Segment Progression: Evolution Explains Life's Unity and Diversity

Integrated Phenomenon: Faster cheetahs catch more food than slower cheetahs do.

Segment Progression: In this integrated segment, students examine how faster cheetahs are able to catch more food than slower cheetahs. Students create a model of the integrated phenomenon to explain it and revise it as they gain knowledge. To understand the phenomenon, students explore evolution's role in life's unity and diversity. First, they take a look at Darwin's theory of evolution through natural selection and observe natural selection in action. Students discover the role genes and mutations have in natural selection and evolutionary relationships. Next, students find out about forms of energy and investigate the transformations between kinetic and potential energy. Students figure out the relationships between kinetic energy, mass, and speed, and understand the potential energy in systems. In the Engineering Challenge, students design musical instruments based on the principles of energy conservation, transfer, and transformations. They then analyze what is happening in a Rube Goldberg machine, construct arguments regarding energy transformations, graph the relationship between mass and kinetic energy, investigate the relationship between kinetic energy and speed, and model energy transformations. Using what they know about diversity and energy conservation, transformation, and transfer, how will students explain why faster cheetahs catch more food than slower cheetahs?

Performance Expectations: MS-LS3-1, MS-LS4-2, MS-LS4-3, MS-LS4-4, MS-LS4-6, MS-PS3-1, MS-PS3-2, MS-PS3-5, MS-ETS1-2, MS-ETS1-4

3D Learning Sequence

Lesson *Phenomenon*	DCI	CCC	SEP	PE	Connection to Segment Phenomenon
Darwin's Theory of Evolution Through Natural Selection *Darwin found many kinds of finches with different sized and shaped beaks on the different islands of the Galápagos.*	Knowing that natural selection leads to the predominance of certain traits in a population and the suppression of others, students construct an explanation for Darwin's hypothesis that posits there was only one population of ancestor finches that had arrived to the islands of the Galápagos. (LS4.B)	Students examine why very similar finches on the Galapagos Islands have such different beaks and discover phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	Students 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-LS4-4	Natural selection occurs when individuals in a population with certain inherited traits are more likely to survive and reproduce than individuals with less favorable traits in a specific environment. Evolution is when inherited changes occur in a population over time through processes like natural selection. Over many generations, natural selection causes populations of living things to evolve traits that make populations more likely to survive and reproduce in the environment. These traits are adaptations. Students create a model of the integrated phenomenon.
Observing Natural Selection in Action *In only 2 years, the average beak size of finches on Daphne Major got almost 1mm larger.*	Students see how adaptation by natural selection acting over generations is one important process by which species change over time by examining the beak size of finches on Daphne Major, playing a natural selection hunting game, and graphing out deer traits across four generations. (LS4.C)	Students predict the changes in fish populations by applying cause and effect relationships in cichlid sexual selection.	Students plan and carry out investigations that uses guppies in identifying the role of camouflage as a selective advantage in a predation situation.	MS-LS4-6	When some traits help individuals in a population live longer than other individuals without that trait in a population, the ones that live longer have more chances to reproduce and pass the trait on to their offspring. Running faster to catch more prey will give animals more energy to help them survive longer, so they can have more chances to reproduce and pass their running speed on to offspring.

Genes and Natural Selection *Lovebirds in captivity have unique colorations not found in the wild population.*	Observing how captive lovebirds have more variety in color than populations in the wild, students find out how genetic mutations result in changes to proteins which can change traits. (LS3.A) (LS3.B)	Examining cause and effect relationships, students get a better look at mutations as they analyze lab results of bacterial plates gaining antibiotic resistance.	Students develop a model of genes, proteins, and genetic mutations by making paper airplanes to show how genetic mutations can change an organism's traits and function.	MS-LS3-1 MS-LS4-4	Genes are instructions for building proteins, which make up the structures of organisms, or their traits. An allele is a specific form of a gene. A mutation is a random change to an organism's DNA. Sometimes mutations change proteins in ways that are beneficial, but sometimes they are harmful or neutral. A cheetah with bigger leg muscles might run faster, catch more food, survive longer, and have more offspring.
Evolutionary Relationships *Crayfish, spiders, and dragonflies may seem very different at first glance, but they have many similarities.*	Students compare embryological development of different species to reveal similarities as they collect data and then create a poster detailing the patterns in anatomical structures they found in various embryonic organisms. (LS4.A)	Students discover how to find patterns in morphology that illustrate the similarities between crayfish, spiders, and dragonflies to understand the evolutionary relationships between different organisms.	Students apply scientific principles to construct an explanation for real-world phenomena as they categorize modern-day organisms to find commonalities that indicate the organisms share a common ancestor.	MS-LS4-2 MS-LS4-3	A species is a group of living things that share traits and can breed successfully with one another but not other groups. Since all cheetahs are one species, any cheetah can mate with other cheetahs regardless of how fast they run.
Performance Assessment	Students explore evidence of common ancestry and diversity as they complete an organism comparison chart used to compare physical features of whales to those of other ocean organisms.	Students use a diagram to identify patterns and traits of land-dwelling mammals to reveal which modern-day animal is the closest living relative to the whale.	To construct an explanation that describes phenomenon, students gather data about whales and use that data to construct an argument.	MS-LS3-1 MS-LS4-2 MS-LS4-3 MS-LS4-4 MS-LS4-6	How is Darwin's Theory of Natural Selection related to adaptations? Could the ability to run faster to catch more prey impact an animal's ability to survive? What might happen if a mutation caused a cheetah to have bigger leg muscles? Are cheetahs that can run fast only able to mate with other cheetahs that can run fast? Students should review their answers to these questions to summarize their findings and make revisions to their model of the integrated phenomenon.

Forms of Energy *A pendulum boat ride cannot swing forever under the force of gravity.*	Students observe a pendulum boat ride and use their knowledge of conservation of energy and energy transfer to determine what happens to the energy of the pendulum as a result of friction and gravity. (PS3.A) (PS3.B) (PS3.C)	Understanding that models can be used to represent systems and their interactions, students model kinetic energy transfers by using drawings and analyzing situations where energy changes, but is always conserved.	Students relate energy to forces as they examine potential energy and kinetic energy and develop a model to demonstrate the forces.	MS-PS3-2 MS-PS3-5	Energy is the ability to cause motion or change. Food has stored energy. When you digest food, the energy is released and your body uses this energy to do things like breathe and move around. Energy is not made of matter, but all matter has energy. The form of energy stored in a system due to the positions of objects interacting at a distance is potential energy. Kinetic energy is the energy an object has due to its motion. Moving cheetahs have kinetic energy because they have the ability to move another object and cause it to move or change.
Measuring Kinetic Energy *A wrecking ball causes more damage when it's bigger or swung from further away.*	Students watch a video of a wrecking ball and consider what factors affect how hard it hits an object by examining how kinetic energy is proportional to the mass of the moving object and grows with the square of its speed. (PS3.A) (ETS1.B) (ETS1.C)	Students graph the relationships between kinetic energy and mass as well as kinetic energy and speed. Students then determine whether these relationships are proportional, linear, both, or neither by understanding how proportional relationships among different types of quantities provide information about the magnitude of properties and processes.	Students watch demonstrations and videos to observe how kinetic energy relates to mass and speed. Students then make predictions about how changes in mass or speed affect kinetic energy. Students develop and test wrecking ball models to see how mass and speed affect kinetic energy.	MS-PS3-1 MS-ETS1-4	Objects with greater mass have greater kinetic energy when moving at the same speed. Objects of the same mass with greater speed have more kinetic energy. Of two cheetahs the same size, the faster one has greater kinetic energy.

Potential Energy in Systems *A firework transforms from a small, cardboard-covered object to a large explosion of fire in the sky.*	How does a firework transform from a cardboard-covered object to a ball of fire in the sky? Students consider the types of potential energy involved in fireworks as they explore the relationship between energy and forces. (PS3.A) (ETS1.B) (PS3.C)	Understanding that models can be used to represent systems and their interactions, students investigate a skate park simulation to understand gravitational potential energy. They give short presentations to demonstrate the relationships between potential energy, distance above the ground, and mass.	Students develop and use a model by using simple objects to represent electric charges and electric forces. They think about what happens to potential energy when they push objects closer together or pull them apart. Students also model other forms of potential energy and energy conversions through hands-on experiments at stations.	MS-PS3-2 MS-ETS1-2	Food has chemical potential energy, which is energy stored in the chemical bonds that hold atoms and molecules together. Because of the properties of the atoms and molecules involved, chemical potential energy is a combination of kinetic energy, electric potential energy, and magnetic potential energy. Chemical potential energy can be released when bonds holding matter together are broken. When a cheetah digests food, the chemical bonds are broken and the chemical potential energy is released. The cheetah then uses the released energy to move.
Engineering Challenge *Design musical instruments based on principles of energy conservation, transfer, and transformation.*	Students are tasked with designing a simple instrument as part of a community service project. Students define the problem and then come up with the criteria and constraints. They also create a rubric for evaluating one anothers' designs. (ETS1.B) (ETS1.A)		Students design and construct a musical instrument. They perform the use of the instrument and describe the transformations and transfers of energy. Students evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	MS-ETS1-1 MS-ETS1-2	Students review the principles of energy conservation, transfer, and transformation by creating a musical instrument.

Performance Assessment	Understanding that when the motion energy of an object changes, there is inevitably some other change in energy at the same time, students act as research physicists studying energy and explain how a small action in a Rube Goldberg machine causes a chain reaction of effects.	Students visit stations that represent systems and their interactions to record information and identify gravitational potential energy. At each station, students draw logical connections between the video and their understanding of the scientific principles.	Students develop a model to describe unobservable mechanisms by drawing diagrams of gravitational potential energy and magnetic potential energy.	MS-PS3-1 MS-PS3-2 MS-PS3-5	What kind of energy is present in a cheetah that is moving very fast? If one cheetah runs faster than another cheetah the same size, which has greater kinetic energy? How do cheetahs use the potential energy in food? Answering these questions helps students to summarize their findings and make the final revisions to their model. Students use their completed model to support their explanation of the integrated phenomenon.

Integrated Phenomenon:

Faster cheetahs catch more food than slower cheetahs do.

Sample Explanation:

These faster cheetahs are more likely to survive and reproduce, so eventually the cheetah population will evolve faster running. Food stores chemical potential energy that can be released when digested and then used for moving around. When animals get more food, they have more energy to move quickly and this helps them survive longer. Organisms that live longer have more opportunities to mate. Cheetahs with more energy to survive longer will have more opportunities to reproduce. Traits form from proteins that are made based on the instructions found in genes. Since genes are inherited, all the cheetah offspring of the faster cheetahs will also be able to run faster (as long as running speed is an inherited trait).