Instructional Segment 3 Teacher Background and Instructional Suggestions

In Instructional Segment 2 students **analyzed climate data** for eight different California regions. As a result of that analysis, four key factors were identified as having strong ***causal effects*** on regional climates: 1) latitude; 2) altitude; 3) proximity to mountains; and 4) proximity to the ocean.

Instructional Segment 3 extends the California analysis to the ***scale*** of regional climates around the planet. Students begin with examining the effects of latitude (very apparent in Figure 12), and also times of the year related to latitude. The spatial and temporal aspects of latitude relate primarily to the position of the planet in its annual orbit around the Sun, particularly as the annual orbit affects the angle of incoming sunlight. One anomaly with respect to the generally applicable ***pattern*** of the latitude effect is also apparent from **analysis of global maps** such as Figure 12, namely that areas of high elevation have much colder temperatures than lower elevation areas at the same latitude. The investigation of high altitude climates naturally also leads students to generalize the ***pattern*** that mountains have strong ***effects*** on nearby lower elevations, especially with respect to the amount of precipitation that the lower elevations receive.

Average Annual Temperatures

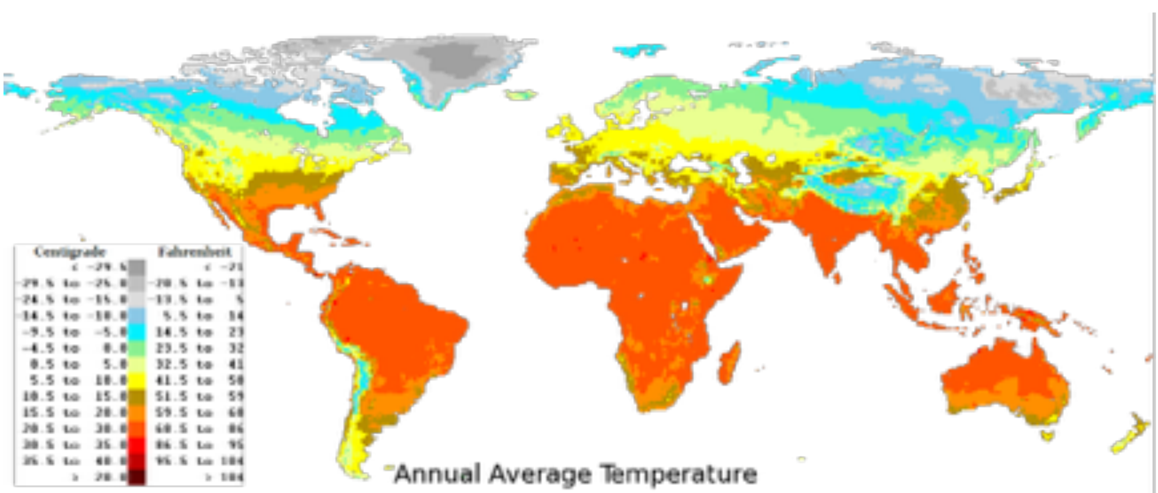

Figure 12: Color-coded map of average annual temperature around the world. Note the

major effect of latitude, and the colder high elevation regions, such as the Himalayas in Asia. Accessed from http://www.climate-charts.com/World-Climate-Maps.html

In Instructional Segment 2 students **described** that areas close to the ocean had smaller differences in day/night temperatures than inland areas and **used evidence** from heat capacity experiments in their **explanations** that the oceans retain thermal energy absorbed during the daytime much longer than the land and the air. The ocean warms the nearby air at night, thereby keeping the night temperatures closer to the daytime temperatures. In Instructional Segment 3, students extend their analysis of ocean effects on temperature by **investigating** 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*** of ocean currents and wind patterns.

Having attained deeper understandings of the many intersecting factors and Earth system interactions that ***cause*** regional climates, students then focus on the ***effects*** that these very different regional climates have on organisms. In grade 4, students cited internal and external structures of plants and animals as **evidence** that organisms have structural adaptations that support survival, growth, behavior, and reproduction. In grade 5, students **developed models** that described how organisms survive only in environments in which their specific needs can be met.

Students deepen and revisit these concepts in grade 6 Instructional Segment 3 by **investigating** plant and animal structures and behaviors through the multiple life science lenses of variations in traits, heredity, and reproduction. This life science component of the integrated Instructional Segment 3 concludes with an **analysis** of various animal reproductive behaviors. Animals that have complex nervous systems (note connection with grade 6 Instructional Segment 1) can respond to stimuli quickly and with more flexible options, and can also optimize their reproductive behaviors based on reliable memories of past experiences with members of their local group. Keeping this broad outline of the Instructional Segment 3 sequence in mind, we now transition to exploring more deeply the effects of latitude on climate. The reddish areas in Figure 12 clearly indicate that latitudes closer to the equator are generally much warmer than latitudes that are much further north or south. The large northern continental areas colored in green/blue clearly have the coldest average annual temperatures.

We can safely assume that California students know that the northern hemisphere experiences colder conditions in the winter months between November and March. Students who live in low altitudes may not appreciate the magnitude of the temperature changes between winter and summer. Students may also not know whether the seasons are the same or different near the equator or in the southern hemisphere. Student groups can **make predictions** about ***temperature patterns*** in all these different locations and then **research** the monthly average temperatures of selected cities in the USA and most world countries.[1] Based on their research, student teams can **communicate evidence-based conclusions** how different regional temperature ***patterns*** vary by latitude.

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[1] World-Climate at www.climate-charts.com has abundant data for the USA and countries/cities around the world.

Earth's Annual Orbit Around the Sun

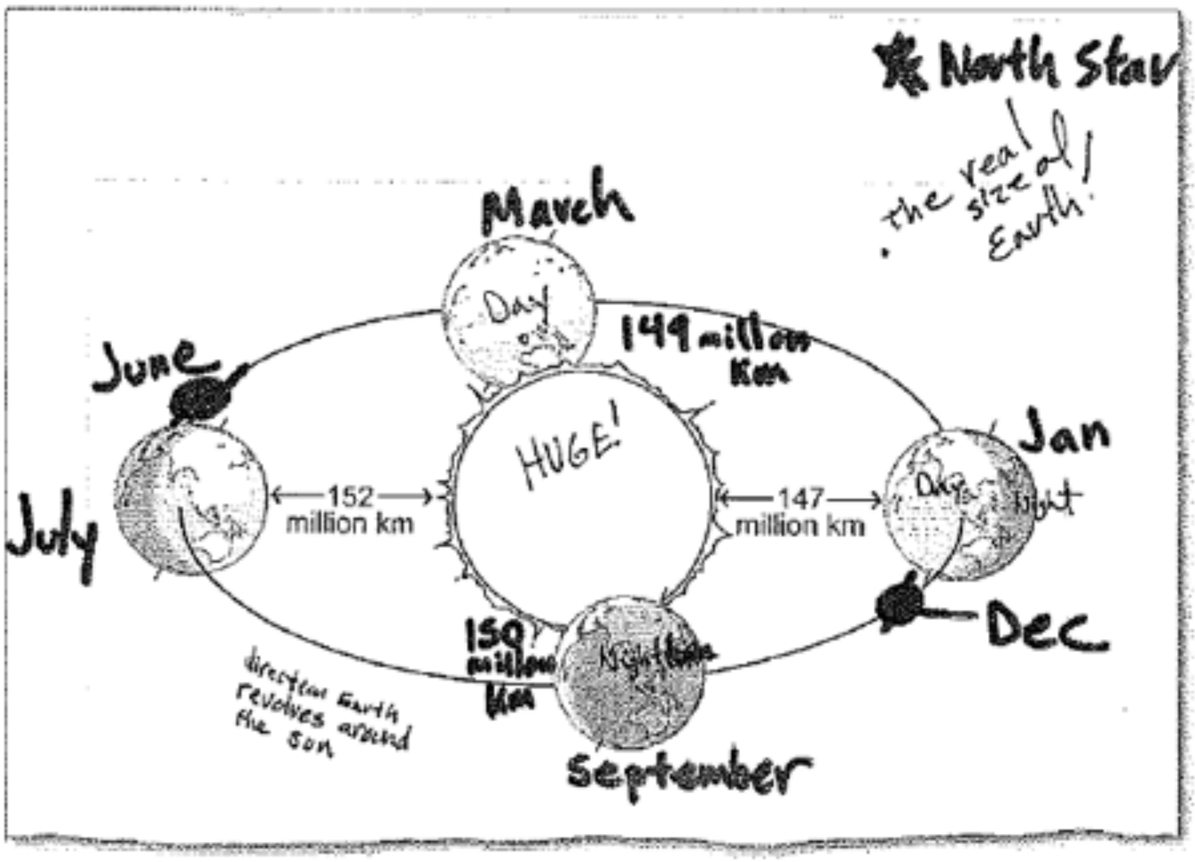

Figure 13: The trip that Earth makes around the sun each year. Note the dot showing the more correctly scaled size of Earth relative to the sun, and the tilt orientation toward the North Star. (Illustration from Making Sense of Science *Weather and Climate* course, courtesy of WestEd)

Teachers can distribute a handout such as Figure 13 that is a **model** that can help address many misconceptions. Note, for example, that Earth's distance from the sun is actually greater in the Northern Hemisphere summer than it is in the winter. The dot showing the real scaled size of the Earth relative to the sun also helps establish the correct size comparison. It is also valuable to always include a position for the North Star so students can see that Earth's tilted axis always points in that same direction (technically 23.5^0 North) as the planet orbits the sun.

Students can then **investigate** the angle of sunlight at different latitudes at a specific time of year, such as the Spring or Autumn Equinox. While we do introduce seasons in integrated grade 6 to teach about the climate effect of latitude, the deeper exploration of seasons happens in grade 8 when students investigate the Earth-Sun system more intensively. The key concept in grade 6 is that equatorial latitudes receive much more direct sunlight annually than temperate or polar latitudes.

Angle of Incidence Assessment Probe

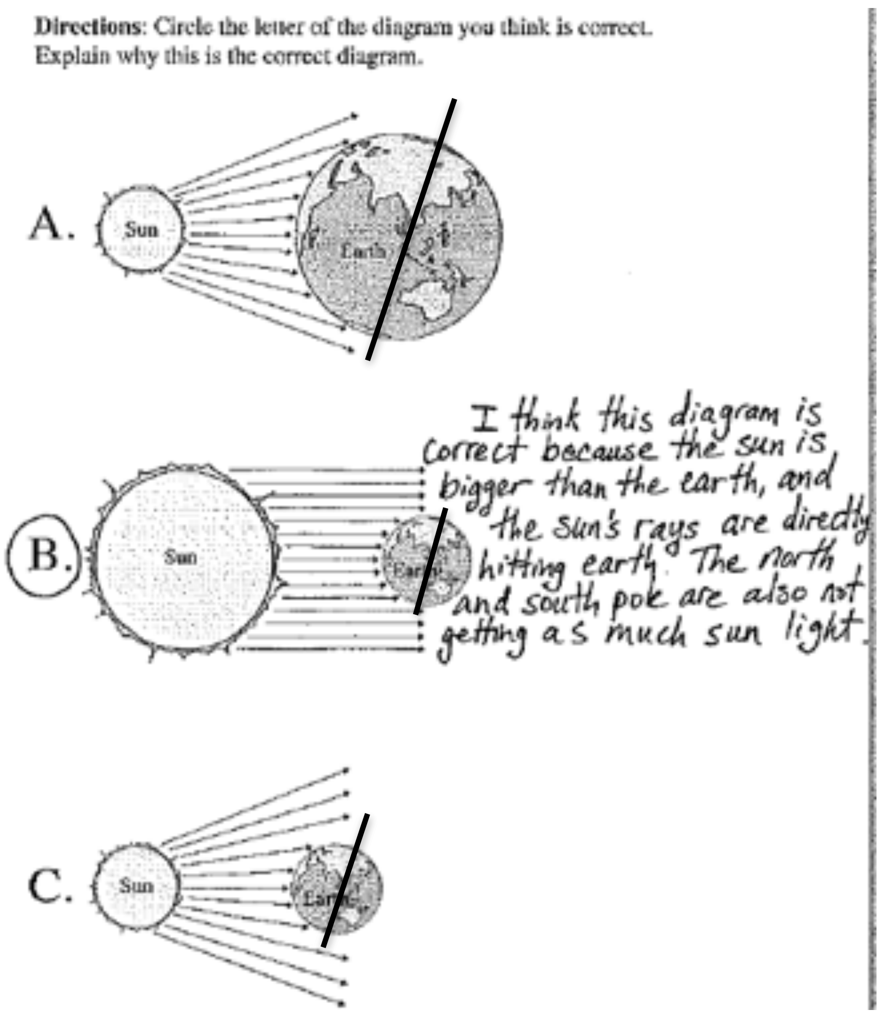

Figure 14: A sample correct student response to an assessment probe about angle of incidence of sunlight at different latitudes. (Illustration from Making Sense of Science *Weather and Climate* course, courtesy of WestEd)

Students can **investigate with different models** how the angle of incidence ***affects*** the intensity of illumination by using various light sources (flashlight with narrow light opening, light bulb, sunlight) and illumination targets (globe, foam ball with marked latitudes, solar cells). Teachers can use a formative assessment probe (Figure 14) to assess student understanding. In the same classroom, a different student answered that A is correct because, “I think in December the light doesn’t reach up to the northern pole. It's cold up there because the light would not reach it." Based on this kind of assessment, teachers can decide how to proceed with the instructional sequence, such as having the student **investigate** a different model to compare the sizes of the sun and Earth, and reason about how the angle of incidence changes with latitude.

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 not involved.	Hot sand burns your feet. Hot ground warms air that touches it. Handle of heated pan becomes hot.
CONVECTION	Warm liquid or gas flows into cooler area and makes it warmer. Electromagnetic waves not involved.	Warm air rises and is replaced by cooler air. Hot water in heated pot rises from bottom to top.
RADIATION	Objects do not touch each other. Electromagnetic waves radiate from warmer object, are absorbed by cooler object, and make it warmer.	Sunlight heats your body. Standing near a hot wall or hot cliff. A wood fire or an outside gas or electric heater heats your body.

Table 6: Contrasting the three different ways that thermal energy moves from warmer objects to cooler objects based on the underlying physical science. (Table by Dr. Art Sussman, courtesy of WestEd.)

Movements of thermal energy are major factors in ***causing*** the observed ***patterns of regional climates***. One major concept is that ***thermal energy 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 6). Students can **investigate** and **research** each of these three ways of heating, **create a brief report** about one or more of them, and **explain** 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.

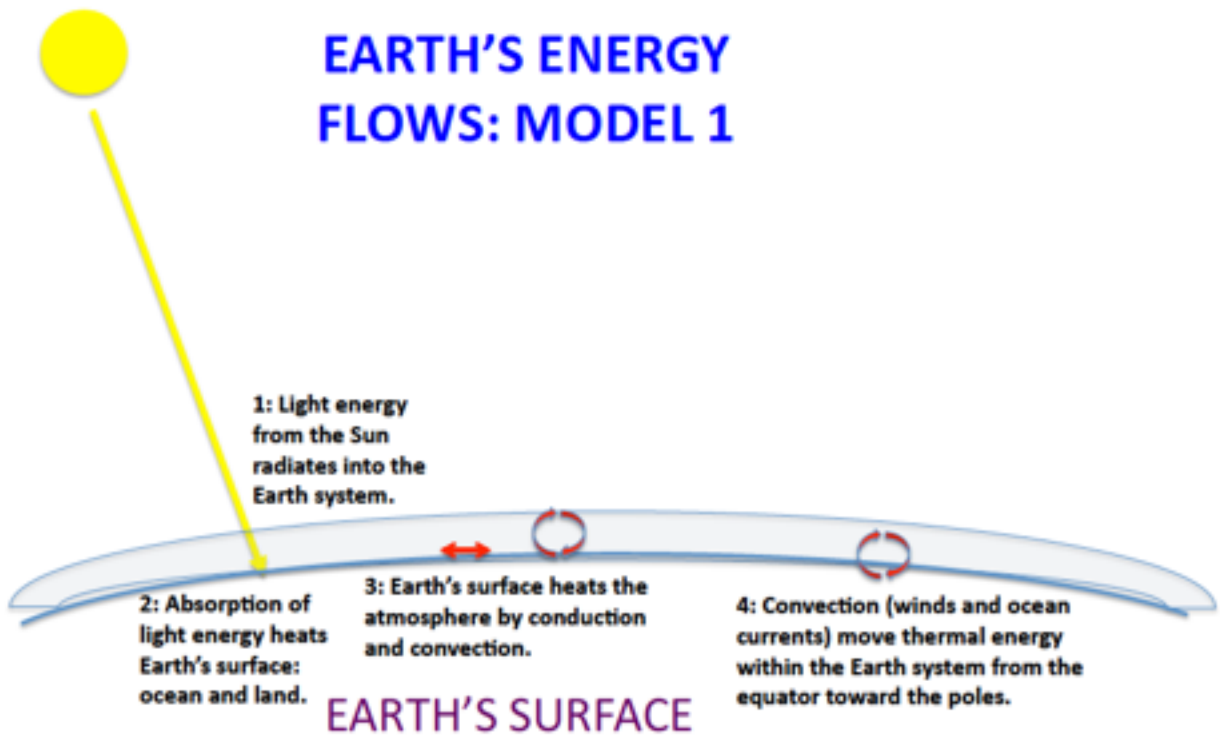

FIGURE 15: A simplified model illustrating energy flows that have major effects on weather and climate. (Illustration by Dr. Art Sussman, courtesy of WestEd.)

Students can **reflect on and discuss** a ***simplified model*** to **apply their experiences and knowledge** of the three modes of thermal energy movement to the context of the Earth system (Figure 15). 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.[2]

The teacher can prompt students to think about and discuss concept number 4 in Figure 15, the transfer of thermal energy by convection. Why does thermal energy move from the equator toward the poles? Student **explanations** should include the **evidence from**

[2] 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.

prior investigations that equatorial regions receive much more direct sunlight, and also the major concept that ***thermal energy moves*** from warmer regions toward colder regions. Students may be confused that there is still such a big latitudinal difference in temperature despite the convection from the equator to the poles. In actuality, 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.

Thermal Energy and Wind Convection Cells

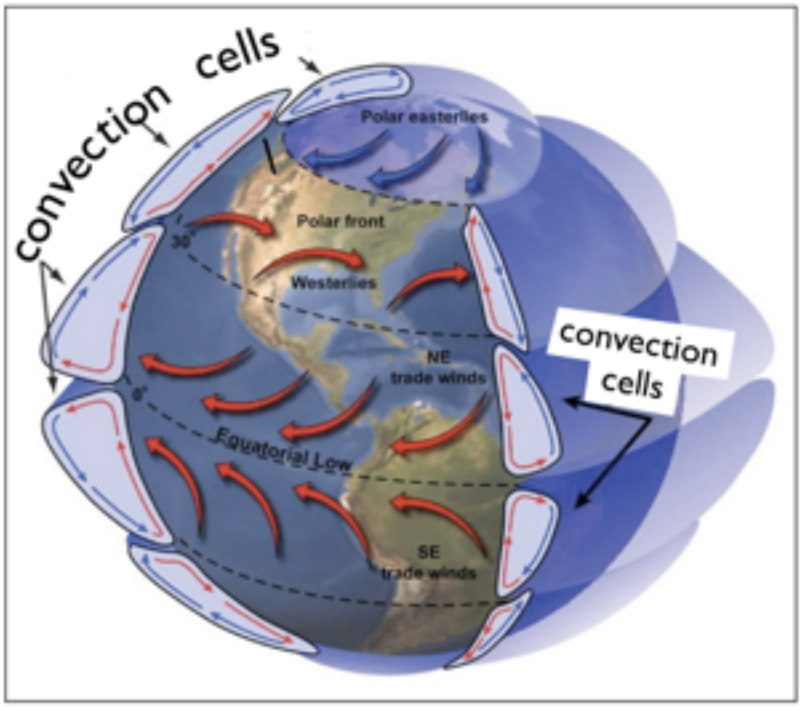

FIGURE 16: Wind convection in the atmosphere moves thermal energy from the equator toward the poles (skinny red and blue arrows in the convection cells). Image credit: (GOV) NASA, accessed at: https://www.nc-climate.ncsu.edu/edu/k12/.atmosphere_circulation.

In the atmosphere, the wind convection from the equator toward the poles actually happens via sequential "steps" that are called convection cells (Figure 16). In this illustration, the equator appears closer to the top than is usually shown, and can be identified as the dotted line passing through Mexico and a little below Florida. The two convection cells just north and just south of the equator 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, but only two of these are visible in Figure 16.

This illustration also shows thicker arrows that represent winds that blow east and west. If simple convection were the only process controlling air movements, all wind would flow in the north-south direction, but we know that is not true. Earth's rotation modifies this path. The assessment boundary for *MS-ESS2-6* states that "Assessment does not include the dynamics of the Coriolis effect," so the exact details of this process are not essential for students, but is included here for curious teachers and students.

Air rotates around the Earth just like the planet rotates around its axis. The atmosphere races around the equator at 1,700 km/hr to complete one full rotation in 24 hours, but it hardly needs to move at all near the poles. As a parcel of air travels north or south from the fast moving equator towards the poles, it is moving faster in the direction of Earth's rotation than the ground underneath it. From our perspective on the surface, it appears to be veering off in the direction of Earth's rotation. Air moving from the poles towards the equator is moving slower than the ground underneath it, so it gets 'left behind' and appears to make a turn away from the rotation direction. Together, these deflections set up predictable bands of wind direction near the surface, and also give rise to the jet streams in the upper atmosphere.

Transitioning from this global view back to a more regional perspective on climate, students can revisit Figure 12 with its color-coded global map of average annual temperatures. Students can discuss in groups any aspects of Figure 12 that raise **questions** for them. The instructional goal is to discuss the effects of altitude, which appear in Figure 12 as blue areas north of India and on the west coast of South America. These blue areas are the most blatant departures in Figure 12 from the general ***pattern*** of latitude determining climate. If students get too sidetracked with discussing other minor climate discrepancies, teachers always have the option to guide instruction into the most productive directions.

Students may be able to share based on personal experience that mountain temperatures tend to be cooler than temperatures at lower elevations. A very important climate consequence of the colder temperatures at higher altitudes is that rising air becomes colder and can hold less water vapor (see Figure 10 in Instructional Segment 2 correlating relative humidity and temperature). ***As a result*** of this cooling, water condenses, clouds form, and there is a much greater likelihood of precipitation in the forms of rain or snow. The **analyses** of California climate regions revealed this correlation of increased precipitation with higher elevations.

Two ***generalizations*** could emerge from consistent research. If wind from a moist area is blowing towards a mountain range, it is very likely that there will be high amounts of precipitation on the side of the mountains that the winds first hits (called windward or upwind). The other side of the mountain (leeward or downwind) tends to be much drier because most of the water vapor has condensed and precipitated on the other side of the mountain. On the other hand, if the wind blowing towards the mountain has very low humidity, then it is likely that both sides of the mountain will be dry. This condition tends to occur in the middle of continents or locations where the prevailing winds tend to blow toward the ocean.

The temperature and amount of humidity in a mass of air reflects where that mass of air first formed. If it first formed over a warm ocean, the air mass will be warm and humid. If it first formed over a dry continental area, the air mass will be dry and its temperature will depend on whether the continental area was hot or cold. Using animations of real-time satellite observations[3]), students **collect data** about the movement of large air masses, noticing that the most intense precipitation and weather events occur where air masses collide (*MS-ESS2-5*). These observations form the evidence that can be used to construct a more complete ***explanation*** or a ***model*** of the relationship between air masses and changing weather conditions (Table 7).

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[3] NOAA, Geostational Satellite Server: GOES Western U.S. Water Vapor and Visible. Accessed at http://www.goes.noaa.gov/browsw3.html

TABLE 7: 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 7 from Dr. Art Sussman, courtesy of WestEd)

Final Note re Weather in Instructional Segment 3: The clarification statement for *MS-ESS2-5* indicates that students will not be assessed on weather map symbols. This is largely a reaction to the fact that these symbols are no longer necessary for illustrating weather patterns in the digital age. For example, real-time wind patterns are indicated with animations of the flow of individual particles[4] or with familiar rainbow color scales[5]. These visualization tools allow teachers to spend more time helping students ***recognize and explain patterns*** with less time devoted to memorizing symbols.

Organism Traits, Heredity and Reproduction

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[4] Viégas, F. and Wattenberg, M., Wind Map, accessed at http://hint.fm/wind/

[5] Beccario, C., Earth, accessed at http://earth.nullschool.net/#current/wind/surface/level/

Climate and major geographical features are key abiotic factors that strongly ***influence*** the kinds of organisms can live in an environment. These same factors also help ***determine*** the organism structures and behaviors (adaptations) that will have the most success with respect to survival and reproduction. Teams of students can **research** a distinctive environment (e.g., an island near the equator), and organize and communicate information about the plant and animal traits that promote success in that environment. Sharing across teams that have investigated very different kinds of environments can then lead to generalizations about significant ***patterns***.

In addition to a general emphasis on adaptations that promote growth and survival (LS1-5), Instructional Segment 3 Performance Expectations emphasize **evaluating** factors that promote reproductive success (LS1-4) and **analyzing** different modes of reproduction (LS3-2). This focus on reproduction helps highlight a general ***pattern*** that biotic factors have a strong influence on organism traits. Organisms from different species can strongly ***determine*** organism structures and behaviors that promote successful growth, survival and reproduction. The interactions of plants and animals involved in pollination provide great examples of organisms from species ***causing*** changes in each other's biological structures and behaviors in the service of plant reproduction. As will be described later, sexual selection by females provides dramatic examples of organisms from the same species ***causing*** changes in biological structures and behaviors.

Organism structures and behaviors are features that generally apply to all members of a species. Examples of human features are eye color, body size, blood type, abd personality such as introversion/extroversio. 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 very 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.

Discussions of traits can get side-tracked by either/or arguments about the roles of genes and the environment in determining traits. Early in Instructional Segment 1, this kind of “either/or” issue arose with respect to the geosphere being either a component or a system, while in fact it is both a component of the whole Earth system and also a system made of parts. Many features and processes of the natural world occur across a very wide spectrum of possibilities. 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 very large environmental component (e.g., large muscles due to exercise or being able to play the guitar). Most traits are a combination of genetic and environmental influence, and can be placed somewhere along the spectrum between the extremes examples (Figure 17).

Cat Example of Continuum of Traits

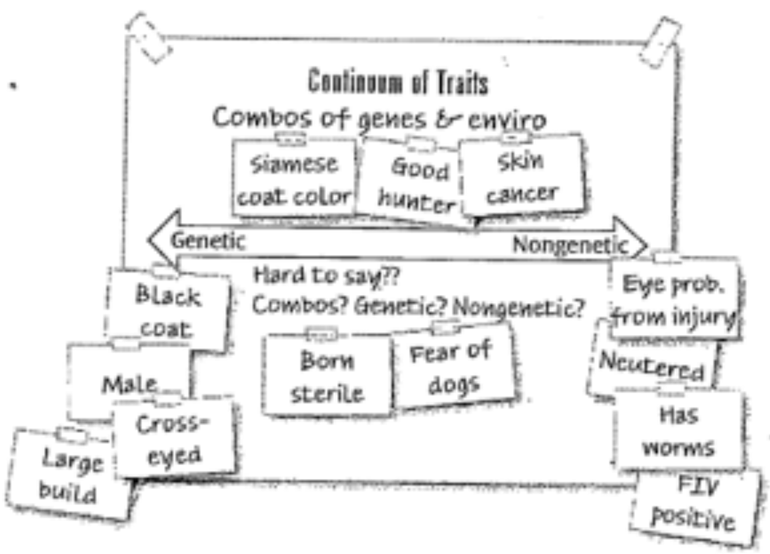

Figure 17: Some traits are essentially all genetic, and some are mostly environmental. Most traits are strongly influenced by genes and the environment. (Illustrations from Making Sense of Science *Genes and Traits* course, courtesy of WestEd.)

With respect to genes, students typically learn about genes by **analyzing** the results of Mendel’s experiments with pea plants. In analyzing these or other classic examples of genetic experiments, students often use Punnett squares to **predict or explain** the traits in progeny, and then **conclude based on evidence** that some gene alleles are recessive, others are dominant, and some do not fit the dominant/recessive dichotomy. Classic genetics tends to reinforce a misconception that each trait is caused by one gene. Students may also hold a parallel misconception that each gene influences only one trait. Students can counter these misconceptions by **citing evidence** 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 18 contrasts incorrect and correct concepts about the ***causal linkages*** between genes and traits.

Incorrect and Correct Ideas about Genes and Traits

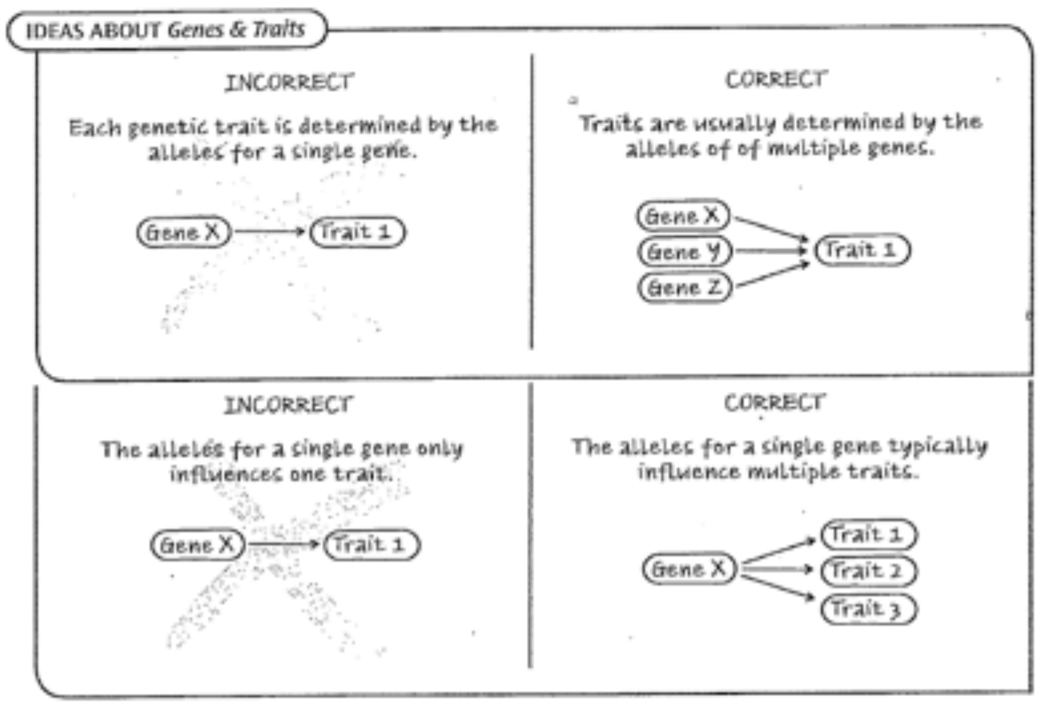

Figure 18: Multiple genes typically determine a specific trait, and an individual gene typically influences multiple traits. (Illustration from Making Sense of Science *Genes and Traits* course, courtesy of WestEd.)

Instructional Segment 3 Snapshot

Asexual and Sexual Reproduction

This snapshot presents an example of how teaching and learning may look in the classroom when the *CA NGSS* are implemented. The purpose is to illustrate how a teacher engages students in three-dimensional learning by providing them with experiences and opportunities to develop and use the Science and Engineering Practices and the Crosscutting Concepts to understand the Disciplinary Core Ideas associated with the topic in the Instructional Segment. A Snapshot provides fewer details than a Vignette (e.g., the Instructional Segment 2 Vignette “Interactions of Earth Systems Cause Weather”).

Ms. Z wanted to use an engaging activity to help students transition from their analyses of the causal connections between genes and traits to comparing asexual and sexual reproduction. Basing the activity on an interactive lesson from the University of Utah Learn.Genetics website,[6] 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** for their categorizations. Whole class sharing resulted in common answers and evidence. Small student teams then had time to explore the website (possibilities would be in computer lab, in class with tablets, at home, in a library) in order to select two organisms that have different processes of sexual reproduction.

The following day, student teams **made system models** of the reproduction processes for each of their two selected organisms. Each of the system models had to **explain 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** each posted model. They pasted Post-Its next to the models with any questions or **disagreements they had with respect to the conclusions and/or evidence**. After the presenters had time to look at the Post-Its, the whole class paid attention as each presenting team **appropriately responded** to the comments.

NGSS Connections in the Snapshot

Performance Expectations

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 identical genetic information.

[6] Sexual vs. Asexual Reproduction accessed at: http://learn.genetics.utah.edu/content/variation/reproduction/

Disciplinary Core Ideas
LS1.B: Growth and Development of Organisms
LS3.B: Variation of Traits

Scientific and Engineering practices
Developing and Using a Model
Develop and/or use a model to predict and/or describe phenomena.
Develop a model to describe unobservable mechanisms.
Constructing Explanations
Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.
Engaging in Argument from Evidence
Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.

Crosscutting Concepts
Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
Patterns may be used to identify cause-and-effect relationships.

Cause and Effect
Cause and effect relationships may be used to predict phenomena in natural or designed systems.
CCSS Connections to English Language Arts
ELA: WHST.6–8.7, 9; SL.6.2, 5

Connection to CA ELD Standards:
ELD.PI.6-8.1, 9

CCSS Connections to Mathematics

None

Sexual reproduction in animals can then lead to investigations that link back to the body systems concepts in Instructional Segment 1. Students **analyze** each of the reproductive processes described in the Snapshot lesson to compare all animal behaviors that play a significant role in the reproduction. In order to do so, the students

discuss the criteria for how they will categorize different kinds of behavior. If students have difficulty suggesting valuable criteria, the teacher can prompt the discussion with examples that exemplify 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.

At the teacher's direction, students **extend their investigations** 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. The teacher provides 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 pick one of the suggested examples of female choice or a different one that they independently **researched and evaluated**.

After the teams have conducted the first round of research, the whole class decides on the criteria for a complete investigation and report. The teacher may exercise male or female choice whether to post the wording of PE MS-LS1-8 and also whether to allot extra credit for teams that provide information about the nervous ***system components that enable the investigated animal behavior***. Teams extend and conclude their investigation by **developing and presenting a report** to the class about their example of female choice including **explaining the evidence and reasoning** how the behavior affects the probability of successful reproduction (MS-LS1-4).

These life science learning experiences in grade 6 provide a foundation for deeper explorations in grade 7 (PEs and DCIs focused on LS2: Ecosystems) and in grade 8 (PEs and DCIs focused on L3: Heredity and L4: Biological Evolution).