UNIFYING THEMES FOR RECOMMENDED SEQUENCES: CROSSCUTTING CONCEPTS

The crosscutting concepts in the NGSS provide a new sensemaking tool for students. They are the explicit unifying themes or big ideas across the sciences that allow students to construct a framework for connecting ideas that may seem unrelated. They provide a window into how scientists and engineers make sense of the natural world, and how they frame the questions they ask and problems they address. As the authors of *A Framework for K–12 Science Education* stated:

> These concepts should become common and familiar touchstones across the disciplines and grade levels. Explicit reference to the concepts, as well as their emergence in multiple disciplinary contexts, can help students develop a cumulative, coherent, and usable understanding of science and engineering. (NAS, 2012, p. 83).

If you opt to utilize these unifying themes based on crosscutting concepts for the recommended sequences, at the end of this document are student-friendly introductions to these themes: Grade 6: Energy and Matter, Grade 7: Systems and System Models, and Grade 8: Scale, Proportion, and Quantity. You may wish to provide these introductions either electronically or as handouts for students to incorporate into their science notebooks.

GRADE 6: ENERGY AND MATTER

The crosscutting concept of energy and matter: flows, cycles, and conservation provides a lens for integrating units in the recommended sequence for Grade 6. An understanding of energy and matter, and how they behave, can help us develop explanations for many phenomena across the life, earth, and physical sciences. While all of the crosscutting concepts are embedded throughout the individual units, energy and matter emerges as a theme that unifies the entire program.

In Land, Water, and Human Interactions, students explore how energy drives the paired processes of erosion and deposition of earth material, often resulting in the movement of sediment that creates new landforms or modifies existing ones. Energy also drives the flow of water in rivers and streams, as well as the water cycle. Human activity can impact these processes in several ways. For example, human activity such as farming may unintentionally add matter in the form of fertilizer into rivers and streams. This matter can then be carried downstream by gravity, causing problems farther away. Human activity such as building on a hillside may result in increased erosion and damage to soil and structures, especially during periods of heavy rain. Paying attention to the flow of energy and matter that results from erosion and deposition can help people make wiser choices about how to interact with land and water.

In Energy, students expand their understanding of energy transformations and transfers. They learn that there are two categories of energy: potential and kinetic. In particular, they learn about transfers and transformations involving thermal energy, a particular type of kinetic energy. Understanding thermal energy transfer can explain many phenomena and lead to practical applications, such as reducing the use of energy resources. Students explicitly explore energy and matter as a crosscutting concept by learning how many kinds of scientists, including ecologists, cell biologists, and meteorologists, track energy flows as they construct explanations for phenomena. Students apply what they learn about energy transfer and transformations to engineer a device—a solar heater—that maximizes solar energy transfer.

In Weather and Climate, students analyze patterns related to weather and climate—processes that are driven by the flow of energy, especially thermal energy. They investigate how an increase in the flow of thermal energy affects the frequency and severity of weather-related events and how climates around the world are being affected by the increase in the thermal energy of the oceans and atmosphere. In addition, students examine data to determine the causes of global warming as they consider how the phenomenon may be linked to human activity. Finally, students assume the roles of different types of scientists as they analyze and interpret data for an urban community. They determine whether there is evidence that humans are affecting the water resources, atmospheric composition, and climate related to the community before making recommendations for mitigation.

In Body Systems, students begin to explore concepts involving energy and matter in the life sciences. They explore the crosscutting concept of energy and matter across human body systems. The transfer of energy and matter drives fundamental biological processes, including those that keep the human body stable and functioning properly. Students investigate the processes used by the body to obtain and use energy and matter from food. For example, they consider the role of the digestive system in the breakdown of food, the role of the respiratory system in providing oxygen needed for cellular respiration, and the role of the circulatory system in carrying oxygen and the products of digestion to cells throughout the body. They also consider the needs of all organs and tissues, such as muscle and nervous tissue, for the matter and energy provided by these processes.

Finally, in From Cells to Organisms, students learn that the transformation of energy and the restructuring of matter required by all living organisms happen at the cellular level. They investigate the role of plants in transforming energy from the sun into chemical energy stored in food, and the role of cellular respiration in both plants and animals in releasing energy stored in food into a form usable by tissues throughout the body. Students use models to track matter and energy supplied by food from the level of the digestive system to individual cells and to examine how the matter and energy are used within cells to synthesize proteins and other molecules needed for growth.

GRADE 7: SYSTEMS AND SYSTEM MODELS

The crosscutting concept of systems and system models provides a lens for integrating units in the recommended sequence for Grade 7. An understanding of systems and system models can help us develop explanations for many phenomena across the life, earth, and physical sciences. While all of the crosscutting concepts are embedded throughout the individual units, systems and system models emerges as a theme that unifies the entire program.

In Ecology, students explore ecosystems, which are systems of interacting biotic and abiotic components. They learn how species interact with other species in the system, and how matter cycles within and energy flows through an ecosystem. Students investigate how the introduction of a new component—an invasive species—can affect all the interactions in the system. They consider design solutions to control or remove invasive species to restore the functioning of the system. In choosing the optimal solution, students realize that they must explicitly define all components in the ecosystem that might be affected by their choices. Failing to account for the entire system may result in harmful, unintended outcomes.

In Geological Processes, students investigate Earth systems, focusing largely on the system of moving lithospheric plates that make up Earth's surface. They explore how components of this system interact to result in changes to Earth's surface at varying time and spatial scales. Students use and develop system models to understand how the various components of the system interact to result in observable changes, such as earthquakes and volcanic eruptions. Students use their understanding of these systems to predict where and when earthquakes and volcanic activity are likely to take place. Additionally, students use system models to learn how system interactions on and below Earth's surface result in the formation of rock and valuable natural resources. Students also consider how other systems interact with Earth's surface, such as how water seeps below ground and collects in aquifers.

In Chemistry of Materials, students learn about the properties of materials that make them more suitable for certain purposes. They learn that acquiring the raw materials to manufacture products can impact the environment, as can disposal of the by-products from the chemical manufacturing process. When considering the entire life cycle of a product, students learn that they need to consider the entire system, from acquiring material resources, to making, using, and disposal of the product to predict the product's impact on the environment. Systems, subsystems, and systems modeling approaches can also be used as a lens for exploring energy transfers as substances change state.

In Chemical Reactions, students develop simple molecular models to describe chemical reactions. They use these models to build an understanding of the conservation of atoms as the basis for the conservation of mass. This challenging concept is made more apparent by adopting a systems approach. The importance of considering whether a chemical system behaves as an open or closed system is introduced. Failure to recognize the boundaries of a system can lead to the misconception that matter can be created or destroyed, especially in situations where one or more reactants or products of a reaction are gases. Students also investigate chemical reactions that involve energy changes. A systems and systems model approach is a lens for understanding the transfers of energy involved in chemical processes.

In Reproduction, students examine sexual and asexual reproduction in plants and animals and how genes are passed down from parents to offspring. They explore how genes become traits that can be observed in organisms. They also investigate how behavior traits in animals and plant-animal interactions affect the probability of successful reproduction. All of these biological processes involve highly organized systems of precise and reliable interactions of components within the systems. When there are disruptions to the components or interactions, the processes may no longer function properly. For example, students explore how a mutation (a change in one component of a system) can lead to changes in a trait (changes in other components in the system). In another example, the flowers of some plants (part of a plant's reproductive system) have traits whose functions are to attract animal pollinators, increasing the boundary of their reproductive system to include animals.

Finally, in Biomedical Engineering, students explore engineering solutions to biomedical problems. Students apply the engineering design cycle to design, test, and then make improvements to artificial heart valves. Their designs are systems with components that must interact in a way to meet the criteria. When determining whether a design is successful, such as for a prosthetic leg, engineers must consider how the device must interact within a larger system. If the person using the prosthetic leg is a child, engineers' criteria might be very different than if the person is an Olympic athlete, in part because the child and Olympian interact with their environments in very different ways.

GRADE 8: SCALE, PROPORTION, AND QUANTITY

The crosscutting concept of scale, proportion, and quantity provides a lens for integrating units in the recommended sequence for Grade 8. An understanding of scale, proportion, and quantity can help us students develop explanations for many phenomena across the life, earth, and physical sciences. While all of the crosscutting concepts are embedded throughout the individual units, scale, proportion, and quantity emerges as a theme that unifies the entire program.

In Evolution, students examine evidence for evolution occurring over time scales from days to billions of years. They learn that natural selection leads to certain traits becoming proportionally higher in frequency and others proportionally lower in frequency in a population over time, depending on the environment. Students learn that when changes in populations continue over long periods of time, from thousands to millions of years, there may be enough change for the populations to be considered one or more new species. Students discover that currently there are an estimated 10 million species on Earth, but the vast majority of species that have ever existed have gone extinct—as many as 5 billion. Extinction rates have not been steady over time. Scientists have identified five major extinction events, with the first one occurring over 440 million years ago. Students evaluate evidence for whether the current rate of extinction represents a sixth extinction event.

In Earth's Resources, students investigate resources found on or below Earth's surface. They learn that it has taken millions of years for some of these resources to form, so they are non-renewable at time scales helpful to people. Students explore where Earth's resources are found across the globe and discover that resources are not distributed evenly. Some places are much more or less like to have a resource based on the history of Earth's processes. For example, copper is found in locations where two lithospheric plates collide. Students consider how human use of these resources has changed over time, and how the quantity of resources being used today is greater than it has ever been because of the growing size of the human population and the growing quantity of resources being used by each person.

In Solar System and Beyond, students use models to explain phenomena that occur at a scale far too large to examine directly, from the Earth–moon system to the solar system and beyond. To help students conceptualize the sizes of planets and the vast distances between them, students create their own scale models of the solar system. Students also investigate relative sizes of objects in the universe, from asteroids to galaxies. The magnitude and reach of gravity is also considered as students investigate how the motions of planets, stars, and solar systems can all be explained by this phenomenon.

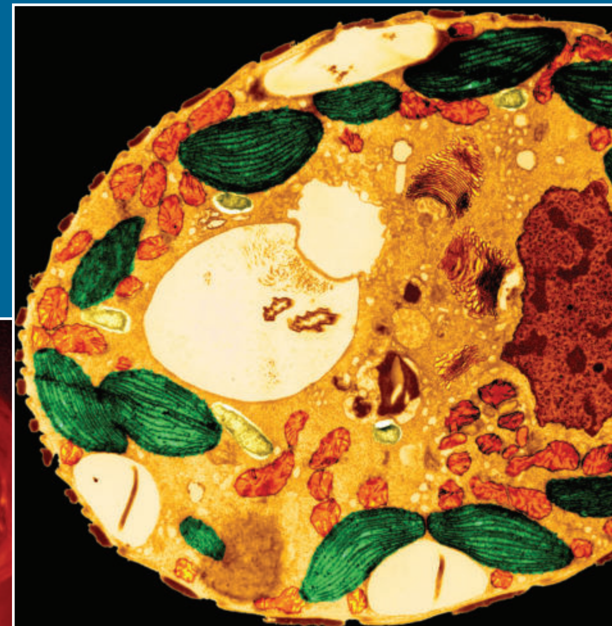
In Force and Motion, students investigate how both mass and speed are related to kinetic energy. They learn that kinetic energy is directly proportional to an object's mass and to the square of its speed. Students consider how speed and mass affect the risk and severity of a vehicle collision. Students learn that as the kinetic energy of a vehicle increases, more force is required to stop the vehicle. Students learn about the proportional relationship between force, mass, and acceleration. While students model collisions and energy transfers in the classroom, they also consider the masses of vehicles commonly found on roads and the relative amounts of force needed to stop those vehicles. This real-world context helps students understand how the proportional relationships investigated in the classroom apply at the scales of the real world.

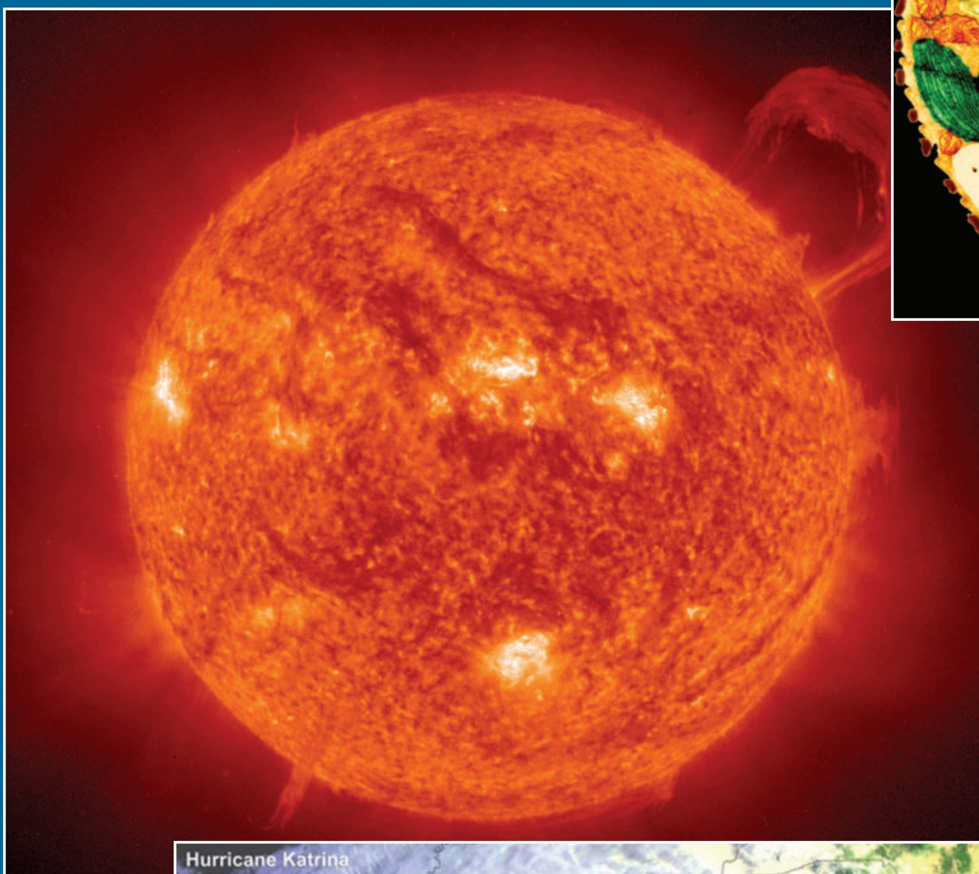
In Fields and Interactions, students explore fields that affect objects even when they are vast distances apart, and then use their understanding to design transportation solutions. Students consider how some fields, like electric fields and magnetic fields, can affect objects at small scales, whereas gravity is responsible for motions of objects out in space. To understand the mechanisms underlying electric fields, students use computer models to explore electric charges at microscopic scales. While students are able to easily observe the macroscopic effects of the fields covered in this unit, they are provided with opportunities to learn how the phenomena are caused by fundamental properties of matter that exist on much smaller scales. Students also consider the proportional strength of the different fields relative to one another as they create systems where an object with mass, interacting with gravity, is being lifted through interactions between magnetic fields.

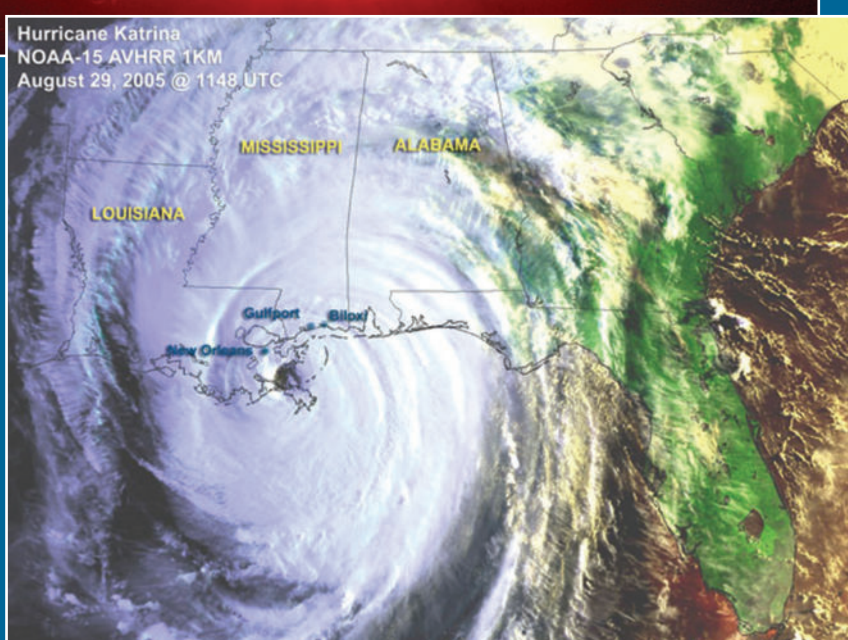
Finally, in Waves, students investigate how waves, which range in scale (wavelength) from longer than a building to shorter than an atom, can transfer energy and transmit information. Students investigate the proportional relationship between energy and the square of the amplitude of a wave. The proportional relationship between the energy and frequency of electromagnetic waves is also introduced. Students learn that the wavelength of visible light determines its color, and the wavelength of sound determines its pitch. Students use macroscopic tools to model wave motion to better understand wave properties. They then apply this understanding to phenomena they aren't able to directly observe with the understanding that the proportional relationships they discovered at the macroscale hold at smaller scales.

The pages that follow are the student-friendly introductions to the unifying themes and are ideal for printing to add to student notebooks. The last 3 pages of this document are full page spreads of the same introductions, ideal for displaying digitally.

Introduction to Grade 6: Energy and Matter



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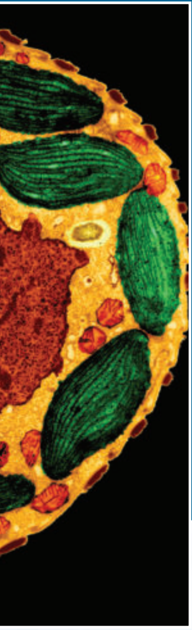
Biloxi
New Orleans



Energy and Matter: Flows, Cycles, and Conservation

The crosscutting concept of energy and matter provides a lens for integrating units in the recommended sequence for Grade 6. This lens is used to explore phenomena across earth, physical, and life sciences.

In Land, Water, and Human Interactions, you will investigate phenomena related to energy and matter flows on land and in water, and how humans impact these flows on small and large scales.

In Energy, you will deepen your understanding of energy transfers and transformations, and engineer a device to maximize solar energy transfer.

In Weather and Climate, you will examine data on weather and climate phenomena that are driven by thermal energy flows.

In Body Systems, you will explore how energy and matter drive all life processes, including those that fuel the human body.

Finally, in From Cells to Organisms, you will investigate the transfer and transformation of energy at the cellular level—processes that are universal to all life.

Tracking the flow of energy and matter into, out of, and within systems helps scientists develop explanations for phenomena and find solutions to issues and problems.

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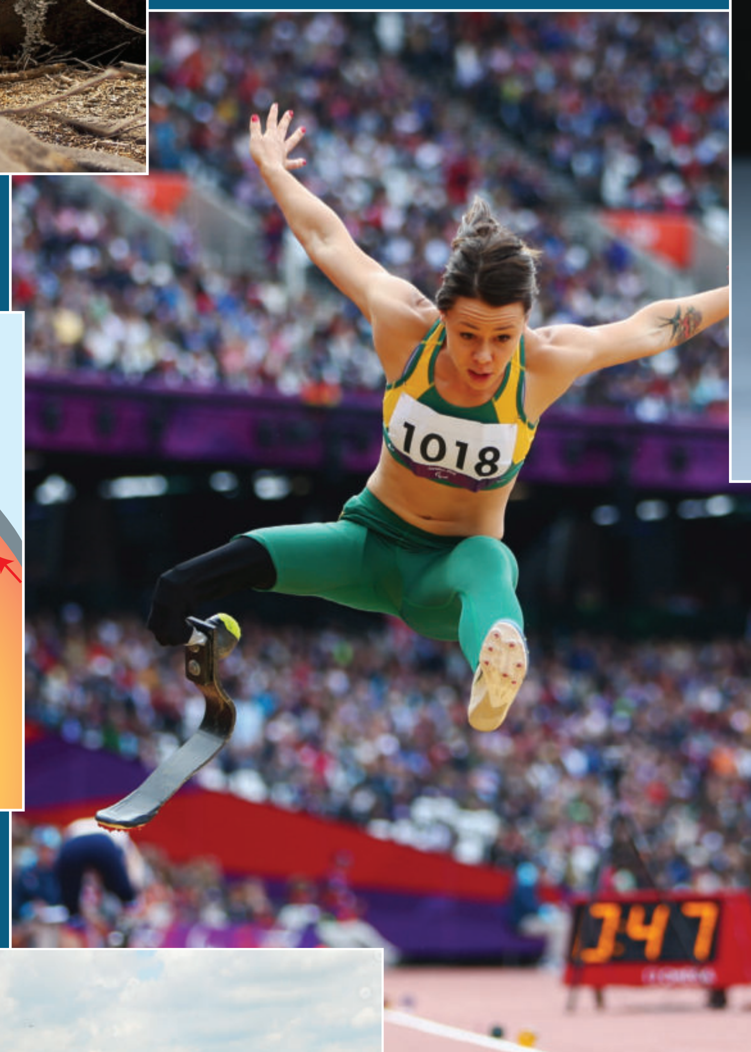
Introduction to Grade 7: Systems and System Models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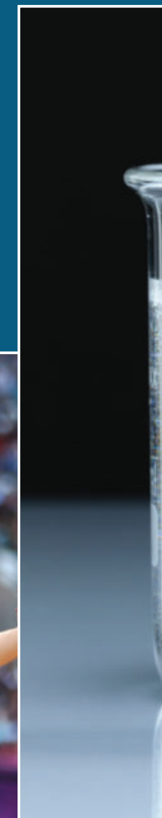

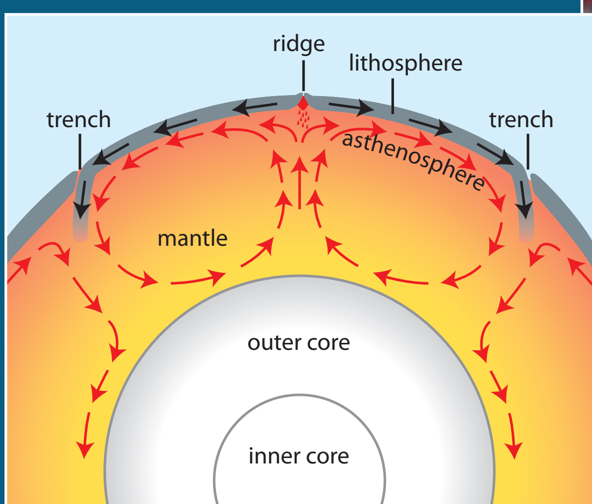
ridge
lithosphere
trench
trench
asthenosphere
mantle
outer core
inner core

Systems and System Models

The crosscutting concept of systems and system models provides a lens for integrating units in the recommended sequence for Grade 7. This lens is used to explore phenomena across earth, physical, and life sciences.

In Ecology, you will investigate ecosystems, which are systems of interacting living and nonliving components, and explore the impact that humans can have on these systems.

In Geological Processes, you will explore earth systems, especially the system of moving plates that can lead to natural hazards like earthquakes and volcanoes.

In Chemistry of Materials, you will learn how the production and disposal of materials may impact the larger environmental system.

In Chemical Reactions, you will investigate changes in matter during chemical reactions, which requires you to understand open versus closed systems.

In Reproduction, you will investigate systems of reproduction in plants and animals, and consider what happens when these systems are disrupted.

Finally, in Biomedical Engineering, you will engineer a device to solve a medical problem. This requires you to understand how this device fits into the human body system.

Understanding systems and developing models of systems help scientists and engineers develop explanations for phenomena and find solutions to issues and problems.

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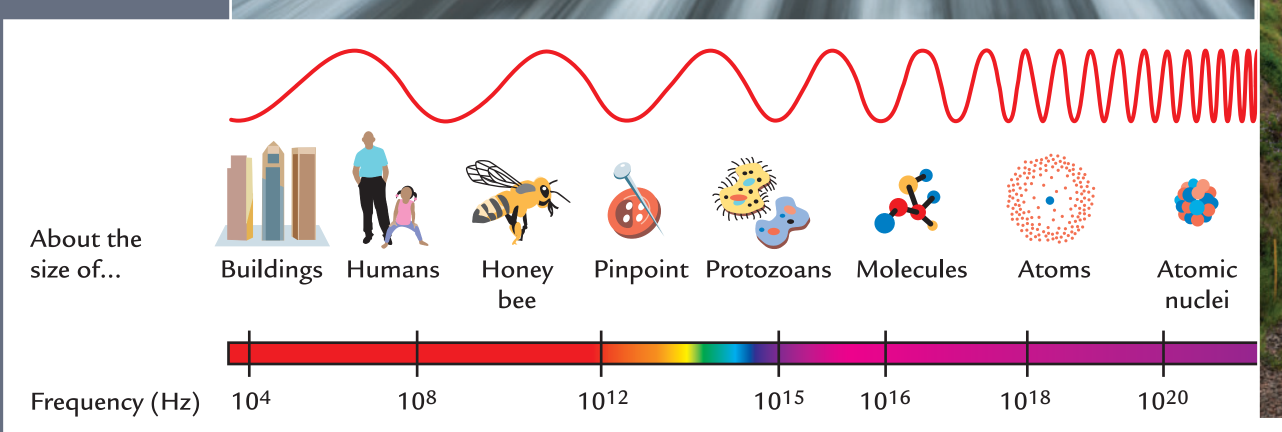
Introduction to Grade 8:
Scale, Proportion, and Quantity


About the size of...
Buildings
Humans
Honey bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic nuclei
Frequency (Hz)
10^4
10^8
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}

Scale, Proportion, and Quantity

The crosscutting concept of scale, proportion, and quantity provides a lens for integrating units in the recommended sequence for Grade 8. This lens is used to explore phenomena across earth, space, physical, and life sciences.

In Evolution, you examine evidence for evolution occurring over time scales from years to billions of years, and you explore the vast number of current and past life forms.

In Earth's Resources, you explore where earth's resources are found across the Earth, the millions of years it takes some resources to form, and the rate at which humans use these resources.

In Solar System and Beyond, you use models to explain phenomena that occur at a scale far too large to examine directly, from the earth-moon system to the solar system and beyond.

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Finally, in Waves, you investigate how waves, which that range in wavelength from longer than a building to shorter than an atom, can transfer energy and transmit information.

Examining phenomena related to objects and interactions at a wide range of scales—from molecules in genes to gravitational fields that operate beyond the solar system, and from those that happen in an instant to those that take billions of years—will help you develop explanations and find solutions to issues and problems.

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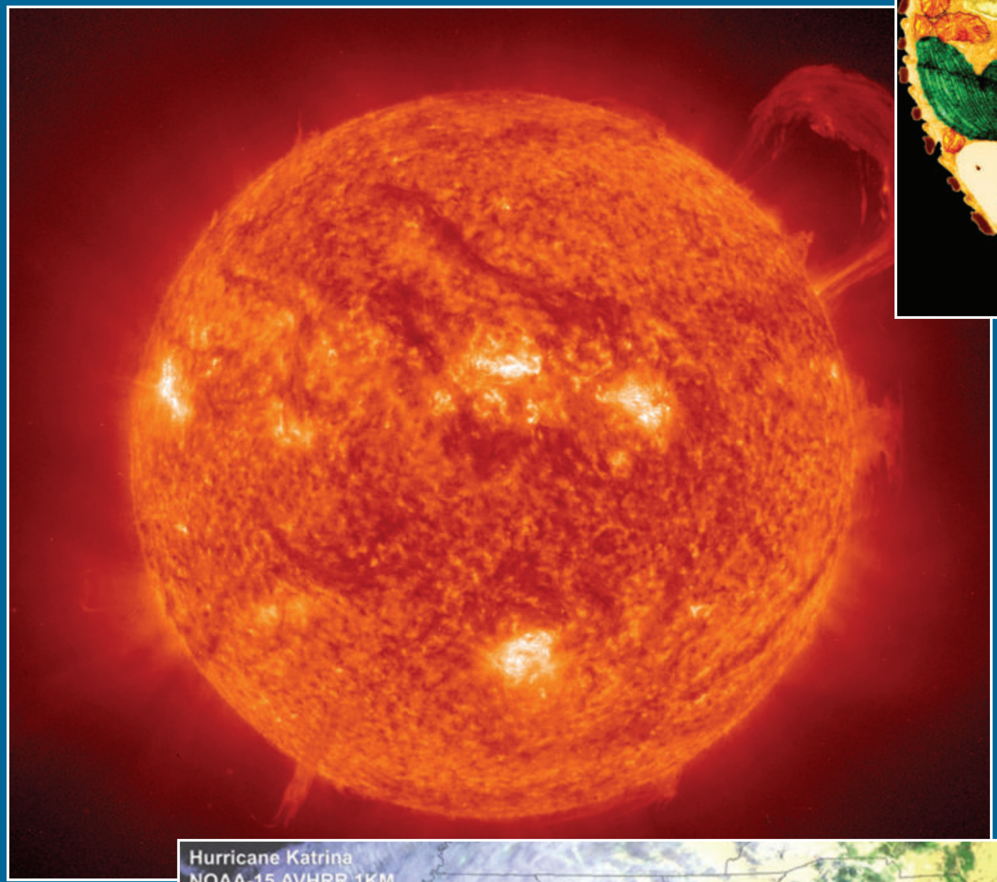

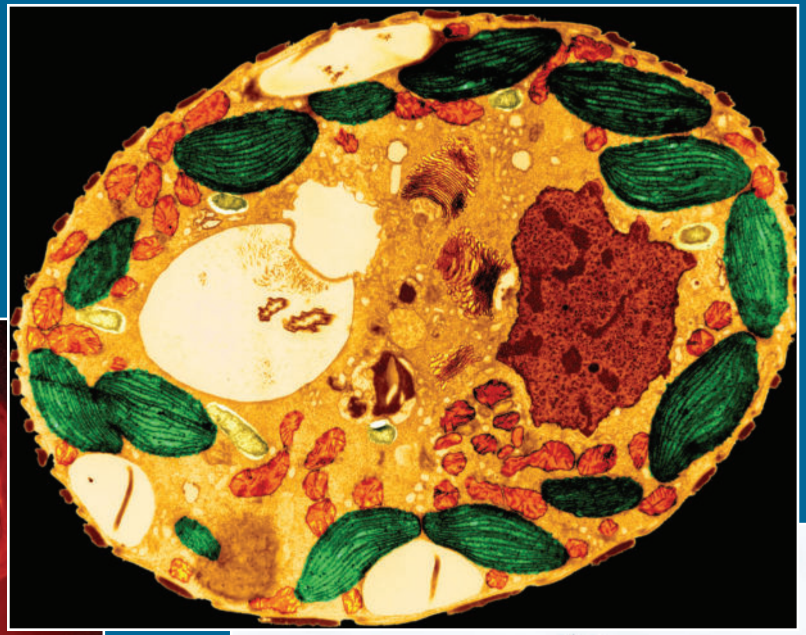

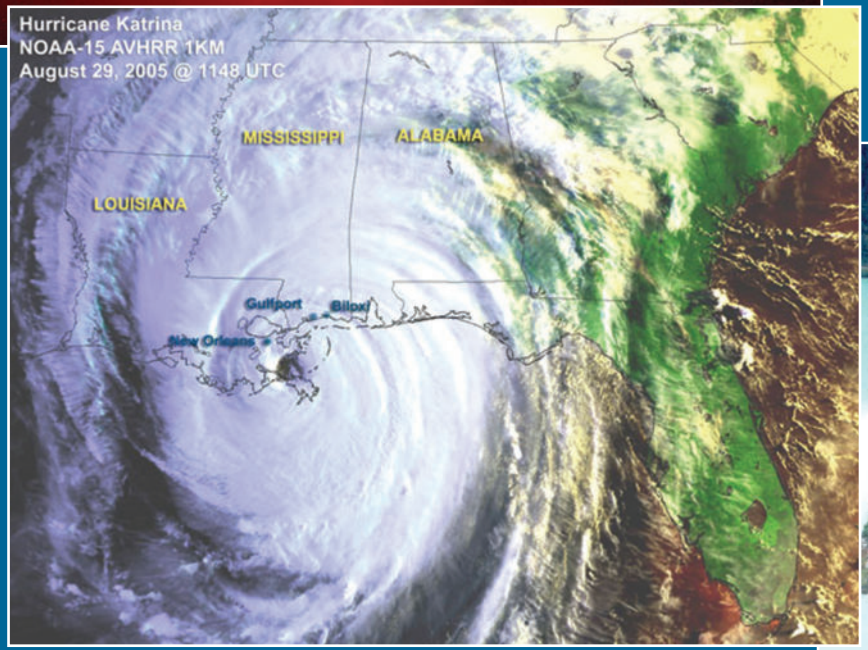

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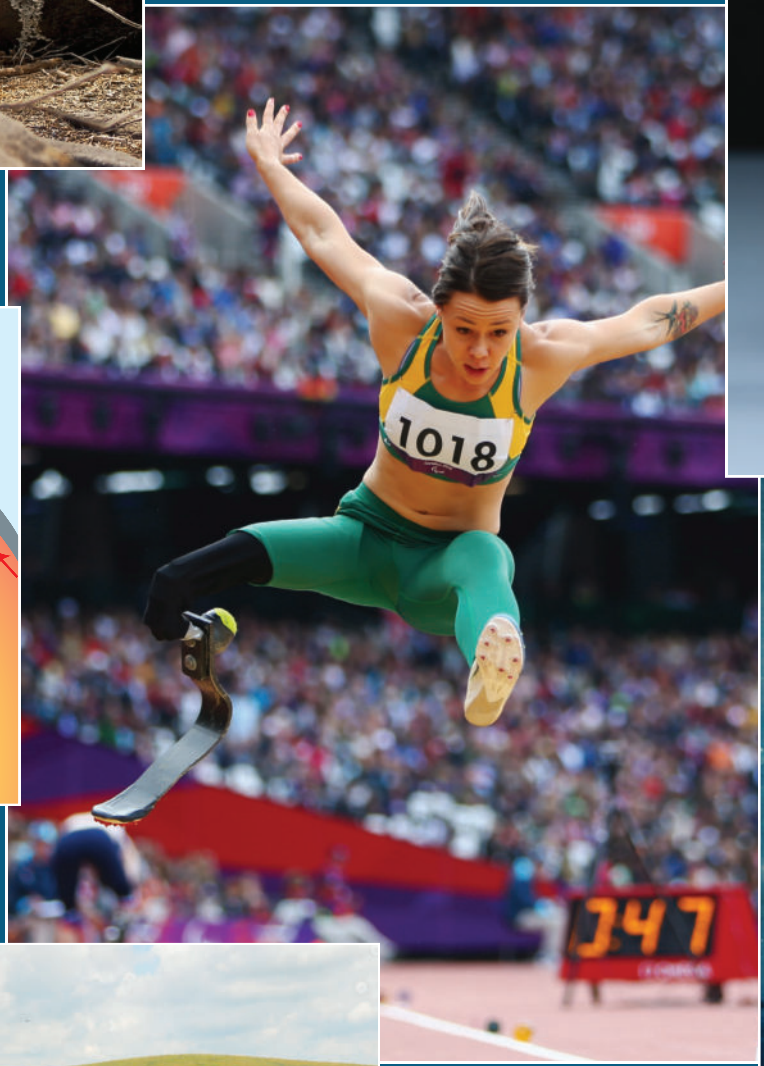

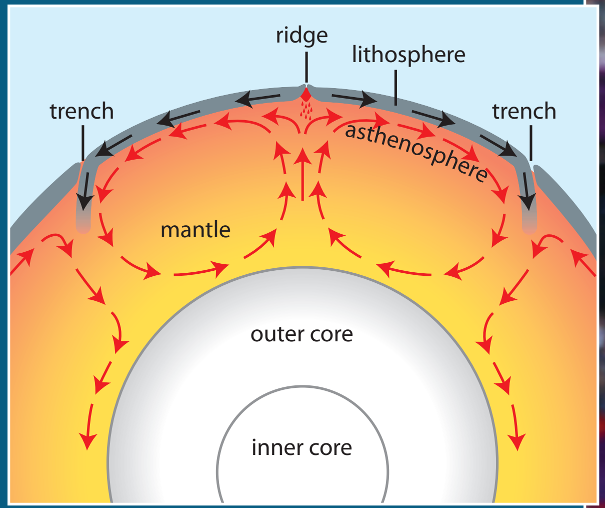

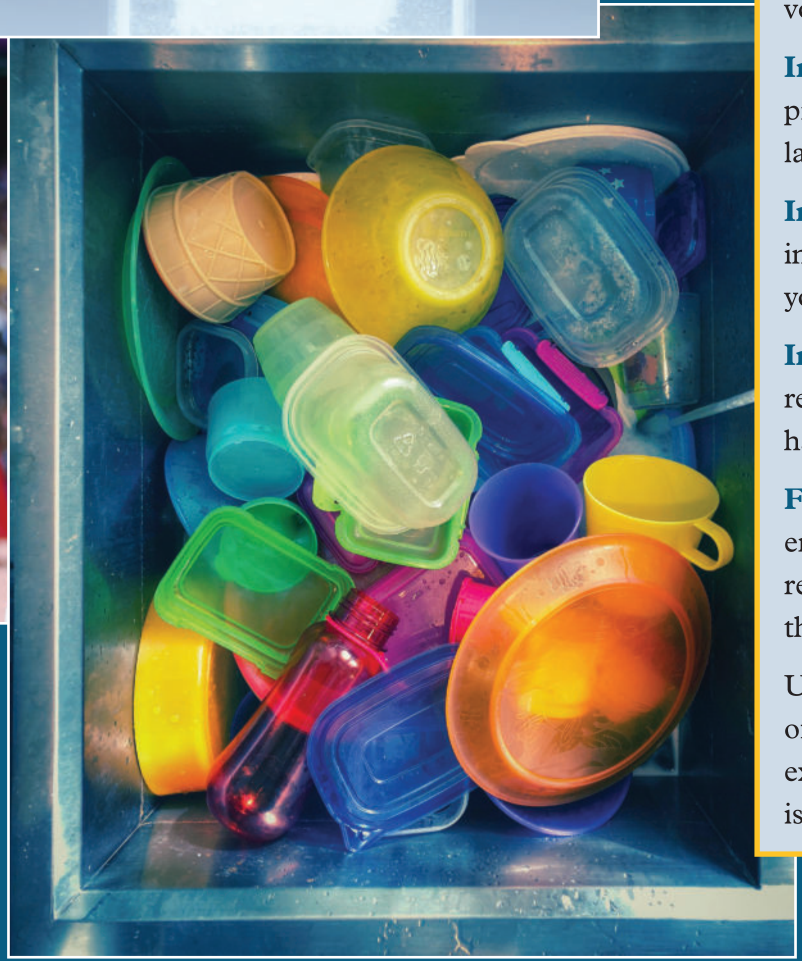

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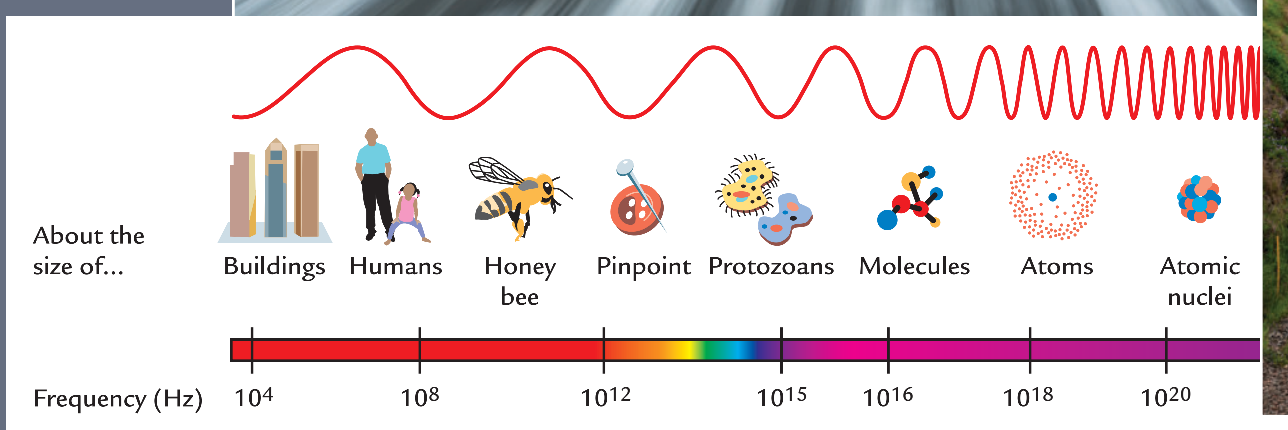

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