half way between the two coastlines, as if the two coasts were spreading apart from this central point. The idea that oceans were growing in size made it easier to understand how the continents could move away from each other.

With some ocean basins expanding, it did not make sense for the entire planet to be growing larger, so scientists began to look at how the growth could be balanced by the surface appearing to get smaller in other locations. Scientists had long recognized evidence [SEP-7] for "shortening" on Earth because of evidence from sedimentary rock layers. In IS2, students discussed sedimentary rocks that form in flat layers, but these layers are often observed to be folded and curved, which could only happen by some sort of squeezing that would push up mountains. At the time Wegener lived, the only process that scientists could conceive of that could cause such squeezing was the overall contraction of the Earth as it cooled after being formed long ago. If the seafloor was known to spread at some locations, it makes sense that plates must crash together at others. This would explain why mountain ranges formed long bands perpendicular to the spreading directions. For example, the Andes Mountains are not oriented randomly—they are at exactly the orientation you would expect if South America were spreading away uniformly from the Mid-Atlantic Ridge and crashing into the floor of the Pacific Ocean on the other side. Seafloor structures also give one more key piece of **evidence [SEP-7]** about plate motions: there are very deep canyons in the ocean that parallel coastlines and island chains in many locations. Just off the west coast of South America, students can notice a very deep trench in the ocean floor. A physical **model [SEP-2]** with two foam blocks (or even notebooks) representing plates helps illustrate why such a trench forms where one of the plates sinks down beneath the other due to density. It is just a simple consequence of the geometry of a bending block, with the trench forming at the inflection point where the block plunging downward starts to curve (figure 5.35). Students can use maps of global topography and bathymetry to see if they notice any **patterns [CCC-1]** between the location of these deep-sea trenches and their relationship to continents, mountain ranges, and islands.

Figure 5.35. Plate Motions Shape Landforms and Seafloor Features



Schematic slice through the Earth's lithosphere showing three different plates with key seafloor and land features caused by their motion. Diagram by M. d'Alessio.

Taken together, the fit of the continental shelves, the separation of similar rocks and fossils across vast oceans, the location of mid-ocean ridges running precisely along the center of oceans basins, and the location of deep sea trenches along the coasts of some continents provide strong **evidence [SEP-7]** that plates move apart at some locations, move together at others, and slide past one another in still other locations. These motions are the driving forces for a wide range of processes that shape Earth's surface and cause interactions with the anthrosphere.

Plate Tectonics and Earth Resources

In IS1, students **obtained information [SEP-8]** about how synthetic materials come from natural resources (MS-PS1-3). Many of these resources are related to plate tectonic processes, which means that different parts of the world have access to different raw materials and different parts of the world are impacted differently by resource extraction. Students should be able to **explain [SEP-6]** why certain mineral, energy, and groundwater resources exist where they do on Earth (MS-ESS3-1). Students can begin by **analyzing [SEP-4]** maps showing the spatial distribution of different resources on Earth, recognizing **patterns [CCC-1]**, and **asking questions [SEP-1]** about what they see. Using computer-based mapping programs, students can turn on and off different layers to help see how locations of different resources compare to one another and other geologic features like plate boundaries.

Students might notice that California is home to some of the world's largest geothermal power plants, with production in both Northern and Southern California that provide a total of 6 percent of the state's electricity (with potential for even more). Other western states also utilize geothermal resources, but there are no geothermal power plants east of North Dakota in the United States. Why? After **obtaining information [SEP 8]** about geothermal power, students can **construct an explanation [SEP 6]** linking their distribution to plate boundaries. Plate boundaries are often places where hotter material rises up from Earth's interior to near the surface. This heat can be harnessed to generate electricity and as a source of **energy [CCC-5]** for heating buildings and commercial purposes.

Copper, gold, and other precious metal resources, however, seem to be located all over the world and not always related to plate boundaries. Why? Students **obtain information [SEP-8]** about how metal ores form and develop a **pictorial model [SEP 2]** showing the steps: 1) hot fluids dissolve metals from rocks deep underground; 2) hot fluids carry the metals until conditions change and the metals solidify in concentrated zones; 3) plate tectonic forces push the mineral deposits close to the surface where they can be easily mined; 4) time passes and plate boundaries can change. Plate motions are usually involved in the first three stages, but the fourth stage means that today's mineral resources can be very far away from today's plate boundaries.

Fossil fuel distribution is one the most politically important uneven distributions of energy resources: it is also tied to plate tectonics. The Middle East has about half of the world's proven reserves of crude oil and California has less than 0.2 percent. Why? Petroleum and natural gas are generally associated with sedimentary rocks. These fuels formed from soft-bodied sea organisms whose remains sank to the ocean floor, decomposed in the relative absence of air, and were further transformed by heat and pressure deep underground. Even areas on dry land today can be the sites of ancient ocean basins that have been uplifted by plate collisions. These same collisions can deform the rock layers in ways that allow oil and gas to accumulate in concentrated locations (where they can be easily extracted) and remain trapped there for millions of years. Students will investigate this process in high school.

Next students can **evaluate the claim [SEP-7]**, "Without plate tectonics, we would have no groundwater resources." Students **obtain information [SEP-8]** about where groundwater basins are located and how they form. The best groundwater basins are in valleys where a large amount of sediment has continuously been deposited, such as the Central Valley, which receives sediment from the Sierra Nevada. Plate motions typically determine the shapes of these basins and are the cause of mountains being uplifted in the first place. The faster they are pushed up, the faster they erode (because rapid uplift produces steep slopes that erode more quickly). Of course, groundwater also requires an abundant source of water. In addition to the important latitudinal controls on precipitation discussed in grade six, mountains have a strong impact on where precipitation occurs; moist air flowing up mountains tends to precipitate on the windward side of the mountains leaving a rain shadow further downwind. The mountains that "squeeze moisture out" are often recently uplifted by plate motions.

Opportunities for ELA/ELD Connections

As a summarizing activity regarding how the process of plate tectonics influences the uneven distribution of Earth's natural resources, students are placed in triads. Each student explains how Earth's mineral, energy, or groundwater resources have given shape to some of Earth's features. The P-E-E structure (Point, Evidence, and Explanation) can be used by each student. In the triads, students take turns sharing their findings.

CA CCSS for ELA/Literacy Standards: WHST.6–8.1, 7; SL.6–8.1
CA ELD Standards: ELD.PI.6–8.3

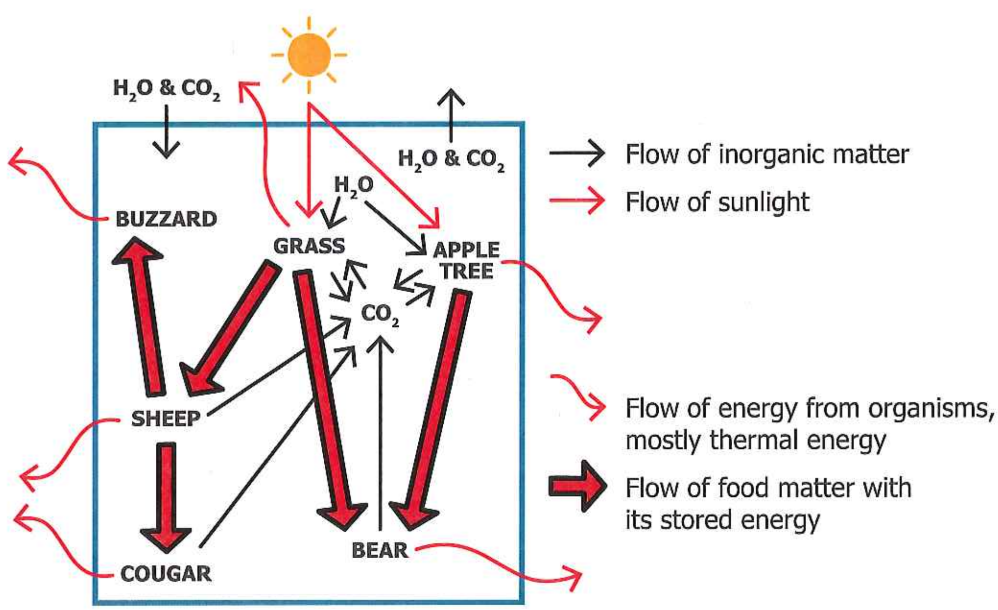
Ecosystem Models

Water and other natural resources provide strong links with the IS3 life science ecosystem performance expectations and DCIs. In IS2, students traced the path of an individual piece of rock matter and then came to IS3 to discover that there were global **patterns [CCC-1]** where certain types of rocks experienced similar paths due to global-scale cycles. Now, students will extend their models at the molecular and organism **scale [CCC-3]** from IS2 up to ecosystems and notice **patterns [CCC-1]** in the way **energy/matter [CCC-5]** are exchanged between **components [CCC-4]** of the ecosystem.

Students return to the environment diagram of figure 5.26 and **develop a system model [SEP-2]** of the ecosystem it depicts. In systems models, students track the flow of energy and matter between components. Biological systems are complex in that food delivers both energy and matter in the same package. Biologists use the term *biomass* to describe complex carbon molecules that organisms can use as building blocks to manufacture, replace, and repair their internal structures. The biomass molecules also have significant stored chemical potential energy that organisms can use to survive and grow. In the example system model diagram in figure 5.36, a black arrow with a reddish interior signifies the transfer of that coupled matter and energy through the eating of food.

Simple black arrows represent transfers of matter that are not biomass, and that cannot provide calories to organisms. Examples are water, carbon dioxide, and the simple minerals that decomposers such as microorganisms release to the soil. These black arrows include respiration of carbon dioxide out of plants and animals back into the local environment.

Figure 5.36. Ecosystem Cycles of Matter and Flows of Energy



A model of the flows of energy and matter into, within, and out of a simplified ecosystem. The wider arrows represent transfers of matter and energy coupled together in biomass. Diagram by Dr. Art Sussman, courtesy of WestEd.

The red arrows in figure 5.36 identify different **flows of energy [CCC-5]**, with the straight arrows indicating sunlight and the red centers of the biomass arrows representing the energy portion of food. The wavy red arrows represent "waste heat" that escapes and leaves the system as heat given off during respiration and other essential chemical reactions in organisms.

A model such as figure 5.36 can become much more complex if the developer of the model chooses to increase the kinds of **flows of matter and energy [CCC-5]** and/or the number and types of organisms that are included. This complexity can pose a problem, but it can also provide great learning opportunities in situations where productive academic discourse flourishes.

Students should be **asking [SEP-1]** themselves and their peers about which features are important to display in the model and why? The CCC of **system models [CCC-4]** teaches that "[m]odels are limited in that they only represent certain aspects of the system under study." The students get to choose what features to include, but they need to provide **evidence-based explanations [SEP-6]** for why they have included those features. A necessary part of gaining proficiency in the SEP of **developing and using models [SEP-2]** involves learning to wisely choose and omit features so that the model is powerful enough to predict and explain phenomena but not too complex so as to be overwhelming or dwell on unimportant details.

Taking time to explicitly focus on the meaning of the CCCs helps students become better scientific thinkers. Ecosystem models provide insight into why the writers of the NGSS purposely differentiated the phrasing "*cycles* of energy" and "*flows* of matter" in CCC-5. In figure 5.36, many of the energy arrows are going into and out of the system (*flow*), but the majority of the matter arrows remain within the system (*cycle*). This particular model includes two black arrows to indicate that no ecosystem is a closed system for matter. There are flows of matter, such as carbon dioxide and water in the air, that move into and out of ecosystems. Human activities can regularly disrupt the cycles of matter by adding pollution or taking away resources (EP&C IV).

With their ecosystem model in place, students can fully use it to identify what happens when one section of an ecosystem changes and there is a scarcity of energy or matter input. Students can use the model to predict which organisms will be affected first if, for example, there is a sudden decrease in sunlight or if CO_2 concentrations change in the atmosphere. Students can then **analyze and interpret [SEP-4]** population data from case studies of ecosystem change (MS-LS2-1) such as the effect of a prolonged drought on California's forest ecosystem. How are tree survival and growth affected and how do these changes affect other organisms throughout the ecosystem? Students can develop new system models for each case study ecosystem. As they compare system models for multiple ecosystems, they begin to see and describe **patterns [CCC-1]** recurring in the relationships between organisms (MS-LS2-2). Students should be able to identify relationships common to most ecosystems such as (1) organisms that compete for resources because they both have biomass arrows originating from the same source; (2) predatory relationships where the biomass from one animal goes to another; and (3) mutually beneficial relationships where arrows of energy, mass, or other benefits point in both directions between a pair of organisms. The goal is that students should be able to use ecosystem models to predict which organisms will compete if resources become scarce (MS-LS2-2).

IS4 Integrated Grade Seven Instructional Segment 4: Sustaining Biodiversity and Ecosystem Services in a Changing World

INTEGRATED GRADE SEVEN INSTRUCTIONAL SEGMENT 4: SUSTAINING BIODIVERSITY AND ECOSYSTEMS SERVICE IN A CHANGING WORLD

Guiding Questions

- What natural processes and human activities threaten biodiversity and ecosystem services?
- How can people help sustain biodiversity and ecosystem services in a changing world?

Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]