Living Earth Unit 4:

Inheritance of Traits

Background for Teachers and Instructional Suggestions

Middle grade students are introduced to genes and the connection to genes and proteins, including what happens if there are mutations in gene sequences (*MS-LS3-1*) and the variation within individuals that are the result of the inheritance of genetic traits (*MS-LS3-2*).

This instructional segment has links to concepts in instructional segments 3 and 5 and these will be noted as discussions expand on how organisms use DNA to code for amino acids, the building blocks of proteins and how this information gets passed from generation to generation. In instructional segment 5 time will be spent on the formation of gametes as a result of cell division a connection to this instructional segment can be made at that time. One way this instructional segment could be taught is through a historical approach, building on what scientists knew at the time, and, more importantly, how they **asked questions and performed investigations** that provided answers to these questions as well as exposed more questions. Discussing the scientists themselves ***science is a human endeavor***. The historical approach also illustrates how ideas have unfolded over time, showing that ***scientific knowledge is open to revision in light of new evidence***. See the chapter on Instructional Strategies for specific advise for teaching science through historical case studies. The history of how DNA was discovered and modeled is particularly well suited to a historical introduction, but it is not the only instructional segment that could be presented historically. Alternatively, the history does not need to be taught explicitly to meet PEs related to this instructional segment.

At the turn of the 20th century, Mendel's conclusions were accepted and it was understood that chromosomes were passed from generation to generation in all living organisms. It was also known that chromosomes were composed of DNA and proteins. What was not clear for scientists in the early 1900's was how these chromosomes could provide the codes for all the phenotypes present in an organism, was it the proteins or

DNA that was important? As scientists grappled with this they began to ask more directed questions on what exactly was directing the translation of proteins. Frederick Griffith was trying to find a cure for pneumonia and was using mouse models to ask specific questions about how mice contracted pneumonia. He found that he could inject strains of bacteria into mice and transform strains of non-pathogenic bacteria into pathogenic bacteria. The full experiment might be demonstrated by a presentation that has a slide with the first part of Griffith's experiment and students predict outcomes and then "see" what comes next switching to the next slide and building on that knowledge continuing with the next set of experiments along with predictions. Students can deduce the control and variables Griffith used in his original work. The conclusion of his work was that some agent "transformed" the non-pathogenic causing strains into pathogen causing strains of bacteria, and the mice ended up with pneumonia.

The next question was "What was that "transforming agent"? Avery, MacLeod, and McCarty attempted to answer that question. They discovered that DNA was the transforming agent, which they concluded after testing the individual components of the bacteria cell in a cell culture system. Scientists were not entirely convinced, so Alfred Hershey and Martha Chase radioactively labeled parts of viruses and provided even more evidence that it was the DNA that was being transported into hosts' cells and transforming those host cells into virus making machines. It was also around this time that Erwin Chargaff and his students who while working on separating out nucleotides in different organisms noticed that adenine and thymine were always in equal amount to each other as were guanine and cytosine. They also noticed that the total amount of adenine and thymine was NOT equal to the total amount of guanine and cytosine. A final piece of the puzzle was the X-ray photograph of DNA that Rosalind Franklin generated that showed the regular pattern and the helix formation of the molecule. (This is a good time to talk about women in science). These experiments along with other evidence gathered during this time led to the building of the model of DNA by Watson and Crick[1]. Teachers can point out that building physical models can help explain data and observations (for Watson and Crick it helped them merge together all that they had learned from others) and also that models can help predict new possibilities (for Watson and Crick it helped others think about how DNA replicates) but models also have limitations (For example, they didn't know how the code determined amino acid order). Having students build this **model** can help them make the connections that Watson and Crick made with the data produced from the experiments above. Students can also begin to see what happens if a component of the model changes? What happens if you switch a thymine with an adenine? (Students should see that having an A nucleotide across from an A nucleotide alters the structure). Again, helping them make predictions of the effect of mutations. Teachers might also have students read an annotated version of Watson and Crick's original paper, which is only two pages long but has had a profound influence on the directions scientists took in the study of genetics and molecular biology.

Much of the work done in the first half of the 20th century looked at the affect mutations had on phenotypes. If a genetic disease resulted, it gave the geneticists evidence of the function of that gene, though they couldn't 'see' the genotype. In the latter half of the 20th century into the 21st century techniques and tools have improved so that scientists have the ability to link a change in a gene sequence with a specific phenotype. A lot of this work has been combined into whole genome studies of a large variety of organisms. As an extension, students can look at what organisms scientists today are working on by looking at the National Center for Biotechnology Information (NCBI) which is a government maintained database and repository for information about genes, proteins and genomes.

To further demonstrate how **asking questions** and answering them often leads to more questions is shown in what happened as whole genomes were sequenced. It turned out that genomes contained much fewer gene sequences than originally thought

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[1] See an excellent educational resource regarding the history of this scientific discovery, UC Berkeley Museum of Paleontology, The structure of DNA: Cooperation and competition, http://undsci.berkeley.edu/article/0_0_0/dna_01

and that many phenotypes are the results of more than one gene. It became clear as more genes were sequenced and functional studies were done that linked them to a phenotype that it was the combination of many genes that results in a single phenotype. For example, there are genes that code for proteins that are involved as transcription factors that then turn on or turn off transcription of another gene into RNA. All of these genes working together then would produce a single phenotype (for example, pigment in animals or plants involve many genes that result in one color). It should be noted that students have not necessarily been exposed to RNA and transcription at this point in their science courses but they will be and once they are they should have an understanding that genes result in proteins by going through a process to take a region of DNA that then is used to translate into protein. Once they have that exposure, students can create **models** using codes that need to be transcribed into making something, maybe a word code that transcribes into a physical code (colored building blocks) that then are ordered into a structure (for example, a building or a bridge) this can help students grasp how cells go from a written code to protein.

Students can look at phenotype studies and **ask questions** as to what changes in DNA result in changes in phenotypes on humans (or other living organisms that have had studies done) looking at the effect of DNA changes on individuals.[2]

This instructional segment can now continue and meld classic Mendelian genetics with the molecular genetics just discussed. As students think about genetics, they can be guided to think about the similarities and differences within a population of organisms recognizing this as variation. This variation is the result of mutation and recombination events that happen at the genetic level. Students can visualize and provide **evidence** for how variation happens by going back to a three dimensional **model** of chromosomes (such as clay or pipe cleaners). Using this model students can demonstrate how pairs of chromosomes physically exchange parts to create new combinations of sequences (one method of variation) and can show that the random

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[2] Students can go to National Center for Biotechnology Information (www.NCBI.nlm.nih.gov) and link to case studies done in humans by looking at the Online Mendelian Inheritance in Man (OMIM) link or they can expand the exercise and look at other animals or plants.

line up of the chromosome pairs during meiosis results in different arrangements of chromosomes within gametes (another method of variation). Students can then show that the random joining of these gametes as one sperm and one egg out of all the possibilities of sperm by the male parent and eggs by the female parent result in an individual who looks different than their sibling (another method of variation) these processes are part of cell division which will be discussed in instructional segment 5. Further validation of this can be shown with Punnett squares which diagram the probability of certain combinations of alleles that can result from the mating of two parents. Looking at the ***quantity and proportion*** of possible outcomes helps explain the variation we see in individuals even between siblings who have the same parents

Mutations in DNA contained in gametes can result in a change in genotype and can produce new allelic forms of genes that are then inherited by the next generation. Linking back to instructional segment 3 some mutations result in viable cells and can produce new allelic forms of genes that are then inherited by the next generation, others result in cell death, still others in uncontrolled replication that leads to cancerous tumors. Some genetic mutations produce viable cells but can result in diseases. Explanations for genetic diseases in humans are studied by looking at how a single nucleotide change, for example the single nucleotide change in the gene sequence for hemoglobin that results in the genetic syndrome for sickle cell anemia or a similar mutation in the gene that is used to form proteins that form a channel for movement of particles between cells producing the condition known as cystic fibrosis (though it should be noted that there can be several single changes that result in the cystic fibrosis phenotype). Extensions could be made that include explanations of cancers and effect of mutation loads on genes including mutations that result in changes in an individual during their lifetime but does not necessarily result in a change in the DNA contained in their gametes so that the change is not passed onto offspring.

Once students understand how variation can occur, they can predict what combinations are possible in offspring. The most common way this is demonstrated in genetics is by the use of Punnett squares (a predictive method designed by Reginald Punnett) but this is limiting as we begin to look at more traits for an individual. For example, if we wanted to look at a tri-hybrid cross we would have to generate cumbersome 8 by 8 Punnett square. Instead, students can be introduced to statistical methods using the product rule and the sum rule of probabilities. Pedigrees are another model used to look at patterns of inheritance across generations. Students can problem solve possible combinations and predict the chance of traits appearing in combinations of an individual offspring. There are interactive computer simulations that students can use to create phenotypes of an organism by looking at combinations of genotypes and again predicting what combinations are plausible.

While genetics dictates some aspects of variation, environment also affects phenotype expression. Some environmental components can affect the phenotype without a change in genotype. In humans, nutrition is an environmental component that can have an effect on height or muscle formation. Just because an individual possesses the genotype to be tall or strong does not mean they will reach full genetic potential. If they are malnourished when young they will not be as tall or as strong. This type of change is not inherited so offspring of individuals who were malnourished can often be taller or stronger than their parents if the parents had the genetic potential to also be tall or strong. Using statistics (mathematical thinking), students can **analyze data** by comparing the probability of certain traits occurring based on genetics alone to the observed frequency or distribution of traits observed in a population. A mismatch in these proportions is evidence that supports the **argument** that environmental factors have affected phenotypes. Students can **perform investigations** manipulating environmental conditions (i.e., pH of soil with hydrangeas) to see if they can shift the distribution of phenotype expressions.

High School Vignette
Natural Selection

This vignette describes how students develop understanding of how variation, genotype and phenotype play a role in evolution by addressing the following overarching questions: What processes influence natural selection? What do changes in ***patterns*** of phenotypes mean? What are the ***causes and the effects*** of ***changes*** in environments on variation in populations?

This vignette illustrates how teachers could engage students in the topics of instructional segment 11 and part of instructional segment 12. It encompasses natural selection and adaptation and outlines sections that would come before and after the instruction and learning described below.

This vignette assumes students have prior knowledge based on the following middle school performance expectations:

> 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
> MS.LS.2-4- Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
> MS.LS4-4- Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
> MS.LS4-6- Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Students will need to know how obtain raw data and construct graphs, both by hand and using spreadsheets on the computer. There is a bit of guidance in some of the documents used for the vignette, but it assumes that students have already some experience with graphing.

The teacher's background knowledge should include how Darwin's observations led to his inferences and how his observations and inferences are used today as the foundation of the Theory of Evolution. Teachers also need to take care to dispel Lamarckian misconceptions (this should be done with the students before starting this vignette), including the fact that evolution is not goal directed and that adaptations are not the result of a change in the environment, but rather are traits or characteristics the organism already has that increases the fitness (the ability to reproduce living offspring) of an individual compared to individuals without these traits. Though natural selection acts on individuals, it is not changing the characteristics of individuals; instead, it changes the frequency of characteristics/traits in a population (in other words, the frequency of particular alleles in the population gene pool). Natural selection can only select from the variation in phenotypes that are present at the moment, it cannot create a new variation. Only mutation and recombination in sexual organisms can create new allele combinations that might result in phenotypic variation. Natural selection acts on the phenotype, but evolution consists of changes in allele frequencies. Therefore, evolution only occurs if the selected traits have a genetic basis. Teachers should also know that the individual postulates of the theory of evolution are testable.

Instructional segment plan

5E Learning – This vignette is based on an iterative 5E instructional model where students engage, explore, explain, elaborate and evaluate each topic (Biological Sciences Curriculum Study [BSCS] 2015). Each activity has a role in the 5Es, but each activity also needs to include each of the 5Es along the way. The 5Es are one approach to teaching the CA NGSS science and engineering practices (SEPs) and while SEPs should be shared explicitly with students, the 5Es are not necessarily relevant to the students, so this information is for the teachers' notes (Table 1 is an overview adapted from BSCS's model available on the Web site above).

Table 1: Outline of the 5E model as modified from the BSCS model (BSCS 2015)

Engage	This portion of the activity is designed to generate student interest through the introduction of interesting and relevant activities that access prior knowledge and set parameters for the focus of the lesson.
Explore	Students participate in activities that facilitate conceptual change by experimenting, probing, inquiring, questioning, and examining their thinking.
Explain	Based upon their discoveries, students generate explanations and designs, connecting prior knowledge to new discoveries.
Elaborate / Extend	Students must now apply their new understanding to novel situations. Using academic language, they explain concepts and designs.
Evaluate	Finally, students assess their understanding of phenomenon and success of designs and offer new applications of scientific principles as well as next steps for engineering designs.

Each day is a 50-55 minute lesson. Many of the activities do require some set-up before class starts in order to use time wisely. Though homework is encouraged, it is not spelled out in all cases for this plan. Table 2 provides a snapshot of the 12-day plan.

Table 2: 12-day overview of instructional segment on Natural Selection

	Overview of Lesson	Teacher Does	Student Does
Day 1	**Engage:** lesson on variations in human populations using height as an example	Ask guiding questions and model how to measure and record data	Recognize PATTERNS What is the variation in height in their classroom?

	Overview of Lesson	Teacher Does	Student Does
Day 2	**Engage**: use a pinto bean to show more variation. Watch HHMI video on Galápagos Islands and discuss beak variation.	Ask guiding questions and lead discussion on variation. Show video to link to tomorrow's lesson	Recognize PATTERNS in pinto beans and understand the differences in the beaks that the Grant's observed on the Galápagos Islands
Day 3	**Explore:** Island Beak Lab- Simulate survival of the fittest in different conditions and collect data.	Set-up materials and monitor students' progress	Participate in the island simulations. Collect data
Day 4	**Explore: Analyze and interpret data** collected from Island Beak Lab.	Guide students through analysis of the Beak Lab data.	Summarize beak lab data for ***cause and effect*** linkage.
Day 5	**Explain:** Read about Darwin's observations and make concept maps of what he saw and the inferences he drew from that data	Guide the reading and the concept mapping to keep students involved	Reading and concept mapping.
Day 6	**Explain:** Darwin continued. Finish concept maps and share them out, allowing other students to ask questions in a share out or walk around.	Guide discussion of concept maps.	Engage in SEP for Communicating Information

	Overview of Lesson	Teacher Does	Student Does
Day 7	**Explore:** Darwin continued. Graph finch data obtained from Peter and Rosemary Grant. Use the SEP of **analyzing and interpreting data**	Guide students in graphing and analysis of data.	Graph data set and look for ***cause and effect*** linkage
Day 8	**Explain and Elaborate:** Present findings from Darwin data. Use SEP practices of **analyzing and interpreting data, using mathematics and computational thinking,** and **engaging in argument from evidence**.	Finish analysis of data and assess presentations. Help class reach consensus on the results.	Analyze data and look at ***cause and effect*** and present findings to the class.
Day 9	**Explore:** Simulate population changes over time (colored dot activity) **Explain:** Use SEP of **analyzing and interpreting data, constructing explanations and designing solutions, using mathematics and computational thinking,** and **engaging in argument from evidence**.	Set-up selection pressure over time activity. Monitor student progress and help class reach consensus.	Do the activity and analyze the results and look at ***cause and effect***

	Overview of Lesson	Teacher Does	Student Does
Day 10	**Elaborate:** Lesson 3 from EEI Differential Survival of Organisms Have students look at selection pressures that are biotic and/or abiotic factors. Use SEP of **constructing explanations** and **designing solutions**	Present the lesson with the cards and have students work in group to finish project.	Make connections to what biotic and abiotic pressures result in what phenotype in these marine organisms
Day 11	**Evaluate:** Case Study: Great Barrier Reef from EEI Differential Survival of Organisms. Examine the impact of humans on species survival. Use SEP of **constructing explanations** and **designing solutions**	Guide students through reading and responding to questions.	Work in groups to understand the issues and design solutions.
Day 12	Share out results of the case study analysis. Use SEP **engaging in argument from evidence**.	Invite constructive feedback from students on results of case study.	Present findings to the class.

Narrative

Before beginning this narrative it should be noted that Ms. O's class has electronic devices for each student. She makes use of online collaborative documents (e.g., Google documents and spreadsheets). A description of how to provide this instruction without technology or with limited technology is provided at the end of this narrative.

Day 1: Engage activity-Ms. O's goal for the day is for students to recognize that height variation exists in the classroom and that height has changed over time in baseball and basketball players.

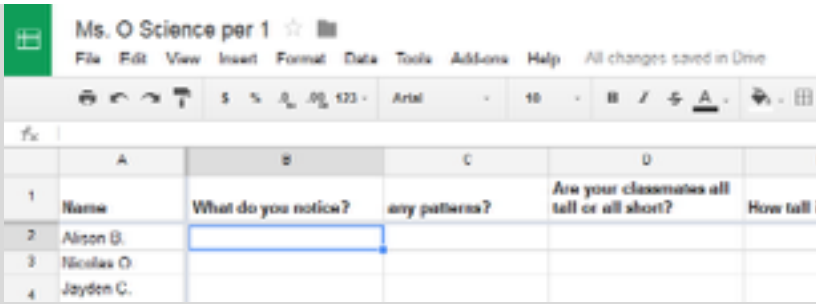
Before class starts Ms. O has taped up measuring tapes exactly 36 inches/ 91.4 centimeters from the ground on the wall at 8 stations around the room.

As the students enter the classroom, Ms. O hands them an index card and tells them to put down their books and go with a partner to a station and measure both their heights in inches and centimeters. Each person writes their measurements and their partner's measurements on the index card. Ms. O then asks them to enter their own data onto the class online spreadsheet. The students also indicate whether they are male or female but they leave their names off.

Ms. O now asks the students, "What do you notice about your height and your partner's height?" They respond by raising their hands. She spends only a minute on this as she then projects the data from the entire class on the screen. She displays the data in a table format with male/female as one column and inches in another and centimeters in the last column. She asks the students a few questions:

"What do you notice? Are there any **patterns** to this distribution? Are your classmates all tall or all short? How tall is tall? How short is short?"

Students respond on the class online spreadsheet for quick writes. (This is a pre-set online spreadsheet with each student's name as a row and the question in the column closest to their name. The students are used to this protocol, which they have used since the beginning of the school year. See example below.)



Ms. O then notes some of the commonalities of their answers and asks students the next guiding question:

“You all noticed that there are differences in the heights of you and your classmates. We call this variation. Why is there variation in height? Answer on the quick write.”

Ms. O reminds the students that in their genetics instructional segment they learned how genotype connects to our phenotype and that the main reason for height in humans is the result of our genotype and that proper nutrition contributes a small part to height.

“Do you think human’s average height has changed over the years? Are people today taller than they were say 100 years ago?” Ms. O takes a quick show of hands and writes down the responses.

“Now we are going to look at data on height and weight of baseball and basketball players in the last century.” Ms. O then has the students open the class Web site and click on the link for Baseball and Basketball statistics (see links below). Working in established pairs or groups of three, the students are asked to write down some observations of the trends they see over time of height changes. They are asked, “What stands out for you in this data?”

Link to baseball statistics
http://www.azsnakepit.com/2010/7/5/1550963/baseball-players-does-size-matter

Link to basketball statistics
http://www.basketball-reference.com/leagues/NBA_stats.html#stats::none

Ms. O leads the students through an analysis of the data, identifying the overall trend including the direction and the shape (is it linear?). For homework, she asks students to write an **explanation** that **interprets the data** in terms of genetics and environmental factors. She asks them to speculate about which factor might have changed most during 100 years, genetics or environment.

Day 2: Ms. O's goal today is to have the students recognize that there is variation in many different populations (not only in humans), including in pinto beans. She also will prepare them for the hands-on activity tomorrow on Islands and variation in beaks of birds. Some of this preparation will be done by watching the HHMI video (HHMI BioInteractive 2014).

Before class Ms. O puts out small metric rulers on the desks of the students, has the spreadsheets of data ready from the day before, and cues up the HHMI video.

Ms. O reviews with the students their comments about the data from the day before; students see that evidence shows that the average height and weight of baseball players and basketball players has increased over the years. She then hands out 2-3 pinto beans to each student and asks them to write down a few observations about what each looks like. They are allowed to measure and draw what they see. Ms. O encourages them to look at their neighbors' beans too. Then, she collects all the beans and puts them into a few bowls that have some additional beans in them too. Ms. O asks the students within the groups to pick out their beans from among the beans in the bowls. She allows about five minutes for students to pick out the beans and then asks the class to come back together.

Ms. O. asks the students if variation is part of all populations. She asks students to call out a few variations that bird populations might have, guiding the students to think about beaks, body size, wing spans, and so on. Then she shows a 15 minute video on the Galápagos Island finch. She also links the video to the class Web site in case students want to review it on their own. She asks the students to fill out an online form on their understanding of what the film was about. She uses the questions that are associated with the video on HHMI website http://www.hhmi.org/biointeractive/evolution-action-data-analysis.

Before class ends, Ms. O explains that tomorrow they will be coming in and starting their assignment immediately on exploring island beaks and how different tools represent different ways of acquiring food. She hands out the worksheets and asks students to read through them tonight, emphasizing that tomorrow part of their grade will be based on whether they were prepared to do the assignment or not.

Day 3: Explore- Ms. O's expectation for the students is that they will complete as many stations as possible and participate in the activity.

Before class, Ms. O sets up each of the islands in duplicate (she has a class of 36 students and has them divided into groups of four). There are 8 stations, so in total she has 16 stations for the students.

Students enter class ready to start at their stations. Yesterday they were assigned roles that they will rotate at each station. Directions are included in the worksheet which Ms. O handed out yesterday, a copy is also linked to the class Web site.

At Ms. O's directions, each student group starts at a station on their side of the room. She lets them have about 7 minutes a station so each group gets through about 6-7 of the 8 stations, depending on whether they are being efficient. As the students perform the tasks of each station, Ms. O walks around helping the students stay on task and making sure the supplies are sufficient. She gives students a one minute warning, then calls time, and has students rotate to the next station.

Students' homework is to put their data into the cloud- based class spreadsheet that Ms. O has linked to the class Web site and to answer the questions for each of the stations they completed. Ms. O makes it clear that they will receive points based on data input BEFORE class starts.

Day 4: The class objective today is to make connections between ***cause and effect*** and apply **analyzing and interpreting data** techniques to the data collected yesterday.

Before class starts, Ms. O double checks that the spreadsheet has been filled out by the students and sets up a quick formative assessment that she will give during class this day.

Students enter class and take out their electronic devices and their worksheets. Ms. O calls the class together and projects the data that was inputted into the class spreadsheet. She asks students to look at the data and complete their worksheets based on what they see in the data sets. The students also have access to the data on their devices. For the stations that they did not get to on Day 3, they can use the class data to answer the questions. She gives them about 15 minutes to finish this and then collects their worksheets.

Next Ms. O directs their attention to the data and asks some guiding questions about the data. Some of the answers she will collect on the class quick-write so that all students can respond. Ms. O first asks, "What ***patterns*** do you notice within and between islands? Which beaks worked best for each island? Is there any beak type that worked well on more than one island? Why or why not? How does this relate to ***cause and effect***?" She has the students input their responses and then talk within their groups to decide if they want to improve on their answers.

For the last 15 minutes of the class, she has the students do a formative assessment by filling out an online form (this will ensure individual responses are gathered as students cannot see other students' responses). They can look at the spreadsheet that Ms. O has projected. She does not let the students go to the sheet on their devices as she wants to see what they know, not their partners.

The Questions for the assessment are:

1. What overall patterns did you observe in the use of the beak tools on each island? Give evidence from the data to support.
2. Did there seem to be a “best” tool for every island? Why or why not? Use data to support your answer.
3. Now that you have had a chance to look at data collected for each island, write a few sentences on how **variation** affects the ability of birds to gather food. Provide examples of cause and effect. What will happen to the separate bird populations over time? Provide evidence for your explanations. Use class data to support your observations.

- (Note this question was asked already but before the discussion, so students should now have more evidence to support their answers).

Ms. O assigns homework for the student that involves reading the section of their textbook on Darwin’s observations and inferences.

Day 5-6: Explain: Students will have produced a concept map outlining Darwin’s observations and the inferences he made and how they connect to the activities done in class already.

Ms. O will have sheets of poster paper and pens at each group’s table.

Ms. O will have the students sit in their assigned groups of four. Students will be tasked with discussing within their groups Darwin’s observations and the inferences he drew from them. Ms. O travels to each group to answer any questions and/or clarify for the students anything about Darwin’s findings. Students will then work together to create a concept map of each of Darwin’s observations and link it to each of his inferences (Ms. O encourages them to be creative. They can use pictures, drawings, or sketches). Once this is done, Ms. O instructs the students to add another layer to their maps by indicating connections to the activities already done in this instructional segment. Ms. O expects these concept maps to be completed half-way through the second day. These will be displayed around the room. The concept map is part of the **Explain** process of the 5E model for this instructional segment.

Ms. O checks each concept map to make sure it has a representation for each of the following of Darwin's observations:

1. Populations have the potential for rapid reproduction.
2. Over time amount of resources and populations don't change in size.
3. Within populations there is variability in structures and behavior.
4. Some of that variability is inherited.

Ms. O also checks for representation of Darwin's inferences, postulates, or conclusions:

1. Individuals within populations are variable
2. The variation among individuals are, at least in part, passed from parent to offspring.
3. In every generation, some individuals are more successful at surviving and reproducing then others.
4. The survival and reproduction of individuals is not random; instead they are tied to the variation among individuals. The individuals with the most favorable variations, those who are better at surviving and reproducing, are naturally selected.

(Darwin 1859, 459):

Ms. O now asks students do a gallery walk and write a question or a comment on a sticky note and attach to each concept map. After the galley walk, each poster is taken down. If clarification of the concept map is needed, the group makes the necessary changes in their concept map. Ms. O then collects the concept maps and takes a photo that she uploads into an online class presentation file that the students will have access to on the class Web site. The students will add information to these posters over the next week.

This exercise is modeled after an assignment described in Passmore et al. 2013.

Ms. O assigns homework for the students to read pp 965-968 of the Bioscience paper, which is linked to the class Web site (Grant and Grant 2003). This paper is a review of the work featured in the HHMI video shown on Day 2.

Day 7-8: Explain and Elaborate: At the end of these two days, Ms. O expects students to take real data collected by the Grants and calculate ***cause and effect*** in a population of finches that have experienced a drought as well as apply the SEPs of **analyzing and interpreting data, using mathematics and computational thinking,** and **engaging in argument from evidence**.

Before class, Ms. O links the raw data in a spread sheet for each group. She downloads this from the HHMI Web site http://www.hhmi.org/biointeractive/evolution-action-data-analysis.

The lesson below is modified from the teacher and students sheets available on this website.

After students enter the room, Ms. O asks them to sit in their groups. She gives each group the same spreadsheet with the raw data gathered by the Grants and their students on Daphne Major in the Galápagos Islands. She explains the data is for wing length, body mass, and beak depth, taken from a sample of 100 medium ground finches (Geospiza fortis) living on the island of Daphne Major in the Galápagos archipelago. She projects the picture of a ground finch (shown below) so that students have a visual representation of what the bird looks like. All the finches were born between the years of 1973 and 1976. Before the students begin to look at the data, Ms. O asks a quick write question, "What do you think will happen to birds after a drought and why?" Then, Ms. O asks the students to look at the data and she asks, "Do you see any patterns in this data before you graph it? Are all the birds of similar size? What measurements seem to vary the most from individual to individual? Why do you think the sample only includes adult birds? Is there a best approach to graphing beak depth measurements?"

(Howard Hughes Medical Institute 2015)

Once students recognize that half of the measurements are from finches that died in 1977 (the year of the drought) and that half of the measurements are from finches that survived the drought, Ms. O asks them to graph the two groups on separate graphs as histograms. After the students generate their graphs, Ms. O has the students **analyze and interpret the data** and she asks them to work in pairs to complete an online form that contains the questions listed below. (She suggests that students first type their answers on a shared word document so they can look back at their answers when studying). Ms. O wants the hypotheses to use evidence from what students know about natural selection where they will **engage in argument from evidence**.

1. What observations can you make about the overall shape of each graph? (Imagine that you are drawing a line that connects the tops of the horizontal bars).
2. What do the shapes of the two graphs indicate about the distribution of beak-depth measurements in these two groups of medium ground finches?
3. Compare the distribution of beak depths between survivors and non-survivors. In your answer, include the shape of the distributions, the range of the data, and the most common measurements.
4. Based on what you saw in the film last week (it is linked to the class website if you want to refer back to it), think about how changes in the environment may have affected which birds survived the drought. Propose a hypothesis to explain differences in the distribution of beak depths between survivors and non-survivors. Use evidence from what you have learned about Natural Selection.

Ms. O has the students determine the mean and standard deviation of the wing length and body length of the survivors and non-survivors and then construct bar graphs to compare the average wing length and average body mass data between survivors and non-survivors. This extension provides an opportunity for students to **use mathematics and computational thinking.**

As a quick formative assessment she asks the following questions:

1. Are there any differences between survivors and non-survivors average wing span?
2. Are there any differences between survivors and non-survivors average body mass?
3. Back to the graphs on beak depth are there any differences between survivors and non-survivors?
4. Why do you think there are differences or if no differences, why do you think that is?
5. Which trait seems to have the most differences and what effect will that have on the finch population over time? Why?

On the second day, the students share out their results and add new information and observations to their concept map.

Day 9: **Explore and Explain:** Students will experience through a hands-on model how variation within populations can change over time due to ***cause and effect*** as well as the SEPs of **analyzing and interpreting data, using mathematics and computational thinking,** and **engaging in argument from evidence**.

Ms. O sets out two types of fabric. One half the room will have swatches of one type of fabric, and the other half will have swatches of the other type. Students will work in their assigned group of four. Each group will also receive a bag with 20 dots each of six different colors made out of construction paper that has been hole punched (red, green, yellow, blue, black, pink). She also puts a bag of additional dots at each of the stations (these have lots of each color in them, no specific number is counted). She also sets up a cloud-based class spreadsheet with color-coded columns for the students to input their data.

Ms. O welcomes the students and tells them that today half of them are going to be birds again, but this time they will all have the same beak type which will be their forefinger and their thumb. One person in the group will be the timer, another person in the group will be a producer who spreads out the colored dots from the baggie on the fabric and the other two individuals will be birds of prey. The individual who is the timer will also be the data entry person and to start with will put 20 for each color under “first generation” on the spreadsheet. When Ms. O gives the okay .the birds turn their back and the producer spreads the dots on the fabric. When the timer says GO, the two birds of prey turn around and quickly pick up dots using just their thumb and forefinger and picking up one dot at a time for 20 seconds. They place the dots into a half of a petri dish. After they are done each member of the group helps count the dots. Ms. O asks them to figure out the number of dots that are left on the fabric. She gently reminds them that this is easy to do because if the birds picked up 8 green dots then there should be 20-8 or 12 dots left on the fabric. Now using a baggie that has “extra” prey in it, the team members count out the new offspring. For every dot left on the fabric, two more dots of that color will be added. So if 12 green dots are left then they need to count out 24 more green dots. Before the next round starts, the timer enters the starting number for each color under “second generation” (for example under green they would put 36). The students repeat the actions of the first round with the producers spreading the dots on the fabric and the birds picking up dots with their forefingers and thumbs for 20 seconds. Again the team counts the dots and calculates how many dots are left, multiplies that number by three, and enters that number onto the spreadsheet as the total number for the start of “third generation” (for example, if the birds picked up 10 green dots that means there are 36-10 or 26 dots left so the beginning of the next generation would be 26 * 3 or 78). Now the students can create bar graphs of their data for each generation and **use mathematics and computational thinking** to come to a consensus on their analysis.

After all students have generated their graphs, Ms. O has them complete an online form answering the following questions which require them to **analyze and interpret the data** and **engage in argument from evidence**.

1. Which, if any, colors of paper dots survived better than others in the second- and third-generation beginning populations of paper dots?
2. What might be the reason that predators did not select these colors as much as they did other colors? Use evidence from your results and what you know about Natural Selection to support your reason.
3. What effect did capturing a particular color dot have on the numbers of that color in the following generations? How does this relate to what you know about Natural Selection?
4. How well does the class data support your team's data and conclusions? Again use evidence from your results and what you know about Natural Selection to support your reason.

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If the students run out of time, answering these questions will be homework.

Day 10: **Elaborate** This lesson has students elaborate on what they learned about Natural Selection as they apply it to selection pressures on marine organisms. They will be using one of the biology lessons from the EEI curriculum, Differential Survival of Organisms (California Education and the Environment Initiative 2011a), and observe ***patterns*** and use the SEP of **constructing explanations and designing solutions.**

Ms. O makes enough copies of the Adaptations to Selection Pressures information cards available on the EEI site http://www.calrecycle.ca.gov/eei/UnitDocs/Biology/B8a/B8aIC.pdf for every group to have a set (California Education and the Environment Initiative 2011b). She will also make up the selection pressure cards so that each group can have one (some groups will have the same card). She also sets up four slides per group in a cloud-based presentation that has a replica of the worksheet available for the students on the Web site. The slides are copies of the table shown below, one for each of the four organisms.

Once students are in their groups they will receive one of the following EEI Selection Pressure Cards. Within their groups, they will discuss the card, add their own examples, and then create a five word poster (they can use drawings and symbols but only five words, besides the title) that demonstrates the pressure and characteristics that might exist in organisms.

Selection Pressures Cards (California Education and the Environment Initiative 2011d))

Need for Energy Examples of survival traits: teeth that can grasp prey, large eyes that help find prey, sensitive noses to smell prey	Predation Examples of survival traits: speed for escaping from predators, camouflage to hide from predators, hard exoskeleton
Abiotic Environmental Factors Examples of survival traits: layers of fat to protect from cold, feathers that shed water, feet that help running through sand	Need to Reproduce Examples of survival traits: ability to sing to find mates, pouches to carry young, nest-building behavior

After asking if there are any questions or clarifications that are needed, Ms. O distributes the marine organism information cards and has each group fill in their four slides on the presentation. She will use this as an assessment of their understanding.

As an exit ticket she has all students complete one question on an online form.
"What selective pressures have led to the characteristics commonly seen in sea otters? Use evidence from Natural Selection and what you learned about today in class.”

The last exercises should be added to the concept maps. Ms. O then takes a new picture of the concept maps and re-uploads them to the class presentation Web site.

Day 11-12: **Evaluate:** Students will apply the knowledge gained during this instructional segment to the Case Study: Great Barrier Reef, Australia, presented in EEI curriculum instructional segment, Differential Survival of Organisms.

Before class, Ms. O makes copies of the readings and the questions associated with the case study which she downloaded from the EEI curriculum website http://www.californiaeei.org/curriculum/.

The case study is available in the EEI biology instructional segment, Differential Survival of Organisms (California Education and the Environment Initiative 2011c, 8–11).

Students work in small groups to read through the short case study and begin to answer the questions on the worksheet. Besides the questions on the worksheet, she also asks students to use evidence based on the activities and on what they learned for Natural Selection to their answers for number 2 and 3 full credit. Students are encouraged to create concept maps, graphs, or other supporting material for their argument.

On Day 11, students complete the worksheet and prepare their argument. Ms. O collects their responses on a collaborative document. On Day 12, each group is given three minutes to make the case for their solution. Ms. O concludes the instructional segment by having students vote on the best solution and asking students if they have any further questions or need further explanations.

Performance Expectations

HS-LS4-2- Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

HS-LS4-3- Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

HS-LS4-4- Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5- Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Science and engineering practices	**Disciplinary core ideas**	**Crosscutting concepts**
• Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions • Using Mathematics and Computational Thinking • Engaging in Argument from Evidence	• LS4.B-Natural Selection • LS4.C-Adaptation	• Patterns • Cause and effect

California's 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 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.

Vignette Debrief

The instructional plan described in this vignette was specifically designed to take into account the three dimensions of learning identified in the CA NGSS. Additionally, because of the ***cause and effect*** relationship between environmental conditions and the selection pressures that directly influence natural selection, this series of lessons provides a wide array of opportunities to reinforce students' understanding of California's Environmental Principles and Concepts (EP&C's).

Science and engineering practices. There are four practices highlighted in this vignette. The most frequently used practice is **analyzing and interpreting data,** which is applied after each hands-on activity that used data (for example, the Island Beak lab). In the finch raw data lesson, students were exposed to **using mathematics and computational thinking** that allowed them to fully analyze the data. The students were involved in **constructing explanations and designing solutions** when they participated in the dot and fabric activity as well as when they observed the selective pressure on the marine organisms. Throughout the vignette the students were asked to **engage in argument from evidence**, which is an important part of the final assessment.

Disciplinary core ideas. The main disciplinary core idea for this vignette was Natural Selection, and it was fully addressed throughout the vignette. The other DCI that was partially addressed was adaptation, especially in the EEI lesson on marine organisms.

Crosscutting concepts: the main ones discussed are ***patterns*** and cause ***and effect***. In the first engagement activity students looked for patterns in human height. There are other examples looking for ***patterns*** throughout the vignette. For ***cause and effect***, the best example is the results of the dots and fabric exercise where there is a change in population variation over time. There are other examples of ***cause and effect*** throughout the vignette.

California's Environmental Principles and Concepts. This vignette incorporates part of the EEI curriculum into the lessons and uses a case study as the final assessment for the unit. This instructional plan provides an opportunity to reinforce three of California's EP&C's, including Principle II: The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human societies; Principle II: Natural systems proceed through cycles that humans depend upon, benefit from and can alter; and, Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both. Environmental Principle II is emphasized in Day 10.

Note on technology use in the classroom: This vignette integrated many uses of technology within the daily lessons. If the students do not have one to one technology, they can use lab notebooks or index cards for quick writes and guiding questions. A teacher can ask students to put data collection into their notebook first and then for homework enter it into cloud-based spreadsheets or take the students to a computer lab the next day. Also, some teachers have access to a few computers and can use these with lab groups, eliminating the need for one to one access to technology.

References for the Vignette:

Basketball-Reference. 2015. NBA League Averages. http://www.basketball-reference.com/leagues/NBA_stats.html#stats::none (accessed July 27, 2015).

Biological Sciences Curriculum Study (BSCS). 2015. BSCS 5E Instructional Model. http://bscs.org/bscs-5e-instructional-model (accessed July 27, 2015).

California Education and the Environment Initiative. 2011a. Differential Survival of Organisms. Sacramento: Office of Education and the Environment.

California Education and the Environment Initiative. 2011b. Differential Survival of Organisms, Adaptations to Selection Pressures. Sacramento: Office of Education and the Environment. http://www.calrecycle.ca.gov/eei/UnitDocs/Biology/B8a/B8aIC.pdf (accessed November 4, 2015).

California Education and the Environment Initiative. 2011c. Differential Survival of Organisms, Student Edition, Case Study: Great Barrier Reef, Australia. Sacramento: Office of Education and the Environment. http://www.calrecycle.ca.gov/eei/UnitDocs/Biology/B8a/B8aSE.pdf (accessed November 4, 2015).

California Education and the Environment Initiative. 2011d. Differential Survival of Organisms, Teacher's Masters, Selection Pressures Cards. Sacramento: Office of Education and the Environment. http://www.calrecycle.ca.gov/eei/UnitDocs/Biology/B8a/B8aTM.pdf (accessed November 4, 2015).

Darwin, C. 1859. *On the Origins of Species by Means of Natural Selection*. London: Murray.

Grant, R.B., and P.R. Grant. 2003. "What Darwin's Finches can Teach us about the Evolutionary Origin and Regulation of Biodiversity." *Bioscience* 53 (10): 965–975.

HHMI BioInteractive. 2014. Galapagos Finch Evolution — HHMI BioInteractive Video. https://www.youtube.com/watch?v=mcM23M-CCog&feature=youtu.be (accessed July 27, 2015).

Howard Hughes Medical Institute (HHMI). 2015. BioInteractive Lesson, Evolution in Action: Data Analysis. http://www.hhmi.org/biointeractive/evolution-action-data-analysis (accessed July 27, 2015).

McLennan, Jim. 2010. "Baseball Players: Does Size Matter?" http://www.azsnakepit.com/2010/7/5/1550963/baseball-players-does-size-matter (accessed July 27, 2015).

Passmore, C., E. Coleman, J. Horton, and H. Parker. 2013. “Making Sense of Natural Selection: Developing and Using the Natural Selection Model as an Anchor for Practice and Content.” *The Science Teacher* 80 (6): 43.

A suggested cumulative project for this unit could involve students researching the importance of organ donors and how genotyping can help with successful matches being found for people who need new organs. Many individuals’ lives can be extended by receiving a new organ (such as a kidney or a heart) through organ transplants. The success of these transplants is much higher when the doctors can find a genotype match for certain traits (for example blood type) and students can discover what types of matching occurs and how it extends the life of the patients[3]. This can also be used as a way to educate students on the importance of understanding genetic variation when planning organ donations and this might be linked to instructional segment 5 through a discussion of the connection of stem cells, mitosis and use of both in organ transplants.

Linking the knowledge learned in instructional segment 3 with this instructional segment will help students draw connections to how variation exists and therefore selection can act on the population. Natural selection acts on the phenotype of an individual, for example the size of a shell or beak but in order for the selection to result in evolution, the variation needs to be heritable, linked to the alleles that result in that phenotype. The allele frequencies for the genes are ultimately what change and are passed on to the next generation. This can be **mathematically modeled** to show the trends in changes over time. Variation also has to exist in the population before selection can act. What this means is that there has to be genetic variation in beak size or shell size before any environmental change has occurred. The environmental change does not “cause” beaks or shells to get bigger or smaller. Individuals with bigger or smaller beaks or shells within the original population had to exist and those individuals who survive the selective pressure and reproduce will pass on their alleles and begin to “fill” the gene pool with the more favorable alleles.

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[3] http://www.organdonor.gov/about/data.html

These organisms are said to be “biologically fit” meaning they survive and reproduce living offspring. This is different then the modern term for “fit” which usually alludes to being strong and healthy.

Living Earth (Three Course Model) Snapshot: Human Evolution

Evolution is driven by natural selection favoring some adaptations over others. But which adaptations or selective pressures allowed our species, *homo sapiens*, to thrive while several other early hominid species died off? Mrs. B recently saw an issue of *Scientific American* (*Scientific American* September 2014) that addresses that very question. Each article offers a different argument supported by different evidence. One article focuses on specific anatomical features (*structure and function, LS1.A*), several articles on group behavior (LS2.D) including mating for life, cooperative hunting, and the power of culture, one article on information processing (LS1.D), and one article emphasizes the role of ancient climate change on evolution (ESS2.E, ESS3.D). Mrs. B assigns different students to read different articles in a classic jigsaw. When students come together, they create a collaborative presentation about their article that summarizes the argument made in the paper. Students must identify the claim, describe the evidence, and tie it all together with reasoning. The students should pay particular attention to fossil evidence (ESS1.C), which is described more in some articles than others. Then, students join together in groups with one expert on each article. Each expert presents the collaborative presentation about their article to their small group. Then, the group lays out a large sheet of butcher paper and must create a comprehensive concept map illustrating the possible explanations of how humans evolved and then tie those explanations to other key course ideas. For example, students know that the pace of present-day climate change is much faster than a climate shift 160,000 years ago that one article mentions may have been a selective pressure that favored larger brains. It's unlikely that humans or other organisms can adapt quickly enough to keep pace with modern changes happening on the scale of decades. Mrs. B emphasizes the fact that today we do not have enough evidence to distinguish between this different possibilities, but one day somebody might discover key evidence that allows us to rule out some of the possibilities or provides direct evidence of a cause and effect relationship for others. Mrs. B adds, "And the person that will make that discovery might be in this room right now…"

Connections to the CA NGSS: **Science and engineering practices** **Disciplinary core ideas** **Crosscutting concepts** Engaging in argument from evidence; Scientific Knowledge is Open to Revision in Light of New Evidence LS4.A Evidence of Common Ancestry LS4.B Natural Selection LS4.C Adaptation Cause and effect; Stability and change
Connections to the CA CCSSM: <CDE, PLEASE INSERT>
Connections to CA CCSS for ELA/Literacy: <CDE, PLEASE INSERT>
Connection to CA ELD Standards : <CDE, PLEASE INSERT>
Connections to the CA EP&Cs: none