that are too spatially and temporally large to directly observe. Each small area of color corresponds to a calculated average based on many locations that measured and recorded the amount of precipitation each day for decades or perhaps a century or more. This kind of map is a systems model [SEP-2] that is especially useful and prevalent in Earth and space science. Color-coded maps can display data in ways that reveal important patterns [CCC-1] related to spatial location. Students may initially respond to the aesthetics of the colors rather than the science patterns and the vast amounts of data that these kinds of models [SEP-2] summarize and communicate.

While this kind of color-coded modeling representation is also used to some extent in other scientific disciplines, its special appropriateness in Earth and space science topics helps reveal a general principle about CCCs. While the CCCs do apply across many domains, they still may apply in somewhat different ways and extents in the different scientific disciplines.

The CCC of Systems and System Models [CCC-4] that is featured so prominently in IS1 still has a very significant presence in IS2. It is a vital and underlying aspect of many of the other CCCs. As mentioned when discussing scale [CCC-3], many systems involve interactions at scales that are so large or so small that they are best understood through system models. Descriptions of the CCC Energy and Matter [CCC-5] often refer to tracking the flows of energy and matter into and out of systems. Finally, each of the California regional climates investigated in IS2 is an example of a whole system property that emerges or arises from the interactions of the components of the regional system with each other and with the incoming sunlight.

IS3 Integrated Grade Six Instructional Segment 3: Causes and Effects of Regional Climates

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 3: CAUSES AND EFFECTS OF REGIONAL CLIMATES

Guiding Questions

- Why is the climate so different in different regions of the planet?
- Why are organisms so different in different regions of the planet?
- What makes organisms so similar to but also different from their parents?
- What makes animals behave the way they do, and how does their behavior affect their survival and reproduction?

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 3: CAUSES AND EFFECTS OF REGIONAL CLIMATES

Performance Expectations

Students who demonstrate understanding can do the following:

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*] Introduced in IS3 but not assessed until IS4.

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.*] Revisited from IS1.

MS-LS3-2. Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

MS-ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 3: CAUSES AND EFFECTS OF REGIONAL CLIMATES

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-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

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-3] Planning and Carrying Out Investigations [SEP-6] Constructing Explanations (for science) and Designing Solutions (for engineering) [SEP-7] Engaging in Argument from Evidence [SEP-8] Obtaining, Evaluating, and Communicating Information	LS1.B: Growth and Development of Organisms LS1.D: Information Processing LS3.A: Inheritance of Traits LS3.B: Variation of Traits ESS2.C: The Roles of Water in Earth's Surface Processes ESS2.D: Weather and Climate PS3.A: Definitions of Energy PS3.B: Conservation of Energy and Energy Transfer	[CCC-2] Cause and Effect [CCC-3] Scale, Proportion, and Quantity [CCC-4] Systems and System Models

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.

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

INTEGRATED GRADE SIX INSTRUCTIONAL SEGMENT 3: CAUSES AND EFFECTS OF REGIONAL CLIMATES

CA CCSS Math Connections: 6.SP.2, 4, 5; MP.2, MP.4

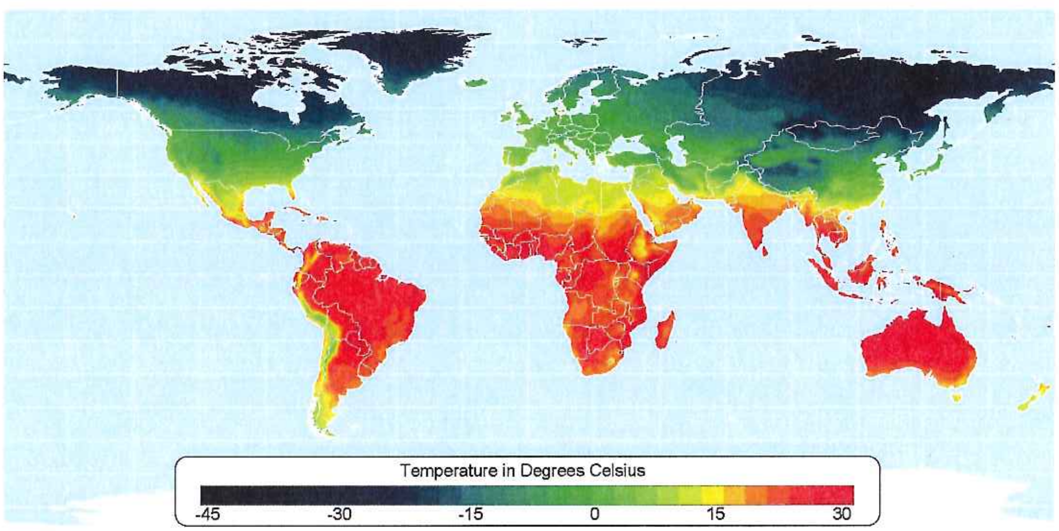
CA CCSS for ELA/Literacy Connections: RST.6–8.1, 2, 3, 4, 7, 9; RI.6.8, WHST.6–8.1, 2, 7, 8, 9; SL.6.5

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

In this instructional segment, students grapple with the anchoring phenomenon that it is warm in the tropics and cold at the poles. In IS2 students analyzed climate data [SEP-4] for eight different California regions. As a result of that analysis, four key factors were identified as having strong causal effects [CCC-2] on regional climates: (1) latitude, (2) altitude, (3) proximity to mountains, and (4) proximity to the ocean.

Figure 5.14 illustrates the combination of these four factors at the scale [CCC-3] of regional climates around the planet. Students begin IS3 by investigating the temperature at different latitudes and different times of year around the globe. These investigations lay the groundwork for Integrated Grade Eight when students will finally explain the seasons (MS-ESS1-1) after collecting data on seasonal weather patterns since kindergarten.

Figure 5.14. Average Annual Temperatures



Color-coded map of average annual temperature around the world. Note the major effect of latitude, and the colder high-elevation regions, such as the Himalayas in Asia. *Source:* Used by permission of The Center for Sustainability and the Global Environment, Nelson Institute for Environmental Studies, University of Wisconsin-Madison

In IS2, students explained [SEP-6] that the oceans have a strong effect on temperatures near the coast because the water retains heat much longer than the surrounding land or air. In IS3, students extend their analysis of ocean effects on temperature by investigating [SEP-3] the effects of ocean currents that transport thermal energy from equatorial regions to colder temperate regions. This analysis is then connected to the more global scale [CCC-3] of ocean currents and wind patterns.

Having attained deeper understandings of the many intersecting factors and Earth system interactions that cause [CCC-2] regional climates, students then focus on the effects [CCC-2] that these very different regional climates have on organisms. In grade four, students cited internal and external structures of plants and animals as evidence [SEP-7] that organisms have structural adaptations that support survival, growth, behavior, and reproduction. In grade five, students developed models [SEP-2] that described how organisms survive only in environments in which their specific needs can be met.

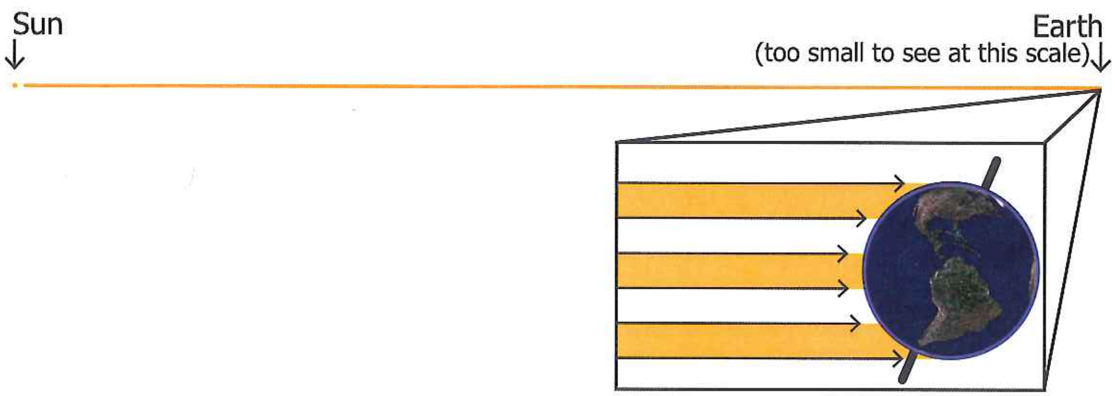
Students deepen and revisit these concepts in grade six, IS3 by investigating [SEP-3] how plant and animal structures [CCC-6] are adapted to climatic and other abiotic conditions in an ecosystem. In elementary school, students provided evidence that animals had specific structures and behaviors that enable them to survive in specific conditions (3-LS4-3). But how is it that all the organisms in a specific environment have the structures and behaviors that allow them to take advantage of that specific environment? This instructional segment lays the foundation for understanding natural selection in grade eight. It focuses on both adaptation and introduces sexual reproduction. It uses specific phenomena related to attracting mates to also introduce sensory stimuli and the nervous system. While adaptation ties well to climate, these other topics are part of a life science storyline that easily could be separated out into its own instructional segment.

Climate Depends on Latitude

Keeping this broad outline of the IS3 sequence in mind, students begin exploring more deeply the effects of latitude on climate. Students should observe maps and ask detailed questions [SEP-1] about what they see. They should be able to describe patterns [CCC-1] they see, such as the reddish areas in figure 5.14 that clearly indicate that latitudes closer to the Equator are generally much warmer than latitudes that are further north or south.

How can the Equator appear to receive more energy than either of the poles despite the fact that they all receive their energy from the same Sun? The key is that the Earth is a sphere. Sunlight arrives at Earth as parallel rays (figure 5.15), but hits the surface at nearly a 90° angle near the Equator and at flatter/smaller angles near the poles because of Earth's round shape. The light spreads out over a larger area near the poles (figure 5.16), meaning that each square foot patch of the surface receives a smaller **proportion [CCC-3]** of the energy coming from the Sun than that same patch does at the Equator, which causes the sunlight on that patch to be less intense. When the Sun shines down at a 90° angle, a patch of land receives twice the energy compared to a 30° angle, so this effect has a big impact on the temperature.

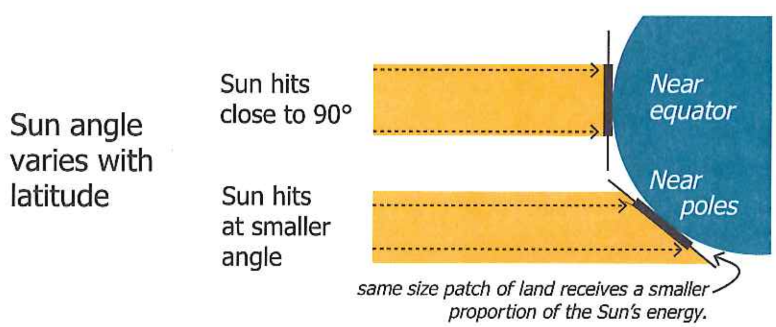
Figure 5.15. Earth-Sun System Scale



A scale illustration of the Earth-Sun system (top). The Sun is 5 pixels wide and the Earth is 1075 pixels away, but is only 0.05 pixels wide, which is too small to display. At this scale, it is easier to recognize that rays of sunlight arrive at Earth as parallel rays at all latitudes (bottom). Diagram by M. d'Alessio.

Students **perform an investigation [SEP-3]** of the relationship between light intensity and angle by shining a flashlight at a piece of paper at different angles while keeping the distance between the light and the paper constant (NASA 2008). Students can directly observe how the patch of light gets dimmer when it strikes the page at a low angle and spreads out over a large area. While a piece of paper is flat, students simulate the parallel rays of sunlight arriving at Earth by shining their flashlight on a round ball and observing how the patch of light is small and intense near the equator but spreads out near the poles.

Figure 5.16. Angle of the Sun's Rays Affect Intensity



Effect of the angle of the Sun's rays on area of the Earth's surface it illuminates. At angles smaller than 90°, the energy is spread out over a larger area. Diagram by M. d'Alessio.

Thermal Energy Transport

Movements of thermal energy are major factors in causing [CCC-2] the observed patterns [CCC-1] of regional climates. One major concept is that thermal energy [CCC-5] moves from warmer locations/objects to cooler locations/objects. A related major concept is that these movements of thermal energy occur in three distinct ways (table 5.5). Students can investigate [SEP-3] and research each of these three ways of heating, create a brief report about one or more of them, and explain [SEP-6] the differences in terms of the underlying science. Given the state of their physical science knowledge, the mechanisms need to be stated in fairly general terms. For example, conduction and convection can be described in terms of particles vibrating or moving, and radiation can be described as waves of energy similar to sunlight that move through space and transfer energy.

Table 5.5. Thermal Energy Moves in Three Ways

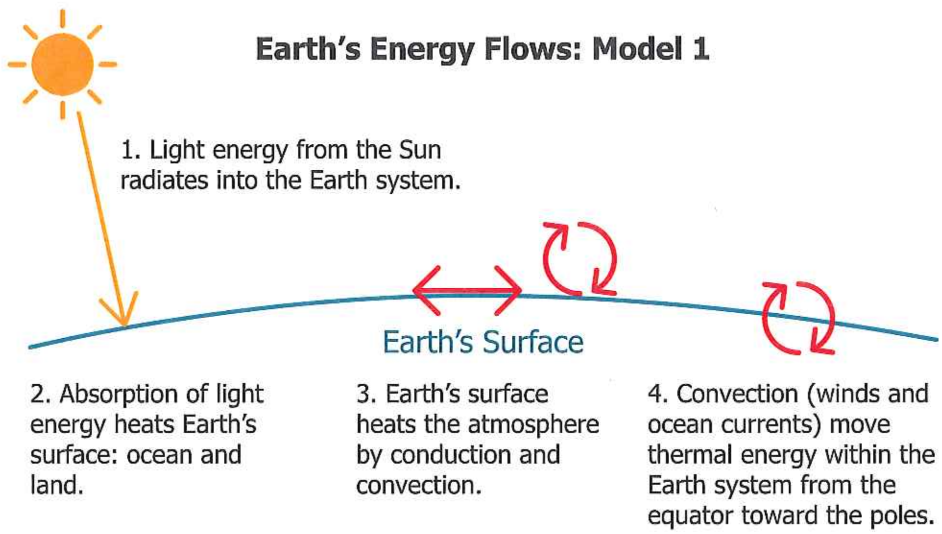
WAYS THERMAL ENERGY MOVES	PHYSICAL SCIENCE	EXAMPLES
CONDUCTION	Warm object touches cooler object and makes it warmer. Electromagnetic waves are not involved.	Hot sand burns your feet. Hot ground warms air that touches it.
CONVECTION	Handle of heated pan becomes hot.	Rainfall and streamflow in, evaporation out.
RADIATION	Warm liquid or gas flows into cooler area and makes it warmer. Electromagnetic waves are not involved.	Warm air rises and is replaced by cooler air. Hot water in heated pot rises from bottom to top.

Contrasting the three different ways that thermal energy moves from warmer objects to cooler objects based on the underlying physical science. Table created by Dr. Art Sussman, courtesy of WestEd.

Students can reflect on and discuss a simplified model [SEP-2] to apply their experiences and knowledge of the three modes of thermal energy movement to the context of the Earth system (figure 5.17). Sunlight travels as radiation from the Sun to enter the Earth system where it initially mostly heats the surface (ocean and land). Earth's surface transfers some of the thermal energy to the atmosphere by conduction, and convection then moves that energy within the atmosphere.[1]

1. In instructional segment 4, students will learn via Model 2 that radiation from Earth's surface also plays a very significant role in heating the atmosphere and in Earth's global climate.

Figure 5.17. Earth's Energy Flows

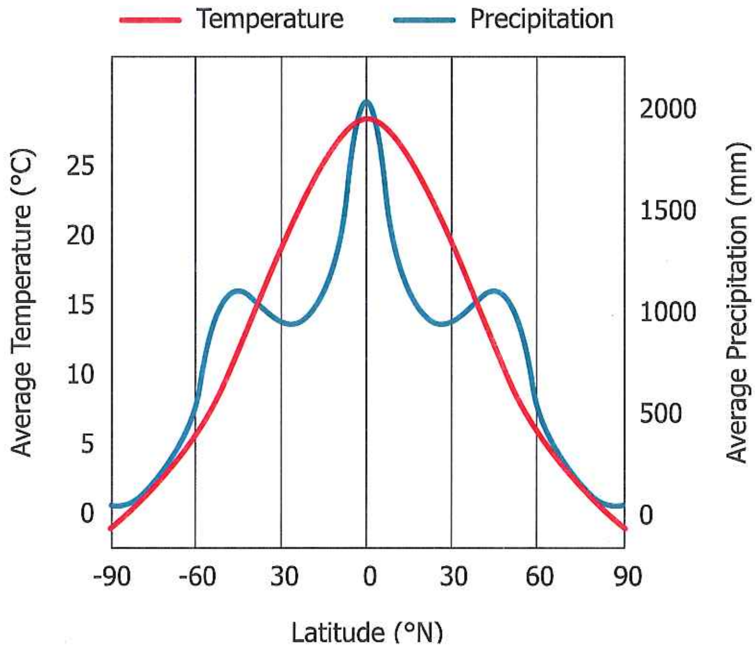


A simplified model illustrating energy flows that have major effects on weather and climate. Illustration by Dr. Art Sussman, courtesy of WestEd.

The teacher can prompt students to think about and discuss concept number four in figure 5.17, the transfer of thermal energy by convection. Why does thermal energy move from the equator toward the poles? Student **explanations [SEP-6]** should include the evidence from prior **investigations [SEP-3]** that sunlight hits equatorial regions at angles closer to 90° than the smaller angles at the poles, and also that **thermal energy [CCC-5]** moves from warmer regions toward colder regions. Students may find it contradictory that there is such a large difference in temperature between the equator and the poles when convection tends to equalize temperature differences. It turns out that the poles would be much colder and the tropics much hotter if winds and ocean currents did not move thermal energy away from the equator.

Students can collect data from cities around the world and create a graph showing the average temperature at different latitudes (figure 5.18). They also know from IS2 that when air masses rise, they cool and condense. They should be able to predict that warm air rising from the equator should cause higher rainfall there. By analyzing data from their cities, students confirm this is true, but recognize another pattern as well. There is another peak in rainfall near 50° latitude (both north and south). Students can **use this evidence to make an argument [SEP-7]** that air could be rising there as well.

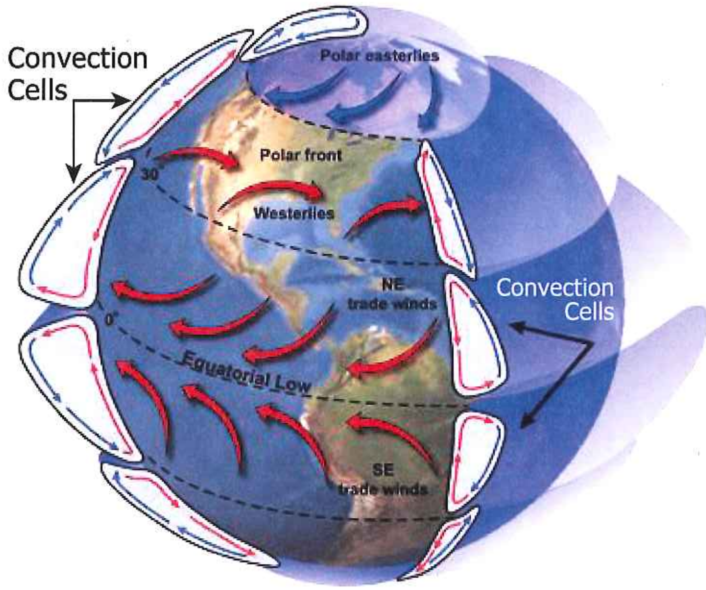
Figure 5.18. Temperature and Rainfall Vary Systematically with Latitude



Source: Thebiologyprimer 2015

The rainfall versus latitude analysis provides evidence that the wind convection from the equator toward the poles actually happens via sequential "steps" that are called convection cells (figure 5.19). The two convection cells just north and just south of the equator (indicated by the line labeled 0°) each have skinny red arrows representing warm air traveling toward the poles and skinny blue arrows representing colder air from the polar regions traveling toward the equator. The illustration shows three sequential convection cells connecting the equator and South Pole. Similarly, three sequential convection cells connect the equator and the North Pole (though the third cell near the South Pole is not visible from the angle shown in figure 5.19). This illustration also shows thicker arrows that represent winds that blow east and west.

Figure 5.19. Thermal Energy and Wind Convection Cells



Wind convection in the atmosphere moves thermal energy from the 30° latitude toward the poles (skinny red and blue arrows in the convection cells). Image credit: Adapted from Summey n.d.

Students can then combine all they have learned in IS2 and IS3 into one summary of the evidence from their data of relationships between the movement of air masses at different scales and weather patterns (table 5.6; MS-ESS2-5). Because many of the conditions that determine weather are "permanent" on the timescale of ecosystems (latitude, topography, proximity to water bodies), the weather patterns in a region remain relatively consistent. The word *climate* refers to these consistent patterns of weather that each location experiences. It rarely snows in San Francisco or Los Angeles, and it almost always rains more often on the western side of the Sierra Nevada than the eastern side, and it rains a lot more in Northern California (closer to the upward motion of air masses for Earth's two northern convection cells) than it does in Southern California (closer to the downward motion of air masses from convection cells).

Table 5.6. Air Movements and Weather

CONDITION	AIR MOVEMENT	WEATHER	SAMPLE LOCATION
Convection cell near equator	Warm moist air rising	Thunderstorms; Heavy precipitation	Equatorial Pacific Islands
Convection cell at 30° latitudes	Dry air sinking	Desert	Sahara Desert Arabian Desert
Warm air mass and cold air mass collide	Warm air rising	Clouds and precipitation likely	Variable
Windward side of coastal mountain	Moist air rising	Rain and/or snow	California Coast and Sierra Nevada
Leeward side of mountain	Dry air sinking	Clear weather	Central Valley Southwest US desert
High pressure system	Air sinking	Clear and sunny weather	Variable
Low pressure system	Air rising	Cloudy and wet weather	Variable

Table created by Dr. Art Sussman, courtesy of WestEd

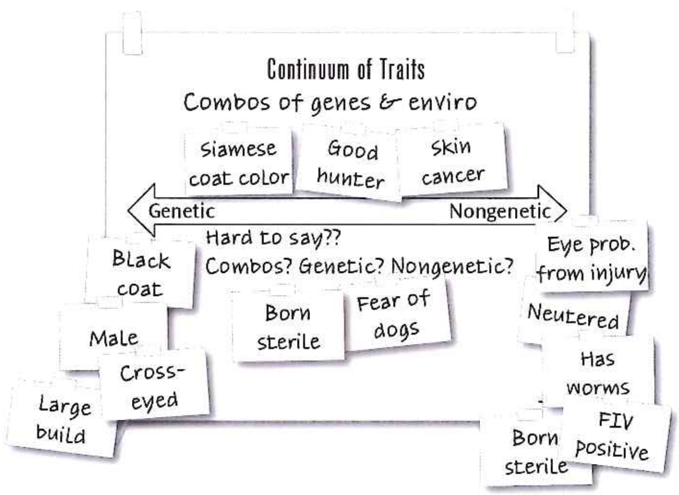
Organism Traits, Heredity, and Reproduction

Ecosystems develop around the abiotic conditions such as climate because these abiotic factors strongly influence the kinds of organisms that can live in an environment. Organisms with certain structures and behaviors (adaptations) survive in the unique conditions present in each environment while organisms without those adaptations might not. Teams of students can research a distinctive environment (e.g., the barren granite of the peaks in the Sierra Nevada, the dark shade beneath towering coastal redwood trees, or the brackish mud of a salt marsh), organize and **communicate information [SEP-8]** about the plant and animal traits that promote success in that environment. Sharing across teams that have **investigated [SEP-3]** very different kinds of environments can then lead to generalizations about significant **patterns [CCC-1]**. The question is, how do these traits develop in organisms? This provides the transition to heredity and reproduction. Students have been gathering evidence that organisms look and act like their parents since grade one (1-LS3-1; 3 LS3-1). Now, they begin to develop models of the mechanisms for heredity.

Structures and behaviors of organisms are features that generally apply to all members of a species. Examples of human features are eye color, body size, blood type, and personality such as introversion/extroversion. If a feature normally has a pattern of varying among individuals, then we describe those variations as being traits of that feature. For example, each different blood type is a trait, as is each different eye color or hair color. Many features vary across a wide spectrum of possibilities, and we usually clump these variations into groups that we generalize and simplify, such as describing people's height feature as being very short, short, average, tall, or very tall. For the middle grades student, this discussion of traits goes beyond scientific facts (Health Education Standards 7–8.1.8G, 7–8.2.2.G).

Discussions of traits can get sidetracked by arguments about the roles of genes and/or the environment in determining traits. Students gathered evidence in grade three that traits can be inherited (3-LS3-1) or influenced by the environment (3-LS3-2), and now they must integrate these two seemingly separate ideas. As discussed early in IS1, many features and processes of the natural world occur across a wide spectrum of possibilities and often do not fall definitively at one end of the spectrum or the other. In the case of organism traits, there are some traits that are essentially all genetic (e.g., blood type) and other traits that have a large environmental component (e.g., large muscles due to exercise or being able to play the guitar). Most traits, however, are a combination of genetic and environmental influence, and can be placed somewhere along the spectrum between the extreme examples (figure 5.20).

Figure 5.20. Genetic Versus Environmental Traits



Some traits are essentially all genetic, and some are mostly environmental. Most traits are strongly influenced both by genes and the environment. *Source*: From Making Sense of SCIENCE: Genes and Traits (WestEd.org/mss) by Daehler and Folsom. Copyright © 2015 WestEd. Reproduced with permission.

Students can experience the interplay between genetics and environment by **analyzing [SEP-4]** actual height data from provenance studies in trees. Ponderosa pine trees have a large range and have been extensively studied. In some areas of the western United States, 100-year-old ponderosa pines might be 60 feet tall, but in other areas they tower more than 150 feet (Meyer 1938). Students can ask questions about what climatic conditions can explain these differences. Then, students can **plan an investigation [SEP-3]** that would determine if any of the height difference is due to genetic differences in the trees rather than the environment. While students can't actually wait decades for the results of their investigations, they can determine what they would control for and what they would vary in an experimental design. Then, they can obtain information from actual provenance studies where seeds of trees from different environments are brought together and grown under the same conditions (Callaham 1962). Seeds from some regions do indeed produce trees that are shorter than other regions under all growing conditions; however, the tree that grows tallest depends on the specific growing conditions in the experiment. For example, a seed whose parents lived at high altitude in Northern Arizona grows taller than a seed from the Sierra Nevada foothills of California in research trials when the days are cold and the nights are warm, but the California seeds grow taller when both day and night are moderate temperatures. In other words, students are now able to provide an evidence-based explanation based on scientific data from the field (MS-LS1-5) for the patterns they observed in the classroom in grade three (3-LS3-1, 3-LS3-2).

In addition to a general emphasis on adaptations that promote growth and survival (MS-LS1-5), the performance expectations in IS3 emphasize evaluating factors that promote reproductive success (MS-LS1-4) and analyzing different modes of reproduction (MS-LS3-2). Students know that some plants depend on animals from lessons in grade two when they developed a simple design that mimicked the role of animals in pollinating flowers (2-LS2-2). Students can examine how climate alters the reproductive behavior of plants by examining the differences between insect-pollinated and wind-pollinated plants. What are the benefits and disadvantages of each? Students consider if different climate conditions would be more favorable to one method over another, providing their reasoning. They then compare the structures of wind-pollinated plants with insect-pollinated plants, eventually sorting through pictures and trying to identify the mode of pollination from the structure (InquireBotany n.d.). Students construct an **argument [SEP-7]** supporting how these structures increase the chance of successful reproduction (MS-LS1-4).

Integrated Grade Six Snapshot 5.3: Asexual and Sexual Reproduction

Anchoring phenomenon: Sunflowers, earthworms, strawberries, and whiptail lizards reproduce using different processes.

Ms. Z wanted to use an engaging activity to help students transition from their analyses of the causal connections between genes and traits to **developing a model [SEP-2]** to compare asexual and sexual reproduction (MS-LS3-2). Basing the activity on an interactive lesson from the University of Utah Learn.Genetics Web site (Sexual versus Asexual Reproduction accessed at http://www.cde.ca.gov/ci/sc/cf/ch5.asp#link10). Ms. Z provided background information about reproduction in sunflowers, earthworms, strawberries, and whiptail lizards. Students discussed in teams how to describe the reproductive process in each organism (asexual, sexual, or both) and the **evidence [SEP-7]** for their categorizations. Whole-class sharing resulted in common answers and evidence. Student teams then had time to explore the Web site (in a computer lab, in class with tablets, at home, or in a library) to select two organisms that have different processes of sexual reproduction.

The following day, student teams made **system models [CCC-4]** of the reproduction processes for each of their two selected organisms. Each of the system models had to **explain [SEP-6]** why the progeny would have identical or different genetic information from each other. Students posted one of their system models on the wall, and then individually walked around the room, and **analyzed [SEP-4]** each posted model. They posted sticky notes next to the models with any questions or **disagreements [SEP-7]** they had with respect to the conclusions and/or evidence. After the presenters had time to look at the sticky notes, the whole class listened carefully as each presenting team appropriately **responded [SEP-8]** to the comments.

Sexual reproduction in animals can then lead to **investigations [SEP-3]** that link back to the body systems concepts in IS1. Students compile each of the reproductive processes described in the online Learn.Genetics resource to list and compare all animal behaviors that play a significant role in the reproduction. To do so, the students discuss the criteria for how they will categorize different behaviors. If students have difficulty suggesting valuable criteria, the teacher can prompt the discussion with examples such as choice, rigid instinctive behavior, memory, reasoning, and flexibility. Students can do more research about some of the examples that may lead to surprising findings, such as the amount of navigation, memory, analysis, learning, and communication involved when a honeybee chooses where to fly to from the hive to gather nectar.

Students then tie their understanding of reproduction back to regional climate. Are there certain climate conditions where asexual reproduction might be advantageous (e.g., when a successful organism needs to quickly reproduce) or where sexual reproduction might be better (e.g., when climate conditions change and identical offspring will all be equally vulnerable

Integrated Grade Six Snapshot 5.3: Asexual and Sexual Reproduction

to dying off)? Ms. Z presents students with several brief case studies and asks students to construct an argument [SEP-7] about which reproductive style is likely to be most successful in each situation.

Investigative phenomenon: Bowerbirds, peacocks, fruit flies, and vervet monkeys all put on displays where the male "shows off" for the female.

Ms. Z instructed students to extend their investigations [SEP-3] into behaviors by focusing on female choice in reproduction (not including humans). Key factors related to these investigations include stimuli provided by the male, female sensory receptors, female behavioral response, and female memory (MS-LS1-8). The teacher provided a list of possible examples (such as bowerbirds, peacocks, fruit flies, and vervet monkeys). For example, female vervet monkeys respond more favorably to males that show caring behavior toward infants. As a result, male vervet monkeys behave better toward infants when a female is watching. Student teams picked one of the suggested examples of female choice or a different one that they independently researched and evaluated [SEP-8].

After the teams conducted the first round of research, the whole class decided on the criteria for a complete investigation and report. Teams extended and concluded their investigations by developing and presenting a report to the class about their example of female choice including explaining [SEP-6] the evidence and reasoning how the behavior affects the probability of successful reproduction (MS-LS1-4).

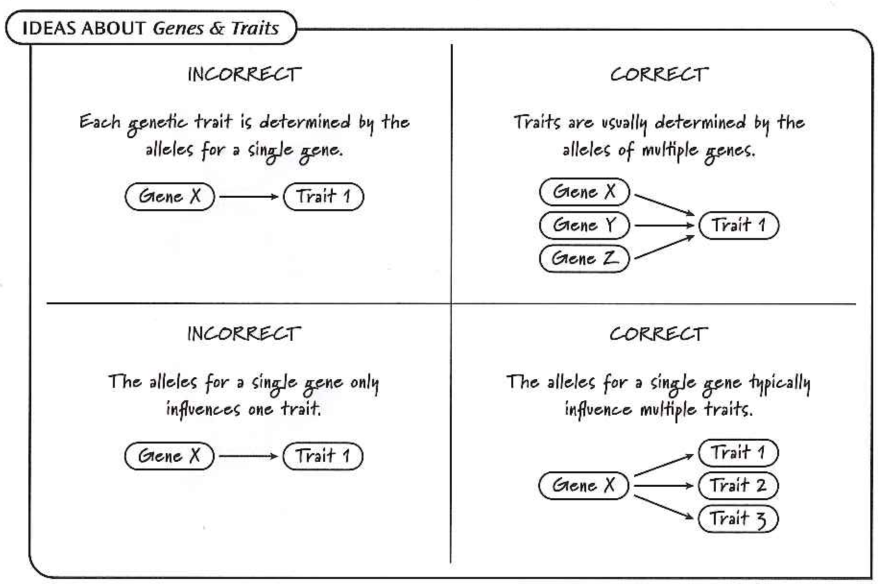
These life science learning experiences in grade six provide a foundation for deeper explorations in grade seven (performance expectations and DCIs focused on LS2: Ecosystems) and in grade eight (performance expectations and DCIs focused on L3: Heredity and L4: Biological Evolution).

Animals and plants have intricate structures and behaviors for sexual reproduction, but why? Whenever students identify patterns [CCC-1] in structure/function relationships [CCC-6], they should be encouraged to ask about the cause/effect mechanisms [CCC-2]. In this case, each parent contributes to the traits of the offspring therefore leading to greater diversity of traits. To connect this otherwise unconnected topic back to climate, students can consider the question, How could a greater diversity of traits help an organism survive in a wider range of climates? Students analyze [SEP-4] the results of Mendel's experiments with pea plants or other simple examples of genetic inheritance that allow students to develop models of inheritance. The clarification statement of MS-LS3-2 indicates that students should be able to construct models [SEP-2] of inheritance such as Punnett squares or other depictions and simulations.

While these simple models are useful, classic genetics tends to reinforce a preconception that each trait is caused by one gene. Students may also hold a parallel preconception that each gene influences only one trait. Students can counter these preconceptions by citing evidence [SEP-7] such as that the ABCC11 gene on chromosome 16 influences the type of earwax a person has and also the amount of underarm odor.

Figure 5.21 contrasts incorrect and correct conceptions about the causal [CCC-2] linkages between genes and traits. As part of the developmental progression of the CA NGSS, students do not need to understand the specifics mechanisms or terminology of DNA or protein synthesis until high school.

Figure 5.21. Incorrect and Correct Ideas about Genes and Traits



Multiple genes typically determine a specific trait, and an individual gene typically influences multiple traits. *Source:* From Making Sense of SCIENCE: Genes and Traits (WestEd.org/mss) by Daehler and Folsom. Copyright © 2015 WestEd. Reproduced with permission.