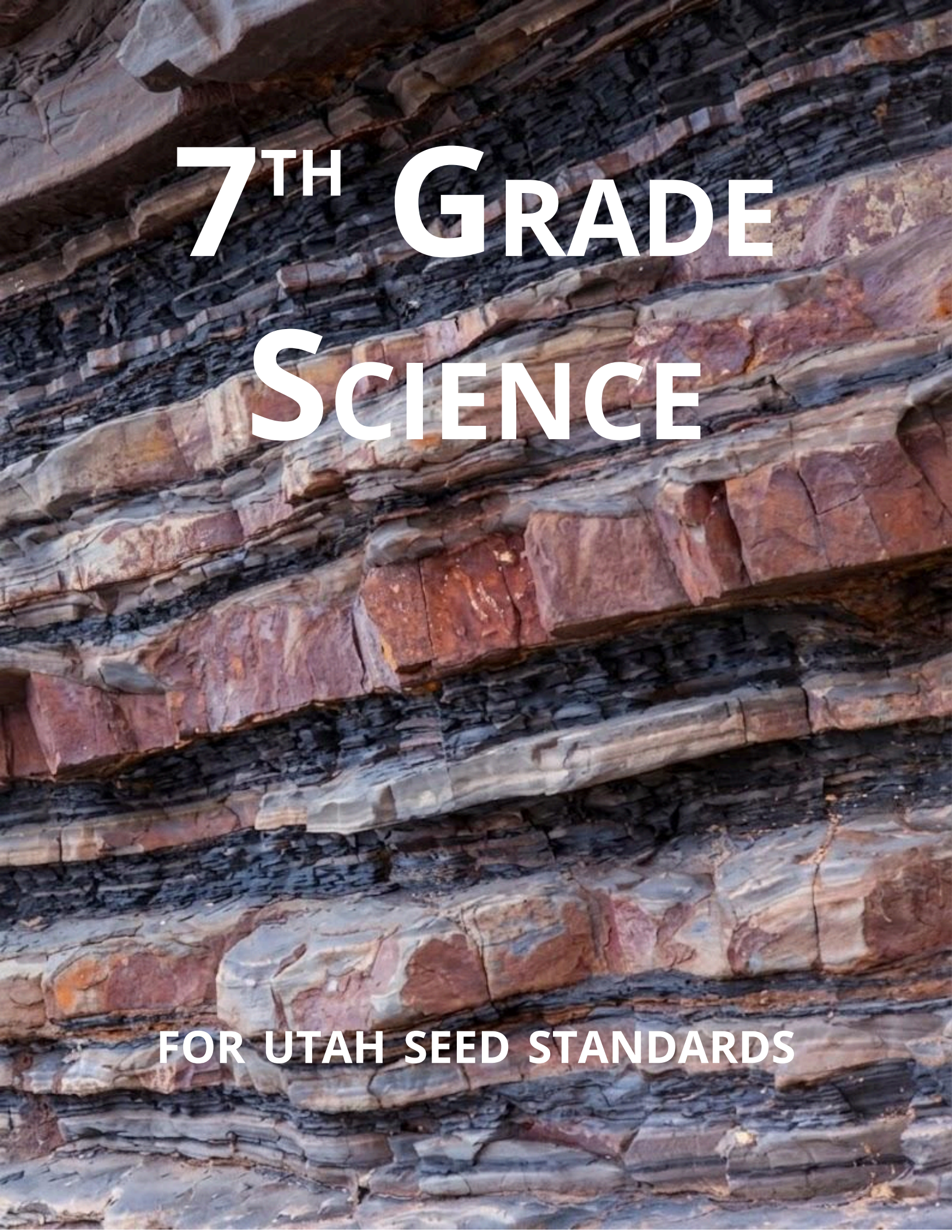




7TH GRADE SCIENCE

FOR UTAH SEED STANDARDS

7th Grade

for Utah SEEd Standards

Revised 2025

Utah State Board of Education OER

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We especially wish to thank the amazing Utah science teachers whose collaborative efforts made the book possible. Thank you for your commitment to science education and Utah students!

Students as Scientists

What does science look and feel like?

If you're reading this book, either as a student or a teacher, you're going to be digging into the "practice" of science. Probably, someone, somewhere, has made you think about this before, and so you've probably already had a chance to imagine the possibilities. Who do you picture doing science? What do they look like? What are they doing?

Often when we ask people to imagine this, they draw or describe people with lab coats, people with crazy hair, beakers and flasks of weird looking liquids that are bubbling and frothing. Maybe there's even an explosion. Let's be honest: Some scientists do look like this, or they look like other stereotypes: people readied with their pocket protectors and calculators, figuring out how to launch a rocket into orbit. Or maybe what comes to mind is a list of steps that you might have to check off for your science fair project to be judged; or, maybe a graph or data table with lots of numbers comes to mind.

So let's start over. When you imagine graphs and tables, lab coats and calculators, is that what you love? If this describes you, that's great. But if it doesn't, and that's probably true for many of us, then go ahead and dump that image of science. It's useless because it isn't you. Instead, picture yourself as a maker and doer of science. The fact is, we need scientists and citizens like you, whoever you are, because we need all of the ideas, perspectives, and creative thinkers. This includes you.

Scientists wander in the woods. They dig in the dirt and chip at rocks. They peer through microscopes. They read. They play with tubes and pipes in the aisles of a hardware store to see what kinds of sounds they can make with them. They daydream and imagine. They count and measure and predict. They stare at the rock faces in the mountains and imagine how those came to be. They dance. They draw and write and write and write some more.

Scientists — and this includes all of us who do, use, apply, or think about science — don't fit a certain stereotype. What really sets us apart as humans is not just that we know and do things, but that we wonder and make sense of our world. We do this in many ways, through painting, religion, music, culture, poetry, and, most especially, science. Science isn't just a method or a collection of things we know. It's a uniquely human practice of wondering about and creating explanations for the natural world around us. This ranges from the most fundamental building blocks of all matter to the widest expanse of space that contains it all. If you've ever wondered "When did time start?", or "What is the

smallest thing?”, or even just “What is color?”, or so many other endless questions then you’re already thinking with a scientific mind. Of course you are; you’re human, after all.

But here is where we really have to be clear. Science isn’t just questions and explanations. Science is about a sense of wondering and the sense-making itself. We have to wonder and then really dig into the details of our surroundings. We have to get our hands dirty. Here’s a good example: two young scientists under the presence of the Courthouse Towers in Arches National Park. We can be sure that they spent some amount of time in awe of the giant sandstone walls, but here in this photo they’re enthralled with the sand that’s just been re-washed by recent rain. There’s this giant formation of sandstone looming above these kids in the desert, and they’re happily playing in the sand. This is ridiculous. Or is it?



How did that sand get there? Where did it come from? Did the sand come from the rock or does the rock come from sand? And how would you know? How do you tell this story?

Look. There's a puddle. How often is there a puddle in the desert? The sand is wet and fine; and it makes swirling, layered patterns on the solid stone. There are pits and pockets in the rock, like the one that these two scientists are sitting in, and the gritty sand and the cold water accumulate there. And then you might start to wonder: Does the sand fill in the hole to form more rock, or is the hole worn away because it became sand? And then you might wonder more about the giant formation in the background: It has the same colors as the sand, so has this been built up or is it being worn down? And if it's being built up by sand, how does it all get put together; and if it's being worn away then why does it make the patterns that we see in the rock? Why? How long? What next?

Just as there is science to be found in a puddle or a pit or a simple rock formation, there's science in a soap bubble, in a worm, in the spin of a dancer and in the structure of a bridge. But this thing we call "science" is only there if you're paying attention, asking questions, and imagining possibilities. You have to make the science by being the person who gathers information and evidence, who organizes and reasons with this, and who communicates it to others. Most of all, you get to wonder. Throughout all of the rest of this book and all of the rest of the science that you will ever do, wonder should be at the heart of it all. Whether you're a student or a teacher, this wonder is what will bring the sense-making of science to life and make it your own.

Adam Johnston
Weber State University

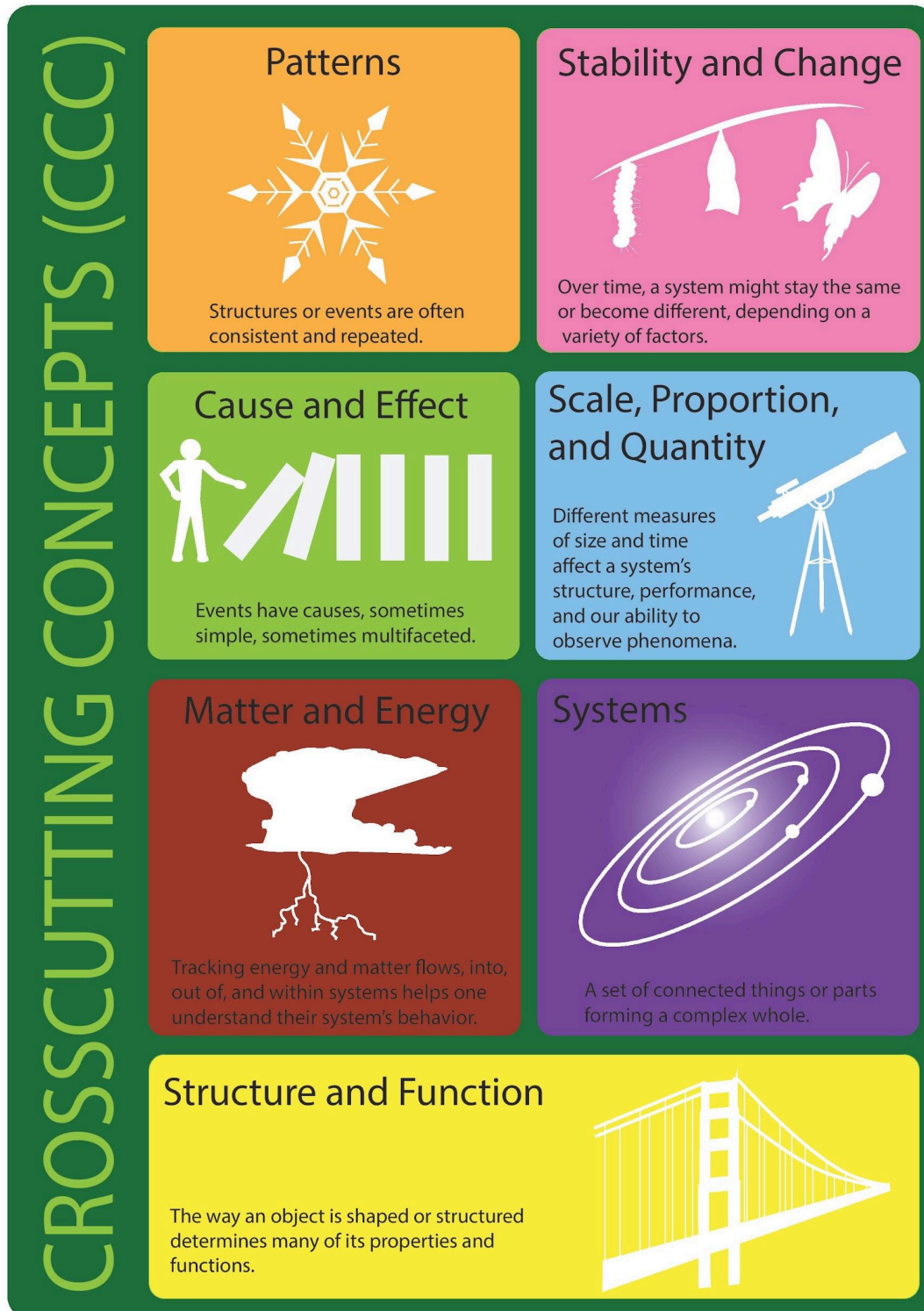
Science and Engineering Practices

Science and Engineering Practices are what scientists do to investigate and explore natural phenomena



Crosscutting Concepts

Crosscutting Concepts are the tools that scientists use to make sense of natural phenomena.



What is involved in Engineering Design?

Engineering is a creative process where each new version of a design is tested and then modified, based on what has been learned up to that point. This process includes a number of components:

1. Identifying the problem and defining criteria and constraints.
2. Generating ideas for how to solve the problem. Engineers use research, brainstorming, and collaboration with others to come up with ideas for solutions and designs.
3. Use criteria and constraints to evaluate possible design solutions to identify the one(s) that best address these parameters for the problem in context
4. Build and test the prototypes. Using data collected, the engineer analyzes how well prototypes meet the given criteria and constraints.
5. Suggest or make improvements to prototypes to optimize the design.

In the Science with Engineering Education (SEEd) Standards, specific engineering standards generally involve two types of tasks:

1. If the standard includes the idea of designing, then the design process will contain components of defining the problem (along with identifying the criteria and constraints), developing many possible solutions, and optimizing a solution (e.g., determining a best solution for the situation based on the criteria and constraints, testing the solution, refining the solution).
2. If the standard includes the idea of evaluating, then the design process will contain components of defining the problem (along with identifying the criteria and constraints) and optimizing a solution. The idea of developing many possible solutions is not included because various solutions will be provided. The idea of evaluating then means determining a best solution from the provided solutions for the situation based on meeting the criteria and constraints requirements.

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Strand 1: Forces Interact with Matter

Chapter Outline

- 1.1 FORCES AND MOTION (7.1.1)
- 1.2 ACTION AND REACTION (7.1.2)
- 1.3 ELECTRIC AND MAGNETIC FORCES (7.1.3)
- 1.4 STRENGTH OF ELECTRIC AND MAGNETIC FORCES (7.1.4)
- 1.5 GRAVITY (7.1.5)



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Forces are push or pull interactions between two objects. Changes in motion, balance and stability, and transfers of energy are all aided by forces on matter. Forces can include electric, magnetic, and gravitational forces. Forces can act on objects that are not in contact with each other. Scientists use data from many sources to examine the cause and effect relationships determined by different forces.

7.1.1 Forces and Motion

Phenomenon



Benjamin D. Esham / Wikimedia
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At the front entrance to Utah's Hogle Zoo you see a giant ball fountain, similar to the one in this photo. You push on the rolling ball and find it rolls with relative ease as long as you push it in the direction it is already moving. But it takes quite a bit of effort to change the speed, to stop the ball, or change the direction it is rolling.

Observations and Wonderings

What do you notice about this fountain?

What do you wonder about this fountain's motion?

7.1.1 Forces and Motion

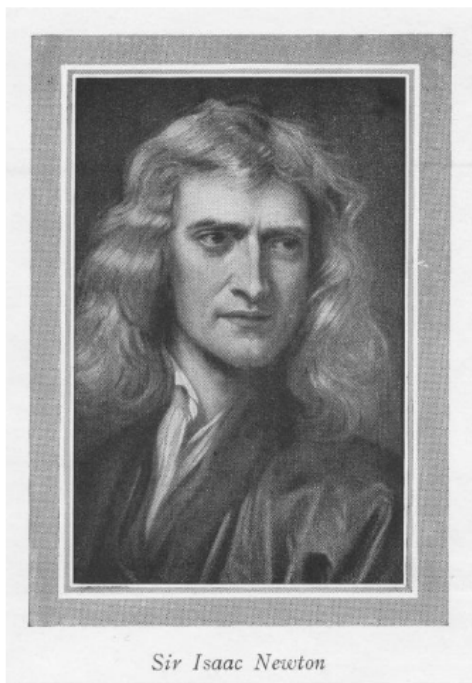
Carry out an investigation which provides evidence that a change in an object's motion is dependent on the mass of the object and the sum of the forces acting on it. *Various experimental designs should be evaluated to determine how well the investigation measures an object's motion.* Emphasize conceptual understanding of Newton's First and Second Laws. Calculations will only focus along one-dimensional movement; the use of vectors will be introduced in high school. (PS2.A, PS2.C, ETS1.A, ETS1.B, ETS1.C)



In this section, focus on the stability or change of an object's motion.

Force and Motion

The English scientist Isaac Newton, who lived around 1700, was curious about how forces affect the motion of objects. After a lot of study and observation he was able to explain the relationship between forces and motion.



Sir Isaac Newton

Public Domain

Newton observed a pattern in the relationship between force (a push or pull) and motion. He noticed a force is needed to make a stationary object start moving. A moving object will only slow down, speed up, or change direction if an outside force pushes or pulls it. In other words, objects tend to stay in whatever state they are in (in motion or at rest) unless another force acts on them. This property is called inertia and is known as Newton's First Law. Consider what happens when you roll a ball across a floor. According to Newton's first law the ball should keep rolling until a force acts on it to make it stop rolling. What force makes the ball stop rolling?



Push by Phil Dolby, <https://flic.kr/p/oziprj> CC BY

In the picture above you can see the two children exerting a force on the ball to move it across the grass. If they do not push on it, it will not move.

Along with forces, Newton observed another property that affects how an object's motion changes; the mass of the object. The relationship between the force on an object, its mass, and how its motion changes is called Newton's Second Law. How would the force needed to push a full shopping cart be different from the force needed to push an empty shopping cart? How is the amount of force needed to move an object related to the object's mass?

The amount of force needed to cause an object to start, stop or change motion depends on the mass of the object (as well as how fast or slow it is already moving.)

The greater the mass of the object, the greater the force needed to achieve the same change in motion.

Changes in Motion

There are always forces acting on every object. If an object is at rest or in constant motion, it means that the forces acting on that object are balanced or are equal. Any change to an object's motion means that the forces acting on that object are unbalanced or are unequal. If you have a pencil resting on your desk, the forces on your pencil are balanced. When your pencil moves the forces acting on it are unbalanced. Can you think of what forces may be acting on it while it is at rest? How can you add a force to your pencil to make it move?

7.1.1 Forces and Motion

Putting It Together



You and your family revisit Utah's Hogle Zoo after you learned about Newton's 1st and 2nd Laws in school.

*Benjamin D. Esham / Wikimedia Commons
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Writing Performance Task:

In the tasks that follow, you will construct an explanation to determine how the motion of the sphere changes when you change the mass or force within the system.

Gather:

A. When you first approach the rock sphere and find it is in constant motion, are the forces acting on it balanced or unbalanced?

B. What would happen if you used an unbalanced force to push in the opposite direction?

Reason:

Motion of sphere	Mass of sphere	Force applied
3 rpm	20kg	2N
6 rpm	10kg	2N
6 rpm	20kg	?

(rpm: revolutions per minute)

A. Based on the chart above, would the force need to be different in row 3 in order to keep the motion at 6 rpm with 20 kg of mass?

B. Explain your reasoning:

Communicate:

Construct an explanation to determine how the motion of the sphere changes when you change the mass or force within the system.

7.1.2 Action and Reaction

Authentic Situation



When you get home from school, you are in a hurry to get out of the car and into your house. You open the door fast and hit the other car in the garage. Now both cars have dents in their doors.

CC0 Image by Author

Observations and Wonderings

What is the problem in this situation?

What criteria do you need to know or consider to fix this situation?

What are constraints (limitations) with this situation?

7.1.2 Action and Reaction

Apply Newton's Third Law to **design a solution** to a *problem involving the motion of two colliding objects in a system*. Examples could include collisions between two moving objects or between a moving object and a stationary object. (PS2.A, ETS1.A, ETS1.B, ETS1.C)



In this section, focus on understanding what happens to two colliding objects in a system.

Engineering Design

This is an engineering standard. Refer to page 10 to read about engineering design. Which type of engineering task is utilized in this SEEd Standard?

Action and Reaction

Whenever you apply a force to an object, it applies the same force back on you. These forces are equal and act in opposite directions. This is Newton's Third Law, which states that every action has an equal and opposite reaction.



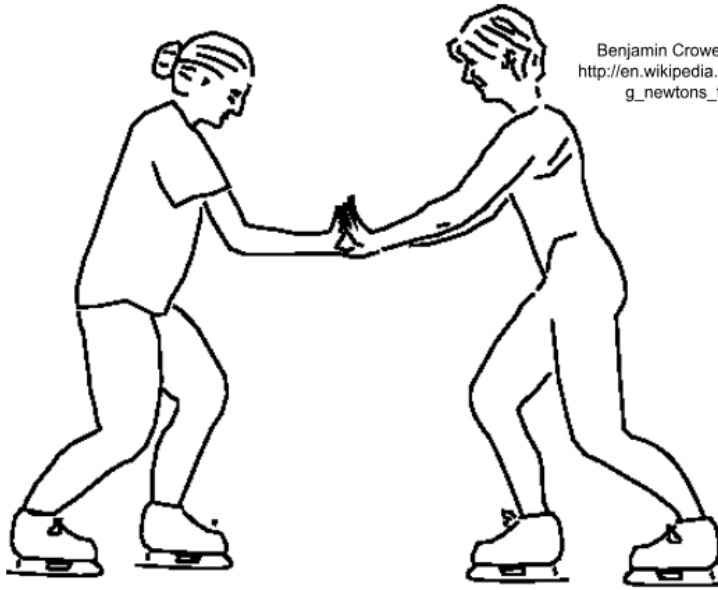
Image by Pexels: pixabay.com; GCO

When you swim through water, you put a force on the water pushing it behind you, but at the same time the water puts an equal and opposite force back onto you pushing you forward.

Just because the forces are equal and opposite does not mean that they have the same effect. When you kick a soccer ball, you apply a force to the ball, and it pushes back on you with the same force. If

the forces are equal, why does the soccer ball move and you don't?

You have a lot more mass than the soccer ball. Remember that the more mass an object has, the more force is needed to move it. The force acting on the soccer ball is big enough to make the ball move. The opposite force acting on you is not big enough to make you move because you have more mass.



Benjamin Crowell (Wikipedia user bcrowell) -
http://en.wikipedia.org/wiki/Image:Skaters_showing_newtons_third_law.png, CC BY-SA

If two skaters were to push on each other's palms, the skaters would move backward, away from each other. What would happen if the skaters just used one finger to push off each other?

Another example of Newton's third law is when you launch a rocket. Once ignited, the expanding hot gas is forced out of the bottom of the rocket by the design of the rocket itself. The gas, in turn, puts an equal and opposite force back onto the rocket causing it to fly upwards into the sky.



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If a car hits a tree, the tree pushes back on the car. Damage to the car and/or the tree depends on what factors?



7.1.2 Action and Reaction

Putting It Together



When you get home from school, you are in a hurry to get out of the car and into your house. You open the door fast and hard and hit the other car in the garage. Now both cars have dents in their doors.

Engineering Design Task:

In the tasks that follow, you will be using Newton's 3rd law (SEPs & CCCs) to evaluate a system in order to design a solution to the problem.

Gather:

- A. What are the subsystems (parts) of this situation or system?
- B. How does each subsystem (part) interact with each other?

Reason:

Using Newton's 3rd law, explain why both doors got dented.

Communicate:

Use Newton's 3rd Law to design a solution to prevent door dents between cars in a garage.

7.1.3 Electric and Magnetic Forces

Phenomenon #1



You are playing at the park with your friends. You see a child coming down a plastic slide with his hair sticking straight up.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.1.3 Electric and Magnetic Forces

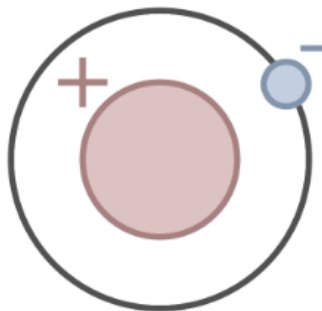
Construct a model using observational evidence to describe the nature of fields that exist between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert. (PS2.B)



In this section, see if you can identify the cause and effect relationships of static electric forces on objects.

Introducing Electric Charge

Electric charge is a physical property. It occurs between particles or objects. It causes them to attract or repel each other. They do not even have to touch. This is unlike the typical push or pull you may be familiar with (as discussed in section 7.1.1 in Forces in Motion). All electric charge is based on the protons and electrons in atoms. As in the image below, a proton has a positive electric charge(+); and an electron has a negative electric charge(-).

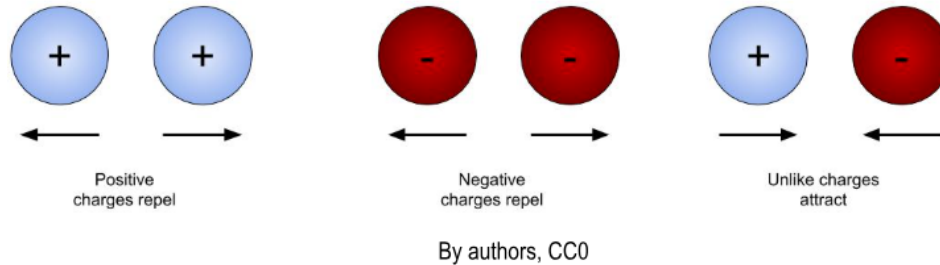


Public Domain

Electric Force

When it comes to electric charges, opposites attract. In other words, positive and negative particles are attracted to each other. Charges that are the same repel each other. If two positive charges are brought close to each other, they will repel or push away from each other. The same is true with two negative charges. They too will repel each other. What if a negative and a positive charge are brought near each other? They will be attracted to each other and the force of attraction

will try to pull them closer together. Can you think of an example of invisible forces that attract or repel each other?



The force of attraction or repulsion between charged particles is called electric force. The strength of the electric force depends on several factors. It depends on how many negatively and positively charged particles there are. It also depends on the distance between the charged particles. How do you think the force will change if you increase the distance? How do you think the force will change if you decrease the distance?

Static Electricity

Static electricity is a buildup of electric charges on objects. Charges build up when negative charges (electrons) are transferred from one object to another. This happens when you rub a balloon on your hair or sweater. Electrons from your hair or sweater are transferred to the balloon and the balloon becomes negatively charged. Your hair or sweater gives up electrons and becomes positively charged.



Electric by Kate Brady,
<https://flic.kr/p/bFuNQ>, CC BY-SA



Simulation by PhET Interactive Simulations,
University of Colorado Boulder, licensed under
CC-BY-4.0 (<https://phet.colorado.edu>).

Positive and negative charges repel each other. This picture of a cat is another example of the effects of static electricity. What charge does the cat have? What charge do the packing peanuts have?



Sometimes, touching a doorknob or light switch causes a shock that can be felt on your finger. This is another example of static electricity. An excess build up of electrons in your body, usually due to walking on carpet, are transmitted from your finger to the light switch. Sometimes, you can see a flash of light, but most of the time, this shock is invisible.



By authors, CC0

7.1.3 Electric and Magnetic Forces

Putting It Together



Electric Slide by Ken Bosma, CC BY

You are playing at the park with your friends. You see a child coming down a plastic slide with his hair sticking straight up.

Writing Performance Task:

In the tasks that follow, you will be developing and using a model to show the cause and effect of forces between the child and the slide.

Gather:

A. Study the pictures of the boy with the balloon and the cat with the packing peanuts. What is causing the boy's hair to stand up and the packing peanuts to stick to the cat?



B. Now look at the picture of the boy on the slide. Is there anything touching the boy's hair as he goes down the slide? How is his hair standing up?



Reason:

Are the charges between the hair and the slide opposite or alike? How do you know?

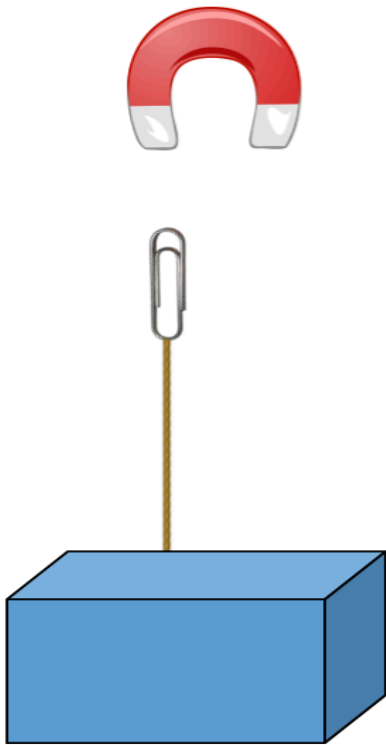
Communicate:

Construct a model to show what is happening to the child's hair when he comes down the slide.



7.1.3 Electric and Magnetic Forces

Phenomenon #2



Your 5 year old cousin shows you a “magic trick” that he saw in school. He connected a string to a paperclip and taped it to a box. Then he waved a magnet above the paperclip and even though the magnet never touches the paperclip, it rises into the air. Your cousin calls it, “The Floating Paperclip.”

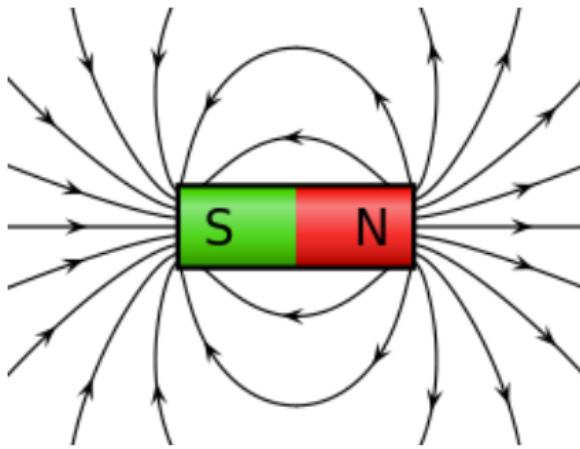
Observations and Wonderings

What are you observing about this phenomenon?

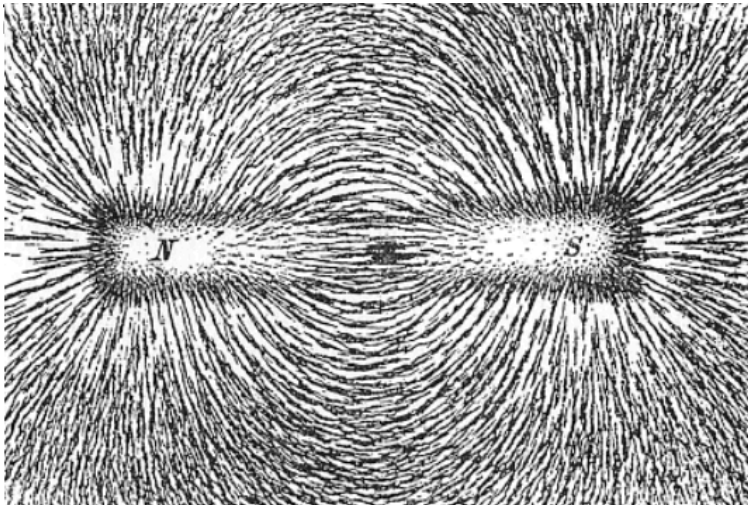
What are you wondering about this phenomenon?

Magnetic Force and Magnetic Field

The force that a magnet exerts on certain materials, including other magnets, is called magnetic force. This force is similar to the electric force because the particles do not have to touch. A magnet can exert force over a distance because it is surrounded by a magnetic field. In the figure below, you can see the magnetic field surrounding a bar magnet. Tiny bits of iron, called iron filings, were placed on a sheet of paper. When a magnet was placed under the paper, it attracted the iron filings. The pattern of the iron filings shows the lines of force that make up the magnetic field of the magnet. The concentration of iron filings near the poles (the ends) indicates that these areas exert the strongest force.

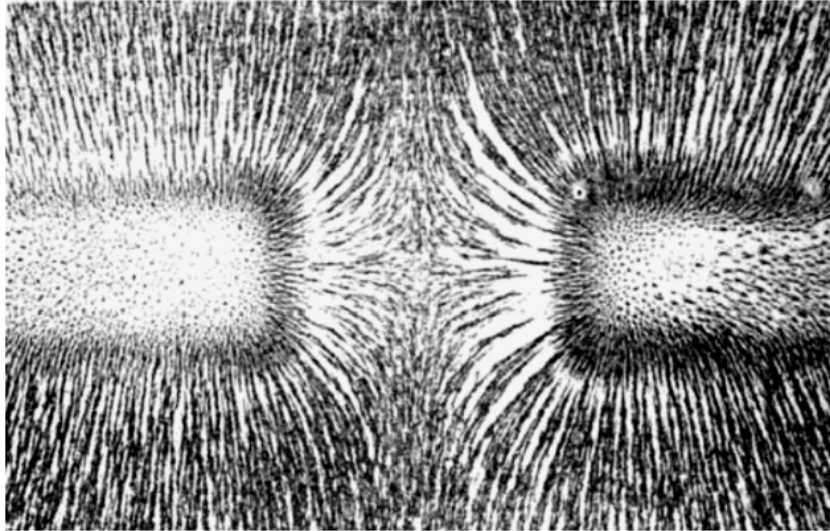


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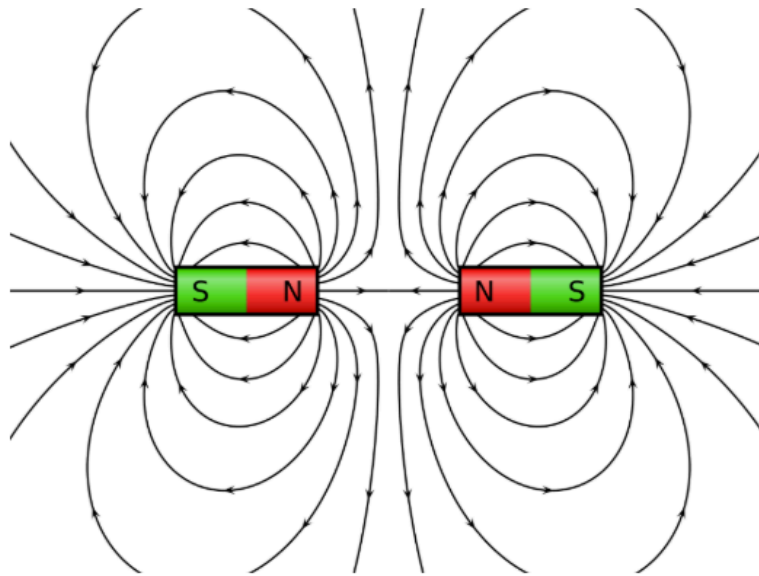


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Magnetics can either attract matter or repel matter. If you put two magnets close with the same poles facing each other, they will repel each other. The following two pictures show magnets repelling each other, as evidenced by the iron fillings.



Wikimedia Commons, CC BY-SA



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7.1.3 Electric and Magnetic Forces

Putting It Together



Your 5 year old cousin shows you a “magic trick” that he saw in school. He connected a string to a paperclip and taped it to a box. Then he waved a magnet above the paperclip and even though the magnet never touches the paperclip, it rises into the air. Your cousin calls it, “The Floating Paperclip.”

Writing Performance Task:

In the tasks that follow, you will construct a model to show how the floating paper clip magic trick works even though they are not touching.

Gather:

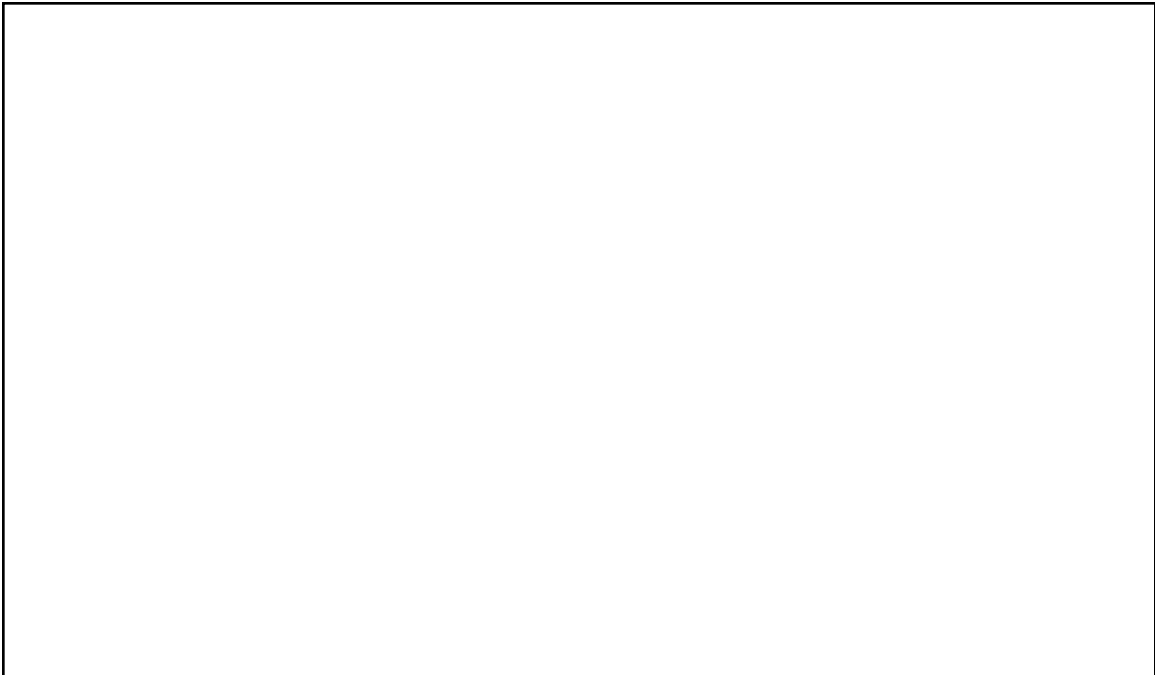
- A. Using your own experiences, describe the attraction and repulsion between magnets.
- B. Can you see the force that causes motion between two magnets? Explain.

Reason:

- A. Identify the cause and effect relationship when you bring the south pole end of one magnet close to the south pole end of another magnet.
- B. Identify the cause and effect relationship when you bring the south pole end of one magnet close to the north pole end of another magnet.

Communicate:

Construct a model to show how the floating paper clip magic trick works even though they are not touching. Make sure to include all the parts of the system, a representation of the force, and whether the magnet and object is attracting or repelling. Be sure to label your model.



7.1.4 Strength of Electric and Magnetic Forces

Phenomenon



Electromagnet by Gina Clifford, CC BY-SA

Your teacher hands you this battery, and a nail wrapped with wire. This nail becomes magnetic when you connect both of the wires to the battery.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.1.4 Strength of Electric and Magnetic Forces

Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor. (PS2.B)



In this section, focus on understanding the factors that can change the amount of strength exerted by magnetic and electrical forces.

Electromagnets



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One of the most famous electric car companies is Tesla, named after Nikola Tesla. These electric cars require an electromagnet to run the engine.

Our knowledge of electromagnets was developed from a series of observations. In 1820, Hans Oersted discovered that a current-carrying wire produces a magnetic field. Later in the same year, André-Marie Ampere discovered that a coil of wire acted like a permanent magnet and François Arago found that an iron bar could be magnetized by putting it inside of a coil of current-carrying wire.

Finally, William Sturgeon found that leaving the iron bar inside the coil greatly increased the magnetic field.

Two major advantages of electromagnets are that they have extremely strong magnetic fields, and that the magnetic field can be turned on and off. When the current flows through the coil, it is a powerful magnet. When the current is turned off, the magnetic field essentially disappears.

Electromagnets are used in many practical applications. They can lift large masses of magnetic materials such as scrap iron, rolls of steel, and auto parts.

The overhead portion of the machine shown in the next image is a lifting electromagnet. It is lowered to the deck where steel pipe is stored and it picks up a length of pipe and moves it to another machine where it is set upright and lowered into an oil well drill hole.



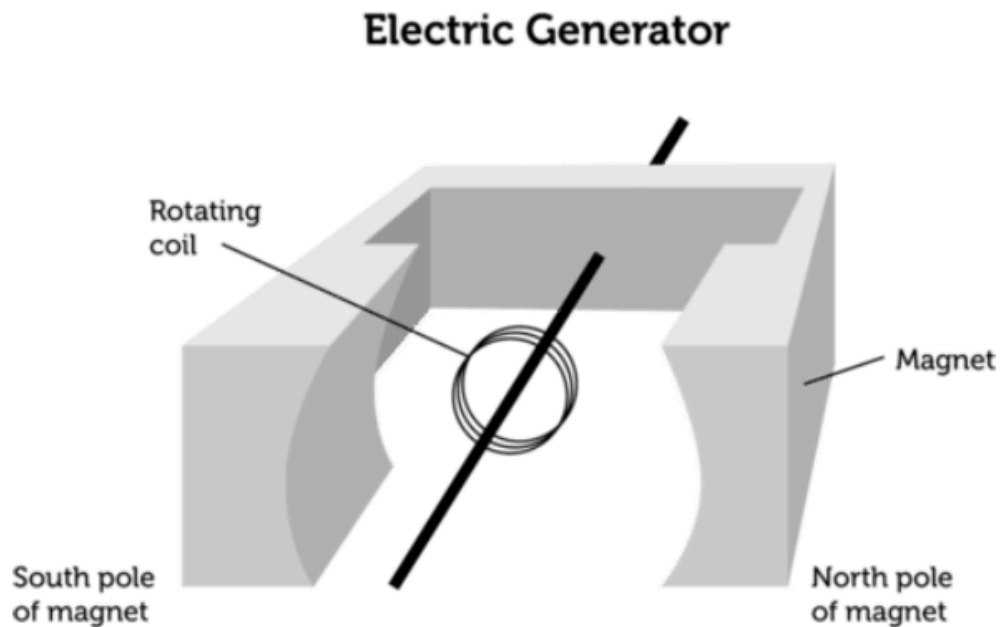
Ck12.org, CC BY-SA

Electromagnets are essential to the design of the electric generator and electric motor and are also employed in doorbells, circuit breakers, television receivers, loudspeakers, electric deadbolts, car starters, clothes washers, atomic particle accelerators, and electromagnetic brakes and clutches. Electromagnets are commonly used as switches in electrical machines. A recent use for industrial electromagnets is to create magnetic levitation systems for bullet trains.

Electric Generators

An electric generator is a device that generates an electric current using a magnetic field. Electricity can be generated when a magnetic field and an electric conductor, such as a coil of wire, move relative to one another.

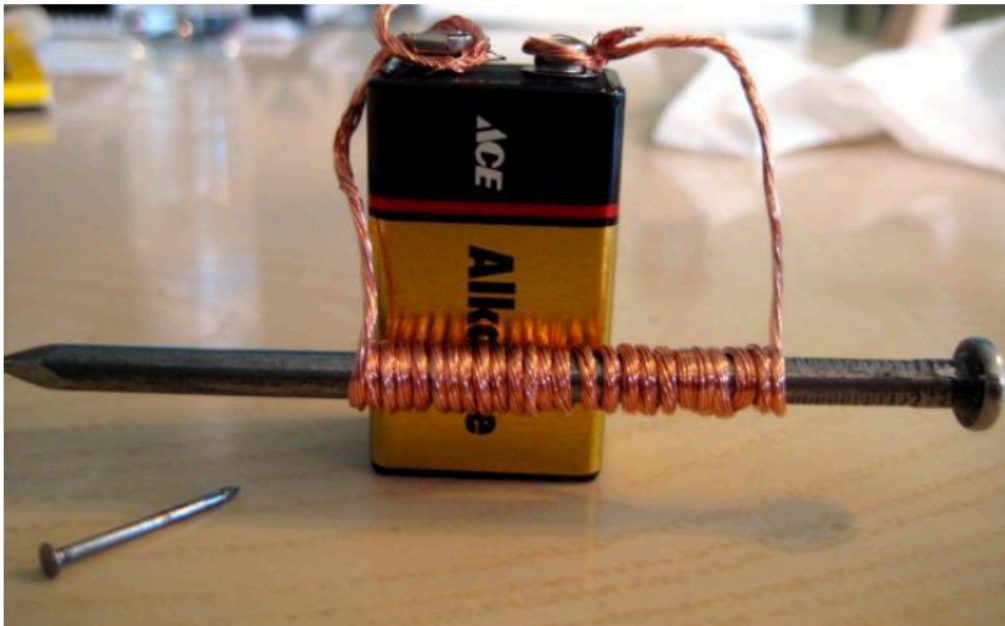
A simple diagram of an electric generator is shown in the image below. In any electric generator, some form of energy is applied to turn a shaft. The turning shaft causes a coil of wire to rotate between the opposite poles of a magnet. Because the coil is rotating in a magnetic field, electric current is generated in the wire.



Ck12.org, CC BY-SA

7.1.4 Strength of Electric and Magnetic Forces

Putting It Together



Electromagnet by Gina Clifford, CC BY-SA

You decide to create a magnet by wrapping a copper wire around an iron nail and connecting the wire to a 9-volt battery, as pictured above. You wrap the wire around the nail 25 times and place it near 3 paper clips. When the battery is connected to the wire, electricity flows through the wire around the nail and allows the magnetic fields in the nail to rearrange and become attracted to certain metals. Now you test changes made to the electromagnet.

Your results are listed in the data table below.

Pay close attention to the differences between variables in the left column of the table, and the results given in the right column. For example, 1 battery picks up 3 paper clips, while 2 batteries pick up 4.

What was changed	Results
Both wire ends connected to the battery	3 paper clips picked up
1 wire end connected to the battery	0 paper clips picked up
Increased coil amount to 30	5 paper clips picked up
Decreased coil amount to 3	0 paper clips picked up
Electromagnet was 20 cm away from paper clips	0 paper clips picked up
Electromagnet was 2 cm away from paper clips	3 paper clips picked up
1 battery connected to the electromagnet	3 paper clips picked up
2 batteries connected to the electromagnet	4 paper clips picked up
Thicker Iron Nail	4 paper clips picked up
Thinner Iron Nail	2 paper clips picked up
Plastic coated paper clips	0 paper clips picked up
Metallic paper clips	3 paper clips picked up

Writing Performance Task:

Construct an explanation using evidence from the data collected in the phenomenon experiment to describe the factors that affect the strength of electrical and magnetic fields.

Gather:

- A. Predict what would happen if you placed this electromagnet next to a paper clip. Explain your answer.
- B. If you placed this magnet next to an empty plastic water bottle, would the magnet have any effect on the container? Explain your answer.
- C. Predict some ways that you can change the strength of your electromagnet?

Reason:

- A. Looking at the data from the experiment, which change had the greatest results?
- B. What do you think would happen to the strength of the electromagnet if you added 100 coils?
- C. Why do you suppose having a thicker iron nail changed the strength of the electromagnet?

Communicate:

Final Task: Now that you have a better understanding of how electromagnets work as well as electrical and magnetic fields, construct an explanation using evidence from the data collected in the phenomenon experiment to describe the factors that affect the strength of electrical and magnetic fields.

7.1.5 Gravity

Phenomenon



Apollo 11 Launch



Command Module



Apollo 11 Return to Earth

You recently read an article about the Apollo 11 Mission which was launched from the surface of the Earth using the Saturn V rocket. The rocket stood approximately 111 m tall, taller than the Statue of Liberty, with a mass of 6.2 million kg, and used approximately 898,698 gallons of fuel to escape Earth's gravity. After the mission was complete and Apollo 11 returned to earth, it only had a total mass of 55,557 kg.

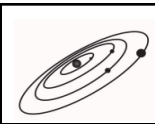
Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.1.5 Gravity

Engage in argument from evidence to support the claim that gravitational interactions within a system are attractive and dependent upon the masses of interacting objects. Examples of evidence for arguments could include mathematical data generated from various simulations. (PS2.B)



In this section, focus on understanding that a system consists of all the parts within that system and everything affecting it.

What is Gravity?

Gravity has traditionally been defined as a force of attraction between things that have mass. According to this concept of gravity, anything that has mass, no matter how small, exerts gravity on other matter. Gravity can act between objects that are not even touching. In fact, gravity can act over very long distances, but the farther apart the objects are, the weaker the force of gravity between them is.

Mass Influences the Strength of Gravity

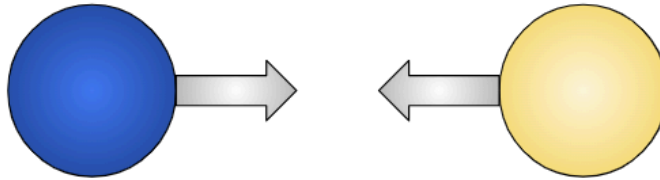
The strength of gravity between any two objects depends on two factors: the masses of the objects and the distance between them. An object with more mass will have a stronger gravitational pull. For example, because Earth is so massive, it attracts your desk, holding it to the ground, more than you can attract your desk. There is a force of gravity between Earth and you and also between you and all the objects around you. When you drop a paperclip, why doesn't it fall toward you instead of toward Earth?

If we look at our solar system, the Sun's mass is about 98% of the total mass of the solar system. Our eight planets are exerting a force on the Sun and the Sun exerts an equal force on the planets. This attraction and the sideways motion of the planets keep them rotating around the Sun.

We can measure the force of gravity on Earth with a spring scale. The unit of measure for gravity is Newtons (N). The more mass an object has the harder it is to pick up because of the pull of gravity on that object. A bowling ball has more mass therefore it takes more force to pick it up than the force needed to pick up a beach ball.



The force of gravity acts between all objects.



If mass increases, the force of gravity increases.



If distance increases, the force of gravity decreases.

CCO by Authors

7.1.5 Gravity

Putting It Together



Apollo 11 launched July 16, 1969 attached to Saturn V Rocket



Lunar module, the Command Module, and return engine

Public Domain

https://en.wikipedia.org/wiki/Saturn_V#/media/File:Apollo_11_Launch_-_GPN-2000-000630.jpg; Public Domain



Apollo 11 Command Module returned to Earth

Public Domain

You recently read an article about the Apollo 11 Mission which was launched from the surface of the Earth using the Saturn V rocket. The rocket stood approximately 111 m tall, taller than the Statue of Liberty, with a mass of 6.2 million kg, and used approximately 898,698 gallons of fuel to escape Earth's gravity. Once Apollo 11 left Earth's orbit, the Saturn V rocket was ejected and eventually fell back to Earth. The rest of Apollo 11 reached the moon on July 20, 1969. The lunar module was detached from the command module and traveled to the surface of the moon. Once the astronauts completed their lunar mission, the lunar module lifted off the surface of the moon, reattached to the command module and return engine, and came back to Earth. Before reentry into the Earth's atmosphere, the command module separated from the lunar module and the return engine. Once detached, the command module began its journey to the surface of the Earth. The command module touched down on the Earth's surface on July 24, 1969, and had a mass of 55,557 kg.

Writing Performance Task:

In the tasks that follow, you will construct an argument from evidence to support the claim that the fuel needed for Apollo 11 to leave the Earth's gravitational pull was much greater than the fuel needed to leave the moon's gravitational pull.

Gather:

- A. What were the components of the system that helped Apollo 11 leave Earth and reach the moon?
- B. Which solar system object do you think has a greater mass, the Earth or the moon?

Reason:

- A. Explain how all of the parts worked together as one system to complete the Apollo 11 mission.
- B. If the astronauts were standing next to the launch system for Apollo 11, why did they not feel the gravitational pull of this system?
- C. Why do you think the Saturn V rocket was not needed after Apollo 11 left the Earth's orbit?
- D. Why do you think Apollo 11 was not affected by the sun's gravitational pull?

Communicate:

Construct an argument from evidence to support the claim that the fuel needed for Apollo 11 to leave the Earth's gravitational pull was much greater than the fuel needed to leave the moon's gravitational pull.

Strand 2: Earth's Processes

Chapter Outline

- 2.1 THE ROCK CYCLE (7.2.1)
- 2.2 EARTH'S SURFACE CHANGES OVER TIME (7.2.2)
- 2.3 ENGINEERING AND GEOLOGIC HAZARDS (7.2.3)
- 2.4 EARTH'S INTERIOR (7.2.4)
- 2.5 PATTERNS IN PLATE TECTONICS (7.2.5)
- 2.6 HOW OLD IS THE EARTH? (7.2.6)



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Flooding by Sam Leivers. CC BY-NC-ND

Earth's processes are dynamic and interactive and are the result of energy flowing and matter cycling within and among Earth's systems. Energy from the sun and Earth's internal heat are the main sources driving these processes. Plate tectonics is a unifying theory that explains crustal movements of the Earth's surface, how and where different rocks form, the occurrence of earthquakes and volcanoes, and the distribution of fossil plants and animals.

7.2.1 The Rock Cycle

Phenomenon



Ductility by Mike Beauregard <https://flic.kr/p/Q31JBL>, CC BY

You are in a museum and come across this rock display. According to the sign, it is a metamorphic folded rock that was found in an area near Tamworth, Ontario. This rock was formed during a mountain building event about 1.1 billion years ago. Since then, weathering and erosion have exposed the patterns in the rock that you see.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

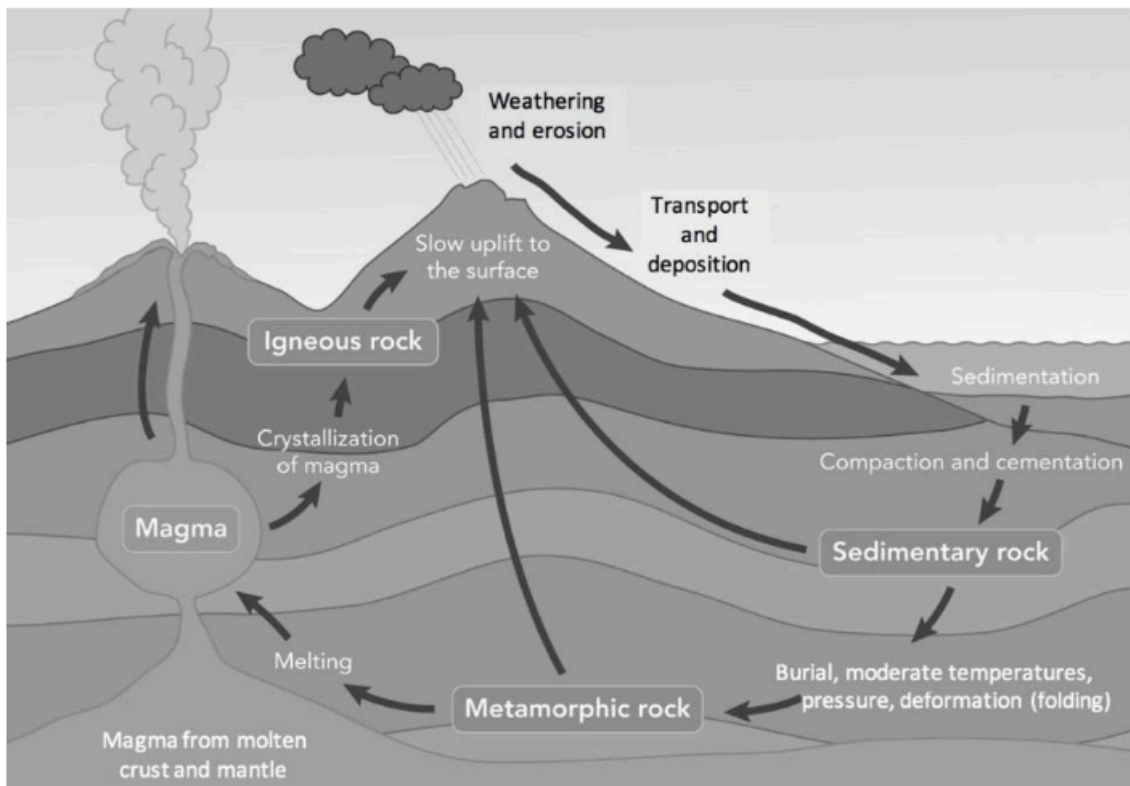
7.2.1 The Rock Cycle

Develop a model of the rock cycle to describe the relationship between energy flow and matter cycling that create igneous, sedimentary, and metamorphic rocks. Emphasize the processes of melting, crystallization, weathering, deposition, sedimentation, and deformation, which act together to form minerals and rocks. (ESS1.C, ESS2.A)



In this section, focus on understanding the relationship between how energy is needed in order to change matter in the rock cycle.

The Rock Cycle



Rock Cycle by Siyavula Education, CC-BY

The rock cycle pictured on the previous page shows the three major rock types: igneous, sedimentary, and metamorphic. The picture also shows how one type of rock can change into another type of rock.

Rocks change as a result of natural processes that are taking place all the time. There are two sources of energy that are found in the rock cycle. The energy at the surface stems from the sun and energy inside the Earth is derived from Earth's interior. Most changes happen very slowly. Right now, rocks deep within the Earth are becoming other types of rocks. Even on the Earth's surface, rocks are changing in ways we might not notice.

The Three Rock Types

Rocks are grouped into three major groups according to how they are formed.

Igneous



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Igneous rocks form by the cooling and hardening of melted rock. Melted rock is called magma found inside the Earth. Melted rock found on the Earth's surface is called lava. Igneous rocks can cool slowly beneath the surface of the Earth (intrusive) or quickly on the surface (extrusive). As the magma cools, crystallization can occur. Different crystals form at different temperatures from different minerals within the rock. For example, the mineral olivine crystallizes out of magma at much higher temperatures than quartz. The rate of cooling determines how much time the crystals will have to form. Slow cooling produces large crystals, found in granite, while fast cooling results in small crystals, found in basalt.

Sedimentary

Sedimentary rocks are formed when sediments, smaller pieces of rock, gravel, sand, silt, or clay, are compacted and cemented together. Sediments can be formed from the weathering and erosion of existing rocks. Wind, heat, and running water all work to weather Earth's surface down into smaller pieces. Also, water that finds its way into the cracks of rocks and then freezes can break even large rocks into small sediments. These tiny sediments are then carried from one place to another by wind, running water, ice, and gravity.

During sedimentation, the sediments are laid down or deposited. Sediments are deposited on beaches and deserts, at the bottom of oceans, and in lakes, ponds, rivers, marshes, and swamps. Landslides drop large piles of sediment. Glaciers leave large piles of sediments, too. Wind can only transport sand and smaller particles. The type of sediment that is deposited will determine the type of sedimentary rock that can form. In order to form a sedimentary rock, the accumulated sediment must become compacted and cemented together.



Arches National Park Delicate Arch by Anna Irene, CC BY-SA

One very famous and iconic area of sedimentary rock is shown in this image. Delicate Arch inside Arches National Park in Southeastern Utah brings people from all over the world to explore the amazing sedimentary rock formations found there.

Metamorphic

Metamorphic rocks form when rocks are exposed to heat and/or pressure within the Earth but do not completely melt. The amount of heat and/or pressure can

actually change the minerals that are in the rock, change its shape like folding the rock, and/or change its texture, which leads to the making of a new type of rock. In the example below, the shale has been exposed to heat from Earth's interior and metamorphosed into a new rock called Schist. A way that geologists can determine the difference between the original rock and the metamorphosed form of the rock is to use the terms Parent and Daughter. The original rock is known as the "Parent" rock and the newly formed rock after experiencing the heat and pressure is known as the "Daughter" rock.



Parent Rock: Shale

Shale by Kai Schreiber, CC BY-SA



Daughter Rock: Schist

Auriferous garnet schist (Dahlonga District, Dahlonga Gold Belt, Georgia, USA) by James St. John, CC BY

7.2.1 The Rock Cycle

Putting It Together



Ductility by Mike Beauregard <https://flic.kr/p/Q31jBL>, CC BY

You are in a museum and come across this rock display. According to the sign, it is a metamorphic folded rock that was found in an area near Tamworth, Ontario. This rock was formed during a mountain building event about 1.1 billion years ago. Since then, weathering and erosion have exposed the patterns in the rock that you see.

Writing Performance Task:

In the tasks that follow, you will develop a model that shows how a sedimentary rock was changed into a metamorphic rock, exposed to the surface, and then changed from a metamorphic rock to an igneous rock. You will then explain how the rock went through the rock cycle and the energy that was used to change the rock from one type to another.

Gather:

1. Is the rock you see at the museum, the same type of rock that was in the area before that rock was formed? Explain your answer.
2. Do you think the energy involved in creating this rock is the same energy that is involved in creating other types of rocks like igneous and sedimentary rocks? Explain your answer.

Reason:

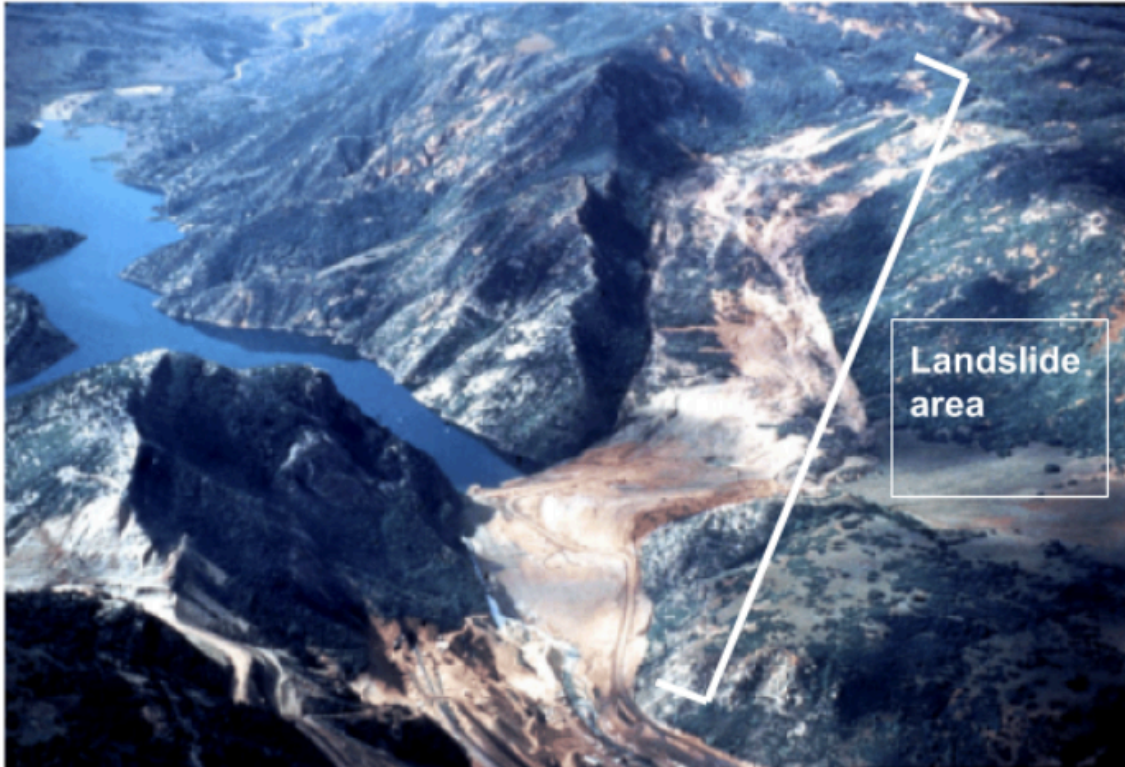
In the picture above, the metamorphic rock was changed from a sedimentary rock. Create a model that would show how the rock changed from a sedimentary rock to metamorphic rock. Then add one more step to your model showing how the metamorphic rock could change to an igneous rock. Include in your model the energy that would be needed to change the rock from one type to another.

Communicate:

Using your model you created and the information given under the picture, explain how the rock went through the rock cycle and what energy was applied to change the rock from one type to another.

7.2.2 Earth's Surface Changes over Time

Phenomenon



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Your teacher had you conduct research about one of the most devastating landslides in Utah's recent history, the 1983 Thistle Landslide. This massive landslide was measured at approximately 1828 m (6000 ft) in length and approximately 304 m (1000 ft) wide. The landslide plugged the Spanish Fork River creating a lake within a matter of days. It also destroyed roadways and railroad tracks. The town of Thistle was evacuated and is now a ghost town.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.2.2 Earth's Surface Changes over Time

Construct an explanation based on evidence for how processes have changed Earth's surface at varying time and spatial scales. Examples of processes that occur at varying time scales could include slow plate motions or rapid landslides. Examples of processes that occur at varying spatial scales could include uplift of a mountain range or deposition of fine sediments. (ESS2.A, ESS2.C)



In this section, focus on how Earth's surface features can form or change very slowly or very quickly. Earth's surface also changes on large and small scales.

Kaboom!

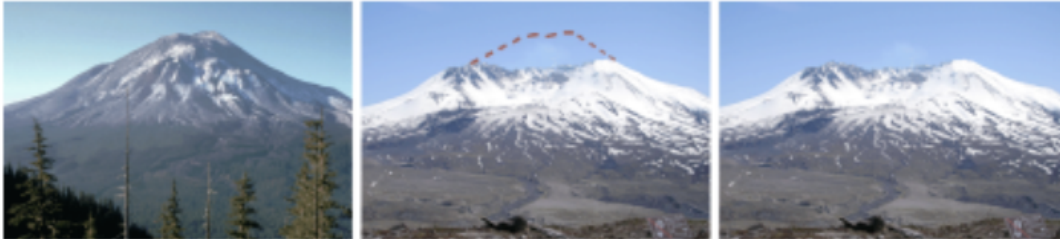


Public Domain

The 1980 eruption of Mt. St. Helens (pictured above) released a cloud of ash 8 to 10 miles into the sky. Sadly, 57 people died, it also destroyed over \$1 billion dollars in property, and permanently altered the local ecosystem.

A volcano is a vent from which the material from a magma chamber deep in the Earth escapes. Volcanic eruptions can come from volcanic cones, fractured domes, a vent in the ground, or many other types of structures.

When a volcano erupts, Earth's surface can be changed in a matter of seconds, which would be considered a fast change on the time scale. As seen in the three images of Mt. St. Helen's below. The picture on the left shows what the mountain looked like before the eruption, and the picture on the right shows what the mountain looked like after the eruption.



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Landslides

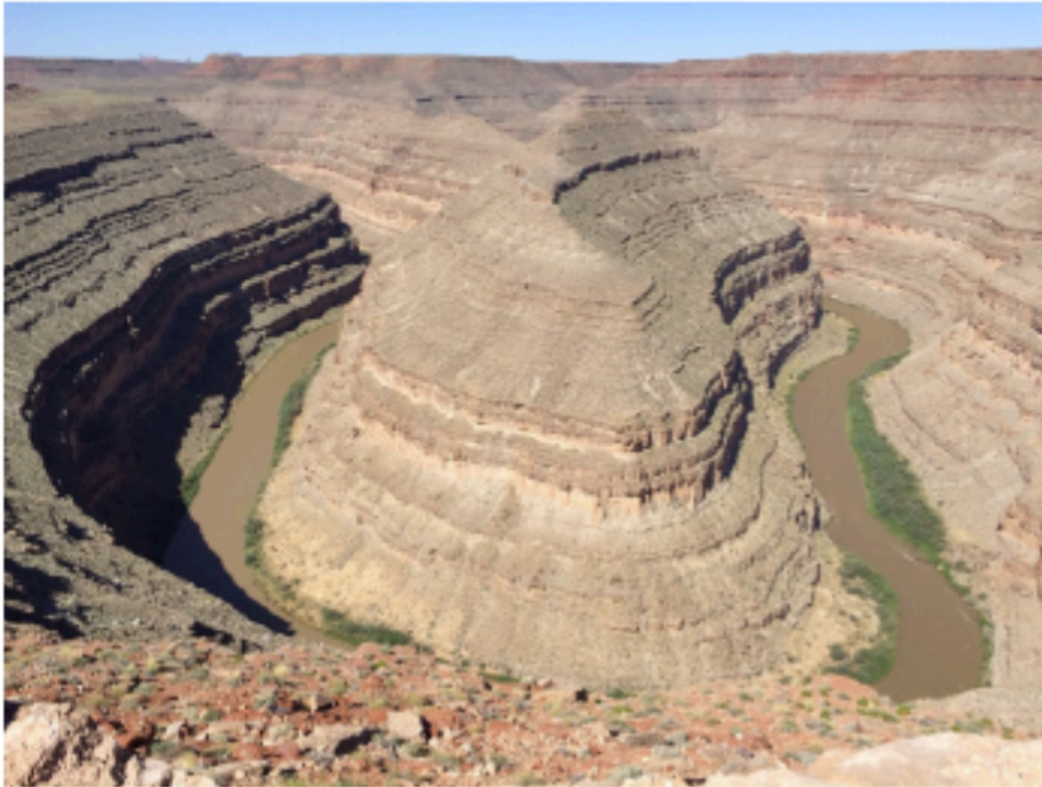


There are other events that can dramatically change Earth's landscape very quickly. A landslide happens when a large amount of soil and rock suddenly falls down a slope because of gravity and other environmental factors. You can see an example of a landslide in the picture to the right. A landslide can be very destructive. It can bury or carry away entire villages in a matter of seconds or minutes.

This 2001 landslide in El Salvador (Central America) was started by an earthquake. Soil and rocks flowed down a hillside and swallowed up houses in the city below. Public Domain

Erosion by Streams

Other landforms take years and years to form and are considered slow changes on the time scale. As streams travel, they break down and/or erode sediment from the rocks on their banks. The running water picks up and transports the sediments further downstream. Pictured on the next page is the San Juan River in Southeastern Utah. The twists and turns have been created over millions of years as water, wind, frost, and gravity have cut 1,000 feet into Earth's crust.

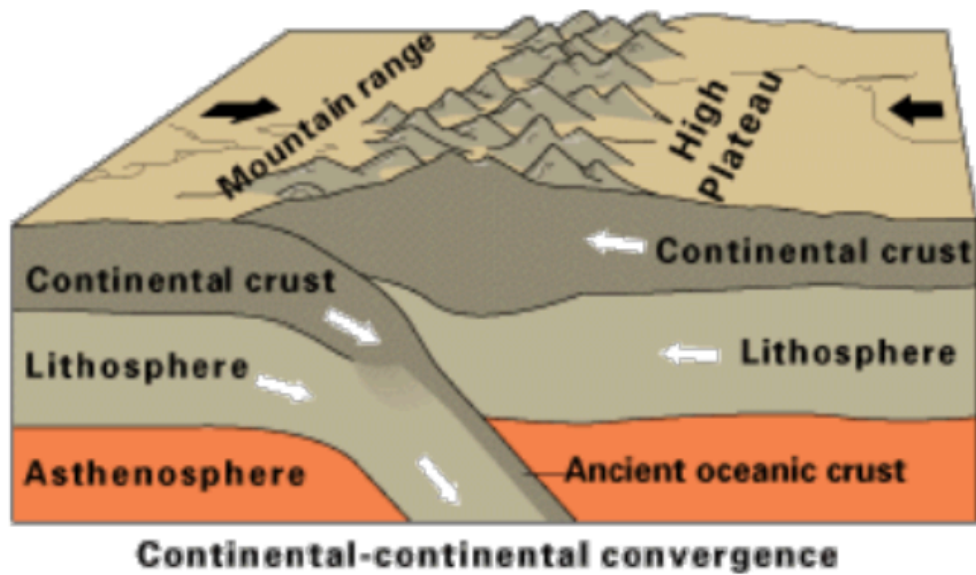


The San Juan River flowing through Goosenecks State
Park in Southeast Utah.
Goosenecks State Park by Nick Amoscato, CC BY

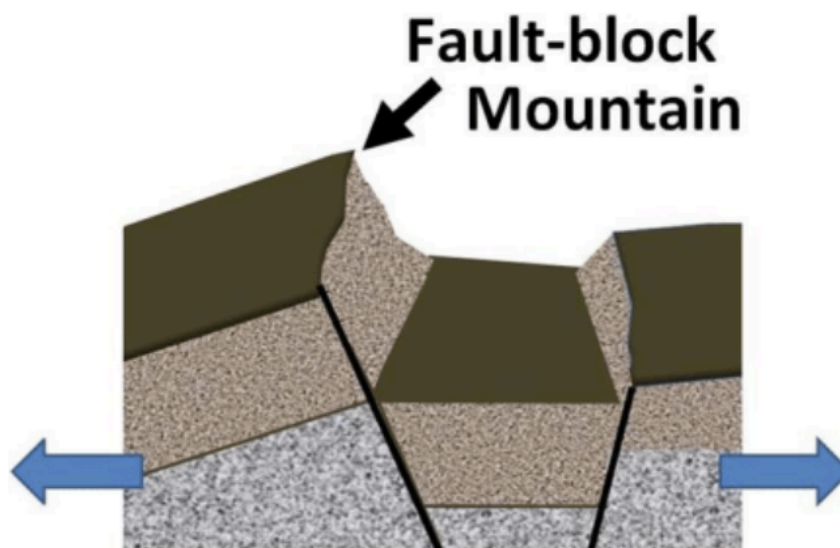
Mountain Building

The Earth's crust is broken into different tectonic plates. These plates move, collide (bump), slide over and under each other, and can even move away from each other. The above image on the left shows how when two plates collide into one another one can be pushed up, creating mountain ranges. An example of this is the Himalayan Mountain Range, which is still growing today. Another way changes occur to the mountains is when the plates move away from each other

like in the above image on the bottom. The Sierra Nevada mountain range was formed this way.

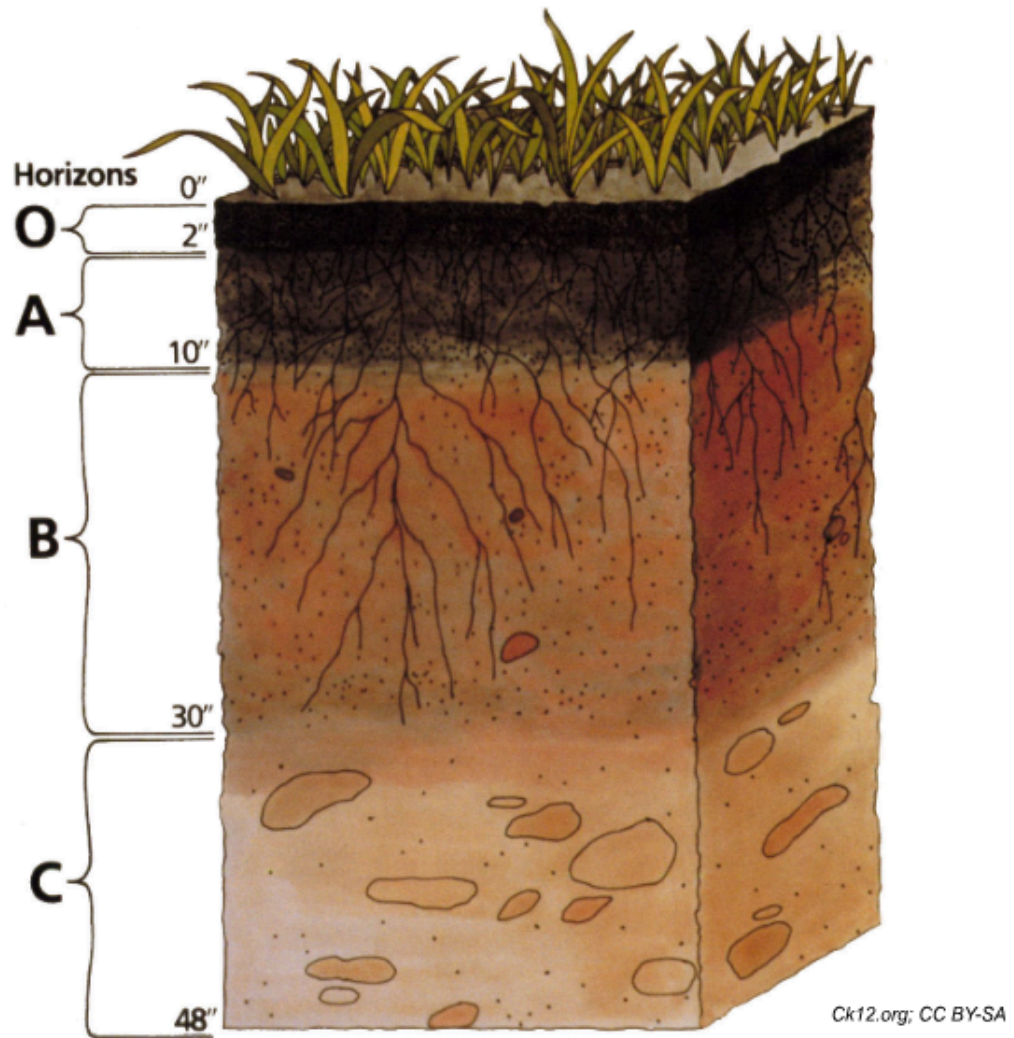


Public Domain



Fault-block Mountain by Brews Ohare, CC BY-SA

Deposition of Sediments



At times, some sediment will become sedimentary rock. Some sediments can be turned into rich soil that is perfect for growing crops and supporting life. However, soil development takes a very long time. It may take hundreds or even thousands of years to form the fertile upper layer of soil. Soil scientists estimate that in the very best soil-forming conditions, soil forms at a rate of about 1 mm/year. In poor conditions, it may take thousands of years! The image to the left gives a general profile of what soil looks like. Check out how many layers actually exist in what we often think of as just 'dirt'.

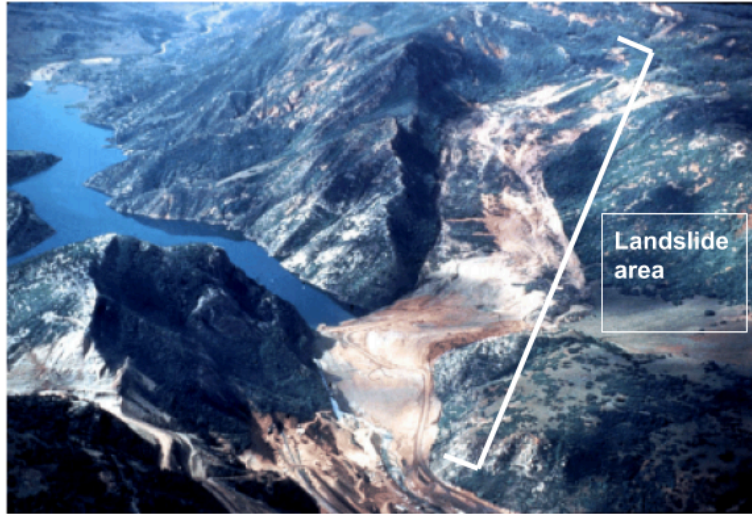
Wind is one of the best movers of sediment. Like water, as wind slows down it drops the sediment it's carrying. This often happens when the wind has to move over or around an obstacle. A rock or tree may cause wind to slow down. As the wind slows, it deposits the largest particles first. Different types of deposits form depending on the size of the particles deposited. When the wind deposits sand, it forms small hills. These hills are called sand dunes (image to the right). For sand dunes to form, there must be plenty of sand and wind. Sand dunes are found mainly in deserts and on beaches.



Pixabay.com, CC0

7.2.2 Earth's Surface Change over Time

Putting It Together



Your teacher had you conduct research about one of the most devastating landslides in Utah's recent history, the 1983 Thistle Landslide. This massive landslide was measured at approximately 1828 m (6000 ft) in length and approximately 304 m (1000 ft) wide. The landslide plugged the Spanish Fork River creating a lake within a matter of days. It also destroyed roadways and railroad tracks. The town of Thistle was evacuated and is now a ghost town.

Writing Performance Task:

In the tasks that follow, you will be constructing an explanation about why some geological events take a very long time to change the Earth's surface and some take a very short time to change the Earth's surface. You will also need to explain why some events cover large areas and some do not.

Gather:

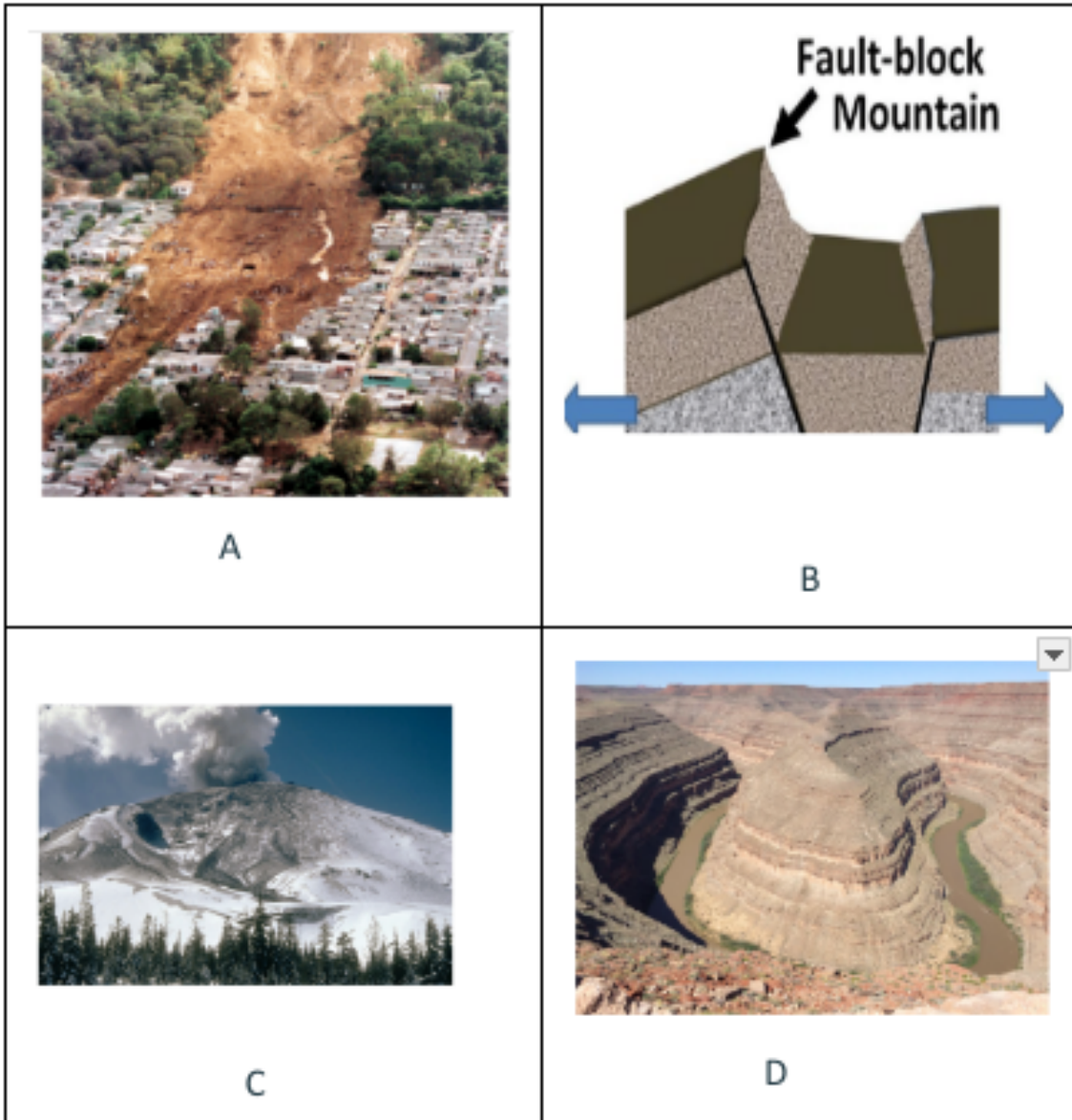
A. What do you think this landslide can tell us about the changes to the Earth's landscape over time?

B. How long do you think it took for the landslide to stop moving?

C. What is a different event that would change Earth's landscape over a longer period of time?

D. What is another event that would change a larger area of Earth's landscape?

Reason:



Using the pictures above and the text, decide which of these pictures would be a slow or a fast geological process? Circle which are slow and which are fast.

Slow: A B C D

Fast: A B C D

Communicate:



*Rafters in Grand Canyon National Park, NPS
Photo / Mark Lellouch (Public Domain)*

Construct an explanation from the evidence you gathered in the chapter, for how you think the layers of the canyon and the canyon itself formed. Include in the explanation how long you think it took to cut the canyon.

7.2.3 Engineering and Geologic Hazards

Authentic Situation



Ck12.org. CC BY-SA

This California Memorial Stadium is sometimes called a "tectonic time bomb".

You recently read an article about the California Memorial Stadium built in 1922. You learned that the Hayward Fault, which produces earthquakes in the area, passes directly beneath both end zones at California Memorial Stadium, the football stadium at the University of California, Berkeley. Many feared that an earthquake would destroy the stadium.

Observations and Wonderings

What is the problem in this situation?

What possible criteria are needed for a positive outcome to this situation?

What are the constraints or limitations that might affect a positive solution?

7.2.3 Engineering and Geologic Hazards

Ask questions to *identify constraints* of specific geologic hazards and *evaluate competing design solutions* for maintaining the stability of human-engineered structures such as homes, roads and bridges. Examples of geologic hazards could include earthquakes, landslides, or floods. (ESS2.A, ESS2.C, ETS1.A, ETS1.B, ETS1.C)



In this section, focus your understanding on identifying geologic hazard constraints which might affect the stability of man-made structures.

Engineering Design

Refer to page 10 for information about engineering design. Which type of engineering task is utilized in this SEEd Standard?

Geologic Hazards Affect Humans



Public Domain

The devastating earthquake that occurred on April 25, 2015 between the cities of Pokhara and Kathmandu in Nepal killed thousands of people, destroyed

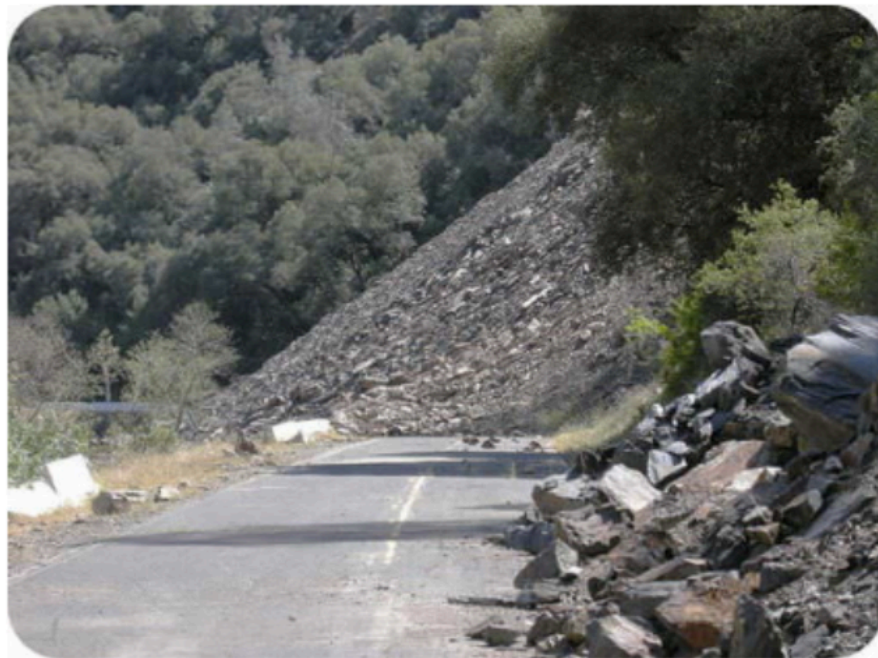
communities, and left millions in need of food and shelter. Events like these can be terrifying and assistance efforts require the coordinated involvement of the entire world.

Earthquakes

The Earth's crust is made of continental and oceanic plates that fit together much like a puzzle. Earthquakes can occur along these plate boundaries. Sometimes one plate moves past another plate and their jagged edges get stuck. When they finally break away from each other, all of the energy that was stored is released and an earthquake occurs. Sometimes one plate can slip underneath another plate causing an earthquake. Regardless of how earthquakes occur, the energy they release can cause problems for people on Earth.

Landslides

Landslides are among the most dramatic, sudden, and dangerous examples of Earth materials moved by gravity and other environmental factors. Landslides are sudden falls of rock much like avalanches are sudden falls of snow. When large amounts of rock suddenly break loose from a cliff or mountainside, they move quickly and with tremendous force. Air trapped under the falling rocks acts as a cushion that prevents the rock from slowing down. Landslides can move as fast as 200 to 300 km/hour.



This landslide in California in 2008 blocked Highway 140.
ck12.org, CC BY-SA

Landslides can be exceptionally destructive. Homes may be destroyed as hillsides collapse. Landslides can even bury entire villages. Landslides may create lakes when the rocky material dams a stream. If a landslide flows into a lake or bay, they can trigger a tsunami.

Floods

A flood can occur when so much water enters a stream or river that it overflows its banks. Flood waters from a river are shown in the image below.



Pixabay.com, CC0

Floods are a natural part of the water cycle, but they can cause a lot of damage. Farms and homes may be lost, and people may die. In 1939, millions of people died in China during a flood.

Floods may occur when deep snow melts quickly in the spring. More often, floods are due to heavy rainfall. Floods happen when rain falls more quickly than water can be absorbed into the ground or carried away by rivers or streams.

How can humans engineer structures to withstand the above mentioned geologic hazards?

New construction can be made safer in many ways. Some of the ways are listed below.

- Skyscrapers and other large structures built on soft ground must be anchored to bedrock, even if it lies hundreds of meters below the ground surface.
- The correct building materials must be used. Houses should bend and sway. Wood and steel are better than brick, stone, and adobe, which are brittle and will break.
- Larger buildings must sway, but not so much that they touch nearby buildings. Counterweights and diagonal steel beams are used to hold down sway.
- Large buildings can be placed on rollers so that they move with the ground.
- Buildings may be placed on layers of steel and rubber to absorb the shock of the earthquake waves.
- In a multi-story building, the first story must be well supported.
- In Louisiana, where flooding is common, houses are often raised on stilts.



J.K. Nakata, U.S. Geological Survey; CC BY

In this image, the first floor of this San Francisco building is collapsing after the 1989 Loma Prieta earthquake

Retrofitting

To make older buildings more earthquake safe, retrofitting with steel or wood can reinforce a building's structure and its connections. Elevated freeways and bridges can also be retrofitted so that they do not collapse.

Preventing Fire Damage



In the 1906 San Francisco earthquake (image above), fire was more destructive than the ground shaking.
Ck12.org, CC BY-SA

During earthquakes, fires often cause more damage than the earthquake. Fires start because seismic waves rupture gas and electrical lines. Breaks in water mains make it difficult to fight the fires. Builders zigzag pipes so that they bend and flex when the ground shakes. In San Francisco, water and gas pipelines are separated by valves so that areas can be isolated if one segment breaks.

Cost Considerations

Why aren't all structures in earthquake zones constructed for maximum safety? Cost, of course. Sturdier structures are more expensive to build. So communities must weigh how great the hazard is, what different building strategies cost, and make an informed decision.

In September 2013, the eastern span of the San Francisco-Oakland Bay Bridge was replaced by a new earthquake resistant bridge. This photo shows the bridge a few days after the new span was put into service and the old span was abandoned.



The SF Bay Bridge reopens by Benjy Feen; CC BY-SA

7.2.3 Engineering and Geologic Hazards

Putting It Together



Ck12.org, CC BY-SA

You recently read an article about the California Memorial Stadium. You learned that the Hayward Fault, which produces earthquakes in the area, passes directly beneath both end zones at California Memorial Stadium, the football stadium at the University of California, Berkeley. The site probably looked flat and easy to build on in 1922, before earthquake faults were well understood. To make the stadium safe for workers, players, and fans, the stadium was renovated in a \$321 million project involving 10 miles of steel cables, silicone fluid-filled shock absorbers, concrete piers, 3 feet of sand, plastic sheeting, and stone columns.

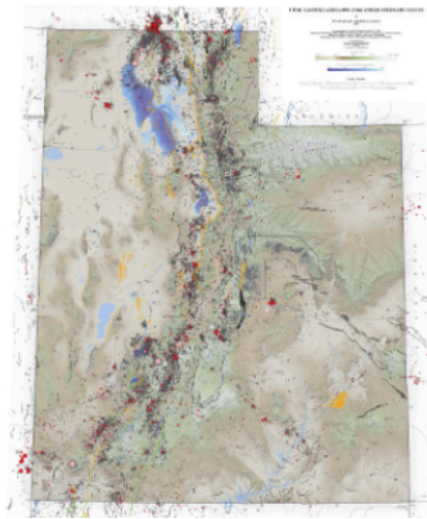
Engineering Design Task:

In the tasks that follow, you will look at information about earthquakes in Utah and decide where you think earthquake proof structures should be used in building new structures. You will then think of a design solution for a stadium that will be built in Utah and decide what structures should be included in the stadium.

Gather:

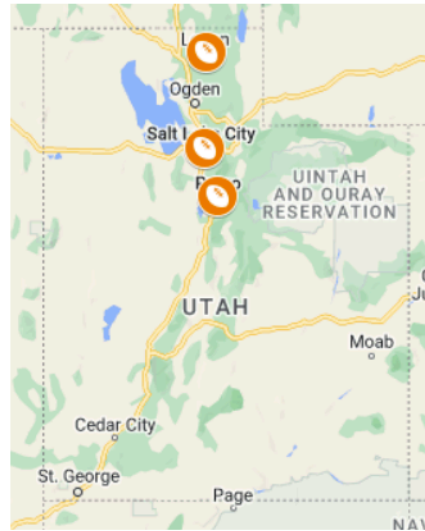
- A. In Utah, what are three criteria we should be aware of when building a structure in areas that are prone to geologic hazards?
- B. What are some things that an engineer needs to be aware of when constructing a new building in Utah?

Reason:



Map A

<https://ugspub.nr.utah.gov/publications/maps/m-277.pdf>

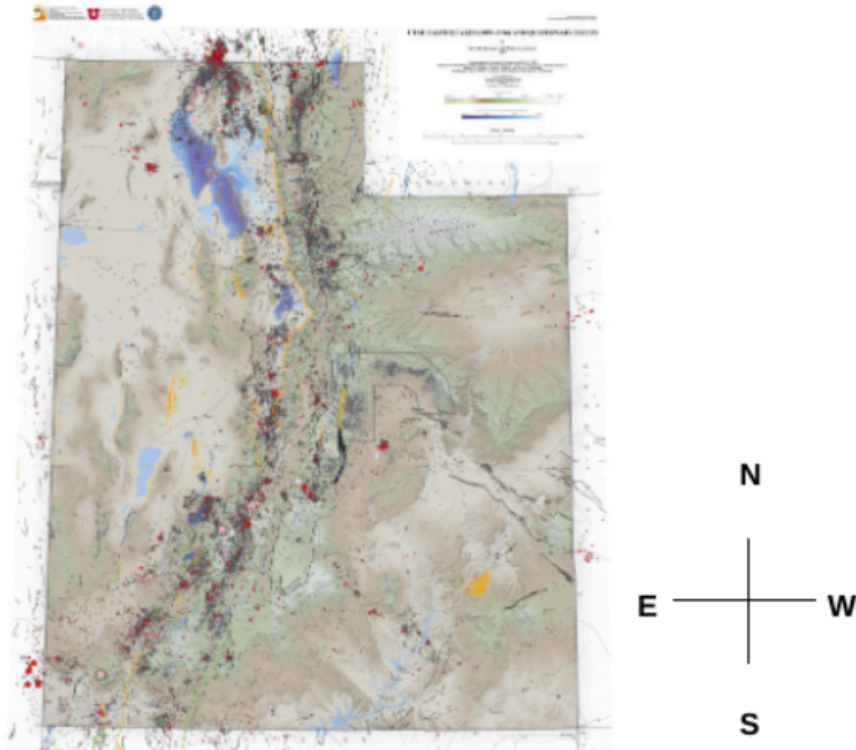


Map B

<https://cfbroadtrip.com/stadium-map>

The University of Utah, Brigham Young University and Utah State University football stadiums were built between 1965 and 1998. They were built during a time when earthquake proof structures may not have been added into the stadium's structure. Buildings are now required to have earthquake proof structures in their structure. On Map B you can see where those stadiums are located on a Utah map. On Map A you can see where earthquakes occur frequently in Utah. Now compare where the stadiums are on Map B to where earthquakes happen frequently in Utah on Map A. Using the information that you have in both maps, would you need to add some type of Earthquake proof structure to these stadiums in order for them to withstand an earthquake? Explain why or why not?

Communicate:

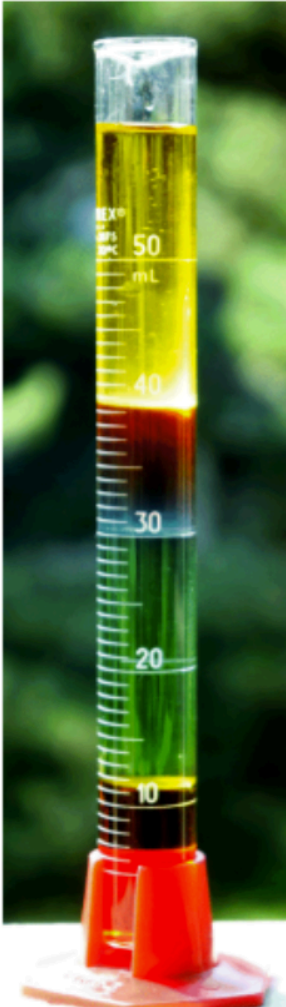


<https://ugspub.nr.utah.gov/publications/maps/m-277.pdf>

Based on the map above , if you have to design a stadium in the southwest region of Utah, what would you add to prevent earthquakes?

7.2.4 Earth's Interior

Phenomenon



Artsy Density Column by Kelvinsong,
https://commons.wikimedia.org/wiki/File:Artsy_density_column.png CC BY

In a science lab, you created a cylinder similar to the photo on the left. The cylinder contained different liquids; maple syrup, water, olive oil, dish soap, vegetable oil, and light corn syrup.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.2.4 Earth's Interior

Develop and use a scale model of the matter in Earth's interior to demonstrate how differences in density and chemical composition (silicon, oxygen, iron, and magnesium) cause the formation of the crust, mantle, and core. (ESS2.A)



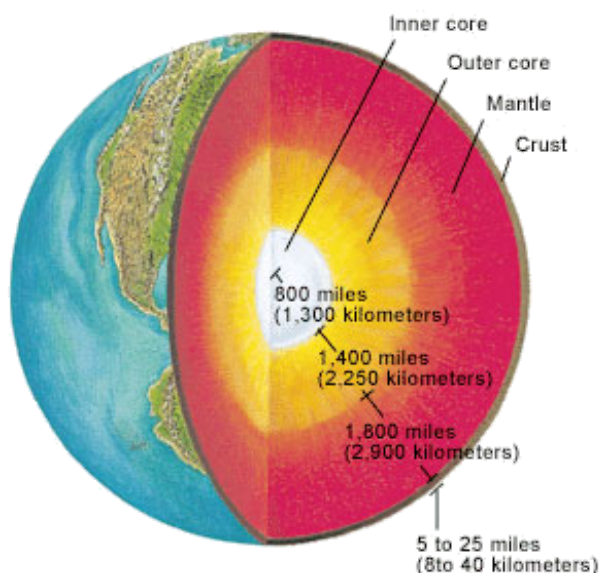
In this section, focus on how different causes affected how the earth formed layers.

“You’re My Density”

A golf ball and a table tennis ball are about the same size. However, the golf ball is much heavier than the table tennis ball. Now imagine a similar size ball made out of lead. That would be very heavy indeed! By comparing the mass of an object relative to its size, we are studying a property called density. Density is the amount of material (mass) contained within a certain amount of space (volume). More dense materials will always form a layer underneath less dense materials. Less dense items float, and more dense items sink.

The materials that make up the Earth follow all of the principles of density that were discussed above. The densest materials in the Earth are located closest to the center, or core, of the Earth. The least dense materials are on top of the Earth. The air, which is the least dense earth material, is located above the Earth.

The Core



Ck12.org, CC BY-SA

The very center part of the Earth is called the core. Earth's core is divided into the inner core and the outer core.

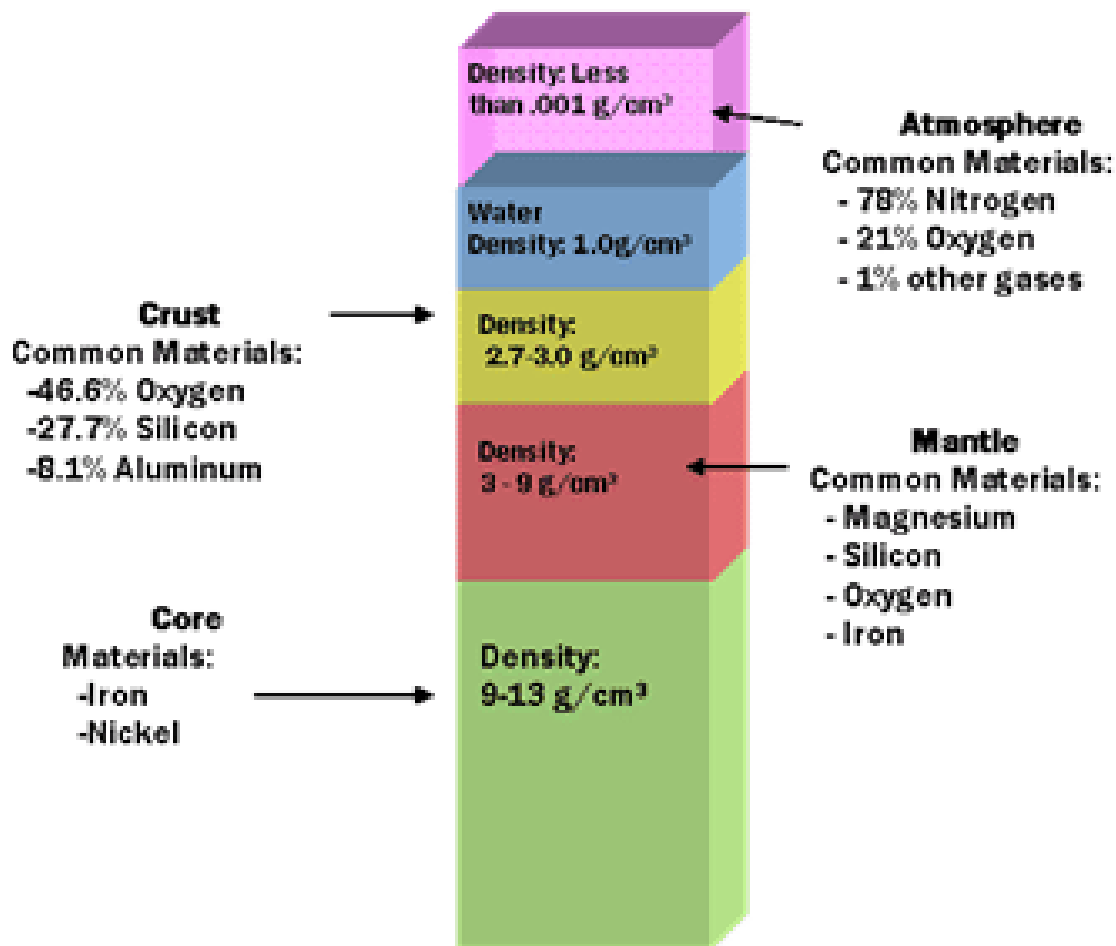
The inner core of the Earth is a solid ball and its chemical composition is made up mostly of iron and nickel. These are very dense materials.

The outer core, like the inner core's chemical composition, is mostly iron and nickel, but the outer core is a liquid. If both the inner and outer

core are made of similar materials then why would the inner core be solid and the outer core be liquid? Temperature and pressure increase as you get closer to the center of the Earth. In order for a solid to become a liquid it must be able to expand. The weight of all of the upper materials on the inner core is so intense that it cannot overcome the pressure and expand to become liquid, therefore, it must remain solid. If the pressure were to ease up, the inner core would expand and liquefy. This means the core of the Earth is tightly compacted. The density of the core ranges between 9 and 13 g/cm³. The core contains about 31% of Earth's total mass.

Scientists use evidence to understand the layers of the Earth, which we cannot see. Seismic waves help scientists to determine which part of the core is solid and which part is liquid. Scientists also study Earth's magnetic field and other properties of the Earth as evidence that the core is made of iron and nickel.

Density and Earth's Layers



Ck12.org, CC BY-SA

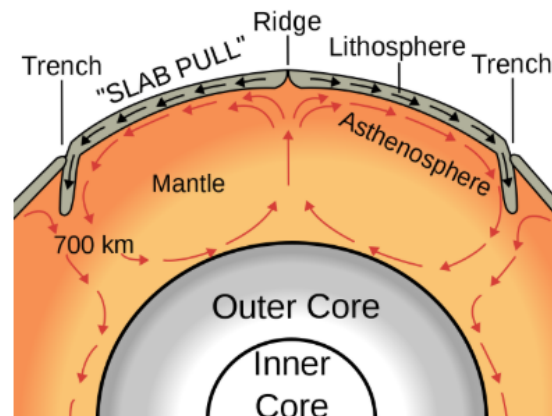
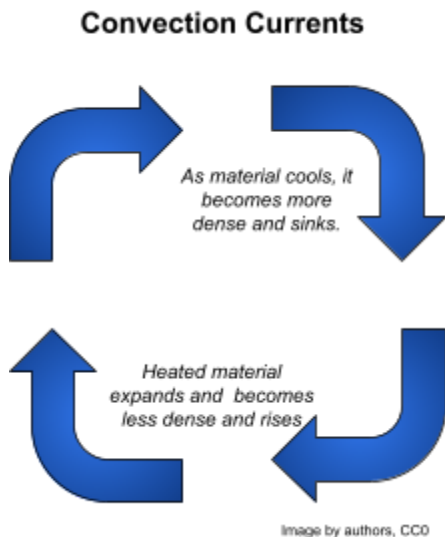
The Mantle

The part of the Earth that lies between the core and the surface is the mantle. It is the thickest layer of the Earth. About 68% of Earth's mass is located in the mantle.

The mantle is located far enough below the crust that no one has been able to go there and study it. Scientists must rely on interpreting data that they have in order to study the mantle. Volcanoes offer some help in studying the mantle. Since magma from volcanoes comes from the mantle, scientists can use lava flows and magma domes to see what materials are present in the mantle. From these sources we know that magnesium, silicon and oxygen are the most common materials found in the mantle making up the majority of its chemical composition.

The mantle is divided into the upper and lower mantle. The lower mantle is about 2,550 km thick and is made up of solid rock. The upper mantle is about 250 km thick and is made of rock that flows very slowly. This rock can best be explained as a semi-solid. It is "pliable", having a consistency like peanut butter. Heat in the lower mantle circulates in convection currents. Convection currents are where heated magma rises up from the bottom of the mantle to near the surface, and then cools down and falls, only to heat up and rise again. Scientists understand convection currents and since the Earth's tectonic plates sit on top of the upper mantle, they ride these currents. It is these currents that are partly responsible for the plate movement in plate tectonics.

The mantle is a fairly dense region of Earth's interior but nowhere near as dense as the core. The density of the mantle ranges between 3 and 9 g/cm³.



"Whole-mantle convection" by Surachit, CC BY-SA 3.0

The Crust

According to current scientific knowledge, the upper part of the Earth where life exists is called the crust. The crust ranges in thickness from about 5 to 100 km. The thickest spots are on land and are called continental crust. The thinner parts of the crust are under the ocean, called oceanic crust. The continental crust is less dense than the oceanic crust.

The most abundant elements making up the chemical composition of the crust are oxygen, silicon, and aluminum. Many other elements are present as well, but in lower quantities.

The density of Earth's crust is between 2.7 and 3.0 g/cm³. Since water has a density of 1.0g/cm³, it is less dense than the crust and it sits on top of the crust and fills in any seams, cracks, and empty areas that may be present.

The Atmosphere

The least dense layer of the Earth is the atmosphere. The atmosphere is the layer of the Earth that contains all of the oxygen, nitrogen, and other gasses in the air around us. It extends several miles above Earth's surface. The reason our atmosphere is above the Earth is because it is far less dense than each of the other layers. The atmosphere has a density of less than .0013g/cm³.

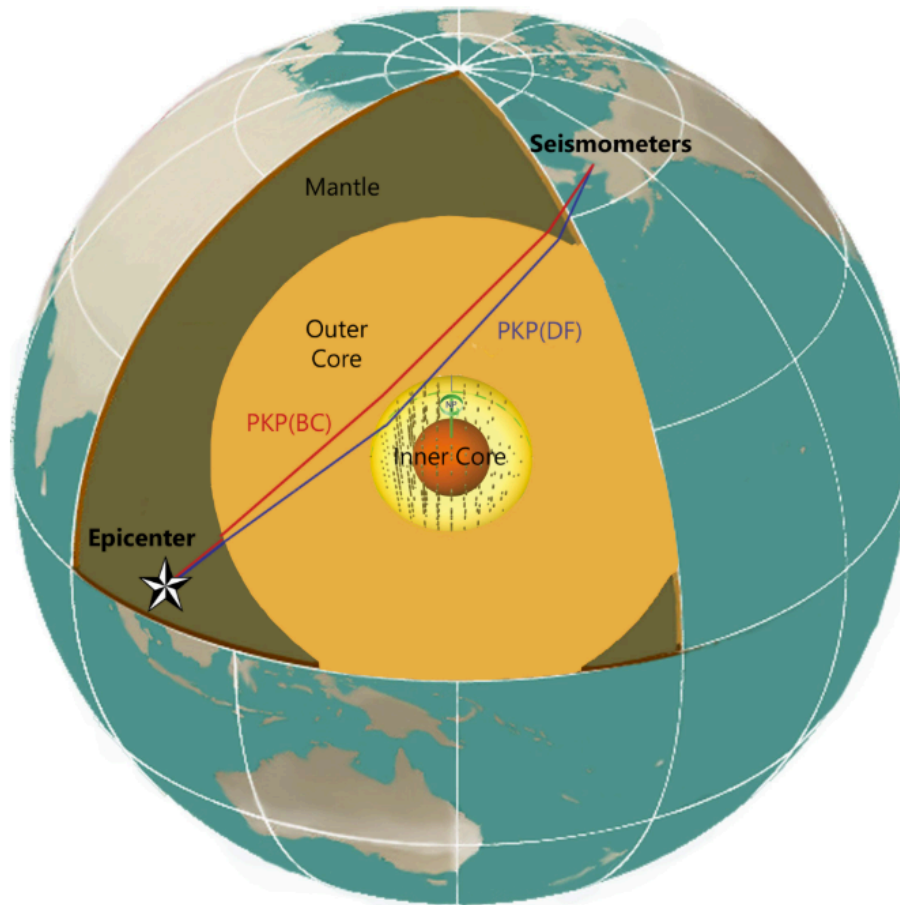
Remember, the densest materials in the Earth tend to be the closest to the core.

Likewise, the least dense materials tend to be located on the surface and above the surface of the Earth.

How Do Scientists Know About the Inside of the Earth?

Seismic waves are another way that scientists can study the Earth's interior without actually visiting there. Seismic waves are the energy waves that are generated by earthquakes. When an earthquake occurs, the energy waves move out from the point of the quake, the epicenter, in much the same way.

There are two types of seismic waves, S waves and P waves. These waves act differently in solids and liquids. When P waves, primary waves, pass through liquids they slow down. They pick up speed when they reach a solid on the other side of the liquid. The S waves, secondary waves, stop completely in liquids. Waves also travel faster in materials that are denser. Scientists look at data that they collect from earthquakes and can determine the composition of Earth's interior by how the waves slow down, speed up, and disappear.



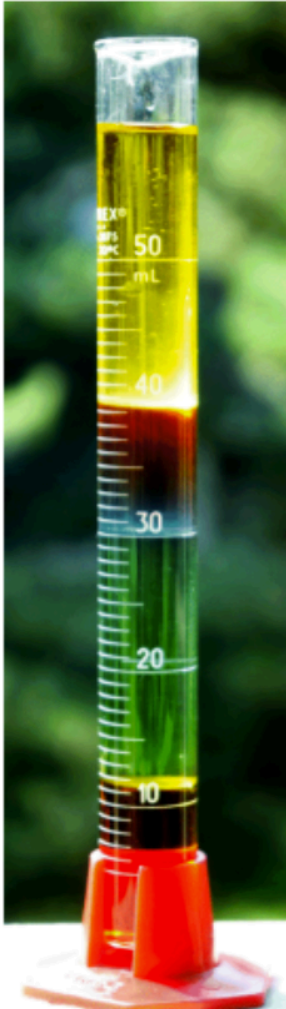
The properties of seismic waves allow scientists to understand the composition of Earth's interior.
Ck12.org, CC BY-SA

Meteorites

Scientists also study meteorites to learn about Earth's interior. Meteorites formed in the early solar system. These objects represent early solar system materials. Some meteorites are made of iron and nickel. They are thought to be very similar to Earth's core. An iron meteorite is the closest thing to a sample of the core that scientists can hold in their hands.

7.2.4 Earth's Interior

Putting it Together



In a science lab, you created a cylinder similar to the photo on the left. The cylinder contained different liquids; maple syrup, water, olive oil, dish soap, vegetable oil, and light corn syrup. You poured your liquids several times, and in several different orders. No matter what you poured the liquids in, they still separated into these different layers.

Artsy Density Column by Kelvinsong,
[https://commons.wikimedia.org/wiki/File:
:Artsy_density_column.png](https://commons.wikimedia.org/wiki/File:Artsy_density_column.png) CC BY

Writing Performance Task:

In the tasks that follow, you will use information to construct an explanation and then develop a model of the earth's layers using what you know about materials and their density.

Gather:

- A. Why do you think the liquids have separated into different layers?

- B. Predict what will happen if you try to pour the different liquids in a different order?

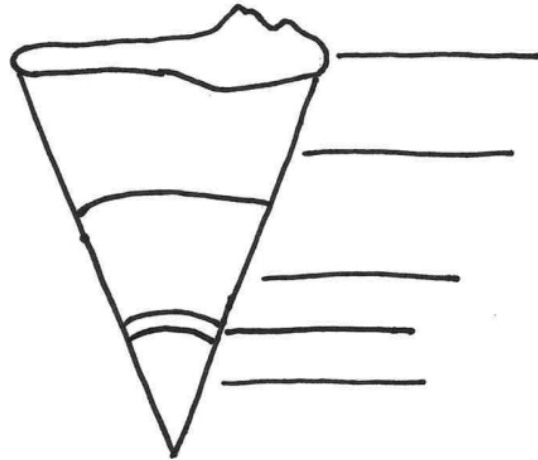
- C. Do the liquids in your cylinder have the same density? Explain your answer.

Reason:

Using the data table below, fill out the model with the increasing density. Be sure to remember which material's density would go with each layer of the Earth.

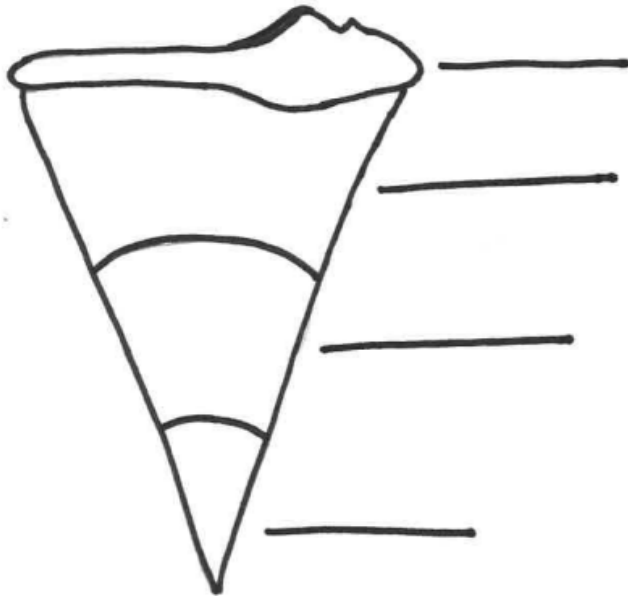
Layer	Depth from center (km)	Density (g/cm ³)
Inner Core	0	12.95
Outer Core	1228	11.05
Mantle	3488	5.00
Upper Mantle	6338	3.90
Crust	6378	2.55

Source: <http://hyperphysics.phy-astr.gsu.edu/hbase/geophys/earthstruct.html>



Communicate:

- A. A new planet is forming in a nearby solar system. Four minerals are being used to form the planet -iron, nickel, magnesium, and aluminum. Use the data from the table below (after question B) to label the model and explain why you choose to put the metals in the model where you did.



- B. Fill out the table below to show which layer of the Earth would match the mineral in the table.

Mineral	Layer	Density
aluminum		2.7 g/cm ³
iron		8 g/cm ³
nickel		8.908 g/cm ³
magnesium		1.738 g/cm ³

7.2.5 Patterns in Plate Tectonics

Phenomenon

world map 3D by kcp4911, <https://flic.kr/p/5mRPYM>, CC BY

Alfred Wegener proposed a theory in the early 1900's. He suggested that continents moved, drifted, from their previous locations to their current location. At one point in time, all of the continents were once connected in one large land mass.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.2.5 Patterns in Plate Tectonics

Ask questions and analyze and interpret data about the patterns between plate tectonics and:

- 1) The occurrence of earthquakes and volcanoes.
- 2) Continental and ocean floor features.
- 3) The distribution of rocks and fossils.

Examples could include identifying patterns on maps of earthquakes and volcanoes relative to plate boundaries, the shapes of the continents, the locations of ocean structures (including mountains, volcanoes, faults, and trenches), and similarities of rock and fossil types on different continents. (ESS1.C, ESS2.B)



In this section, focus your understanding on how analyzing the patterns that we see on Earth today can help explain what has happened in the past and make predictions about the future.

Plates

The crust of the Earth is split into several large chunks called plates. These plates sit on top of the mantle and are able to move. Where two plates interact, it is called a plate boundary. There are three ways that plates can interact so there are three types of plate boundaries. Plates move away from each other at a divergent plate boundary. At a convergent plate boundary they move toward each other. At a transform plate boundary they slide past each other.

Most geological activity takes place at plate boundaries. This activity includes volcanoes, earthquakes, and mountain building and occurs due to plate interactions. Giant slabs of crust and the upper portion of the mantle moving around can create a lot of activity. The features seen at a plate boundary are determined by the direction of plate motion and by the type of crust found at the boundary.

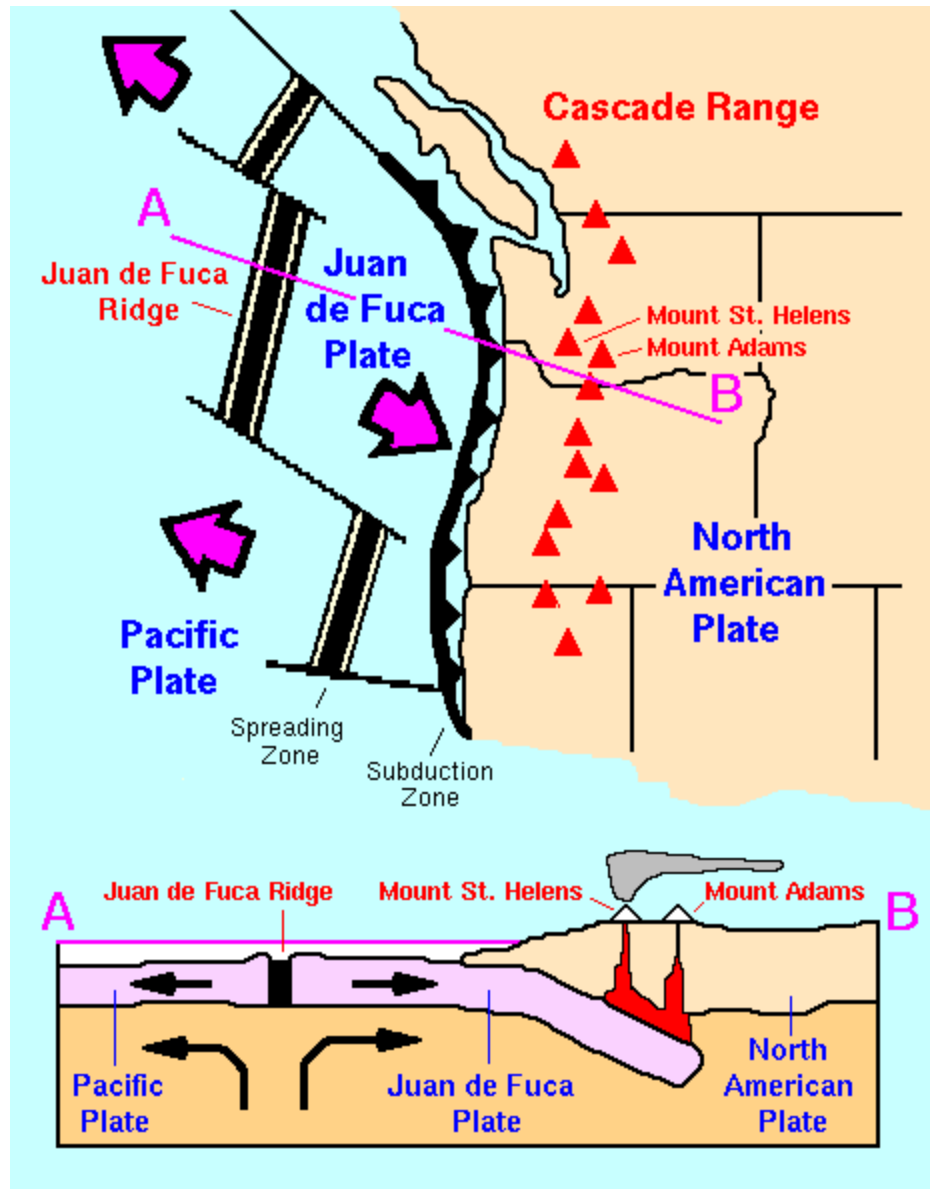
Volcanoes and the Pacific Rim

Volcanoes at plate boundaries are found in several locations including all along the Pacific Ocean basin, primarily at the edges of the Pacific, Cocos, and Nazca plates.

The Cascade Mountains, along the west coast of the North American continent, are a chain of volcanoes at a convergent plate boundary where oceanic crust is moving beneath the continental crust. The reason this is happening is because the oceanic crust is more dense than the continental crust.

The Cascades have been active for 27 million years, although the current peaks are no more than 2 million years old. The volcanoes are far enough north and are in a region where storms are common, so many are covered by glaciers.

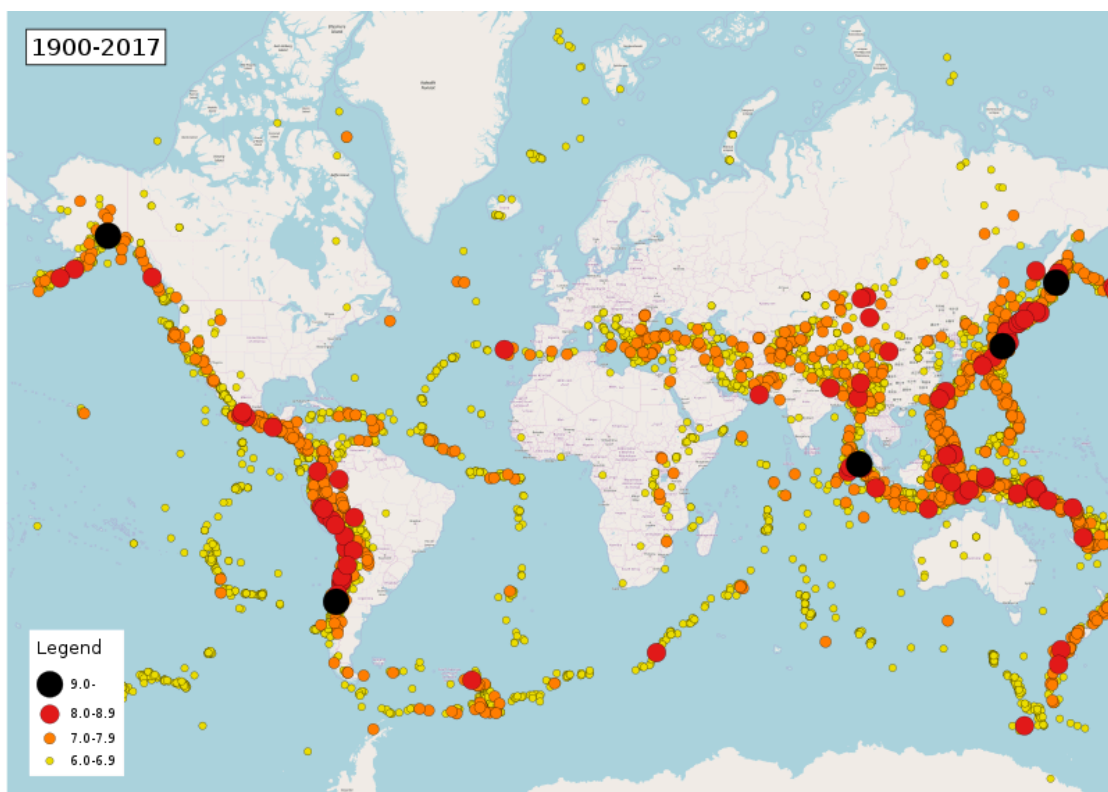
Earthquake Zones



In the image above you can see the Cascade Mountain Range which was formed by volcanoes created from the oceanic crust moving beneath the North American continental crust. (Public Domain)

Nearly 95% of all earthquakes take place along one of the three types of plate boundaries.

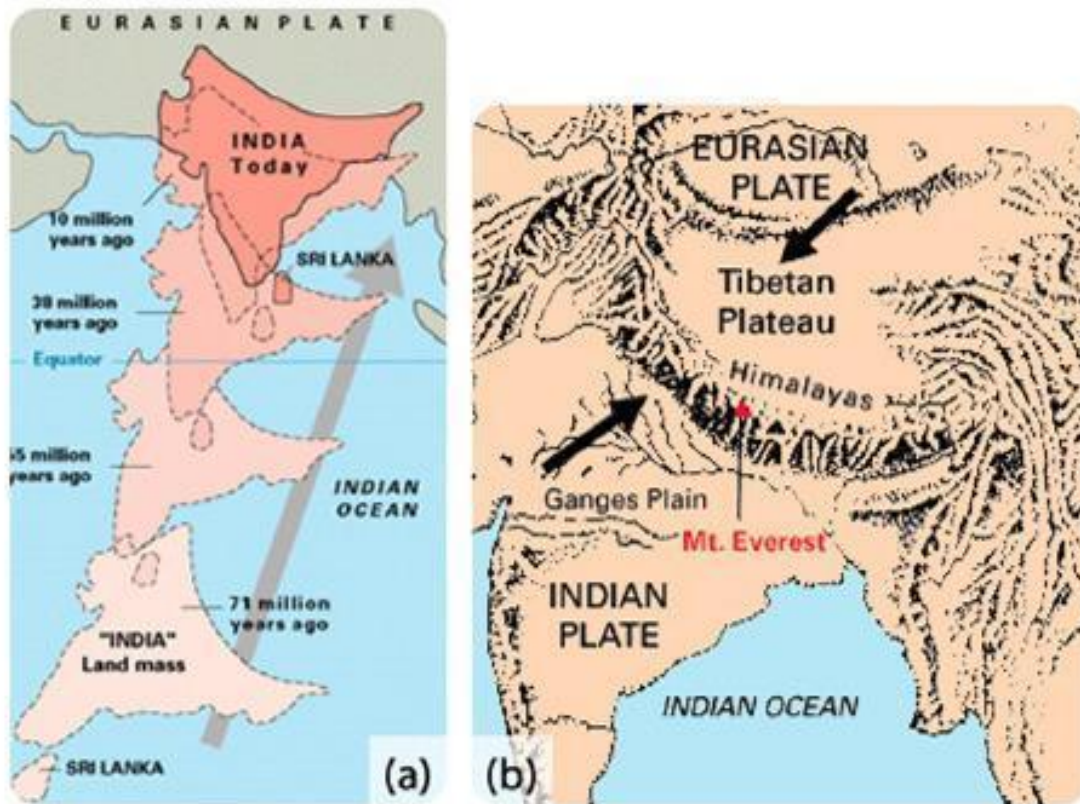
- About 80% of all earthquakes strike around the Pacific Ocean basin because it is lined with plates moving toward (convergent plate boundary) or sliding past each other (transform plate boundary), as seen in the figure.
- About 15% take place in the Mediterranean-Asiatic Belt, where the Indian Plate runs into the Eurasian Plate at a convergent plate boundary.
- The remaining 5% are scattered around other plate boundaries or are intraplate (not at plate boundaries) earthquakes.



Earthquake epicenters since 1900. (Public Domain)

Continental Plates Moving Toward Each Other

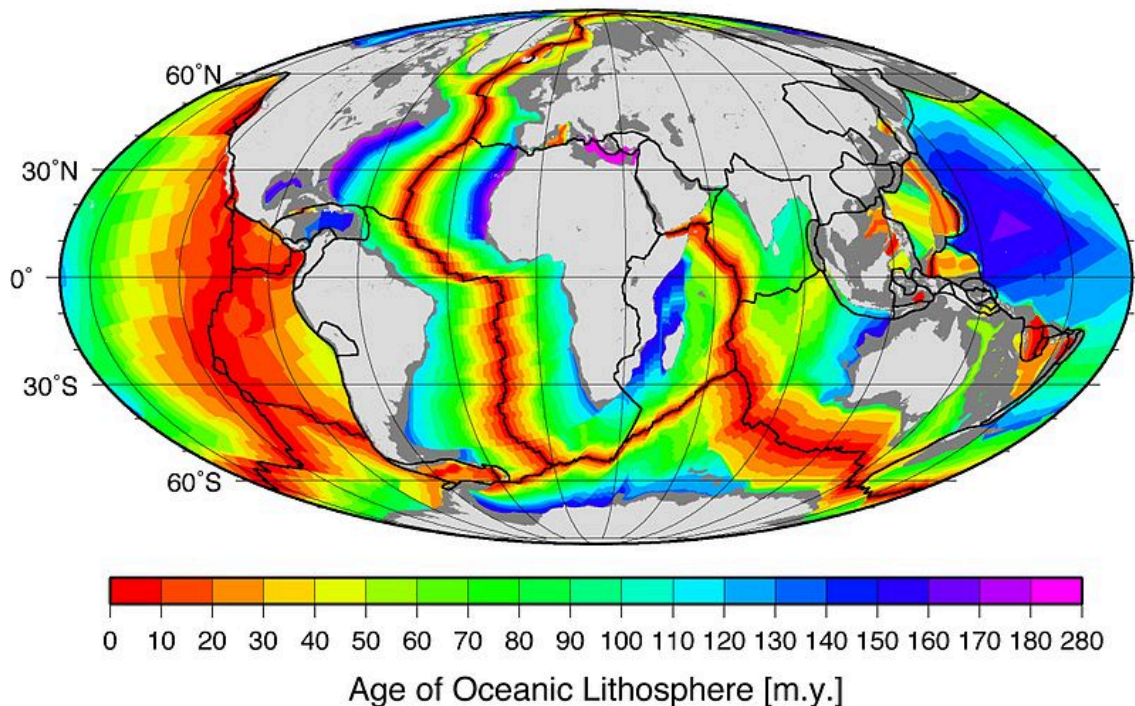
Two continental plates collide and smash upwards to create gigantic mountain ranges. There is currently no mountain range of this type in the western U.S., but we can find one where India is pushing into Eurasia.



- a) The world's highest mountain range, the Himalayas, is growing from the collision between the Indian and the Eurasian plates.
- (b) The crumpling of the Indian and Eurasian plates of continental crust creates the Himalayas.
- (ck12.org, CC BY-SA)

Oceanic Plates Moving Away From Each Other

At plate boundaries where they are moving away from each other, hot mantle rock rises into the space where the plates are moving apart. As the hot mantle rock convects upward it rises higher in the mantle. Lava erupts through long cracks in the ground, or fissures. These boundaries are called divergent plate boundaries. Ocean floor maps show that the youngest seafloor rock is found where these splits happen and oldest seafloor rock is found near the continents.

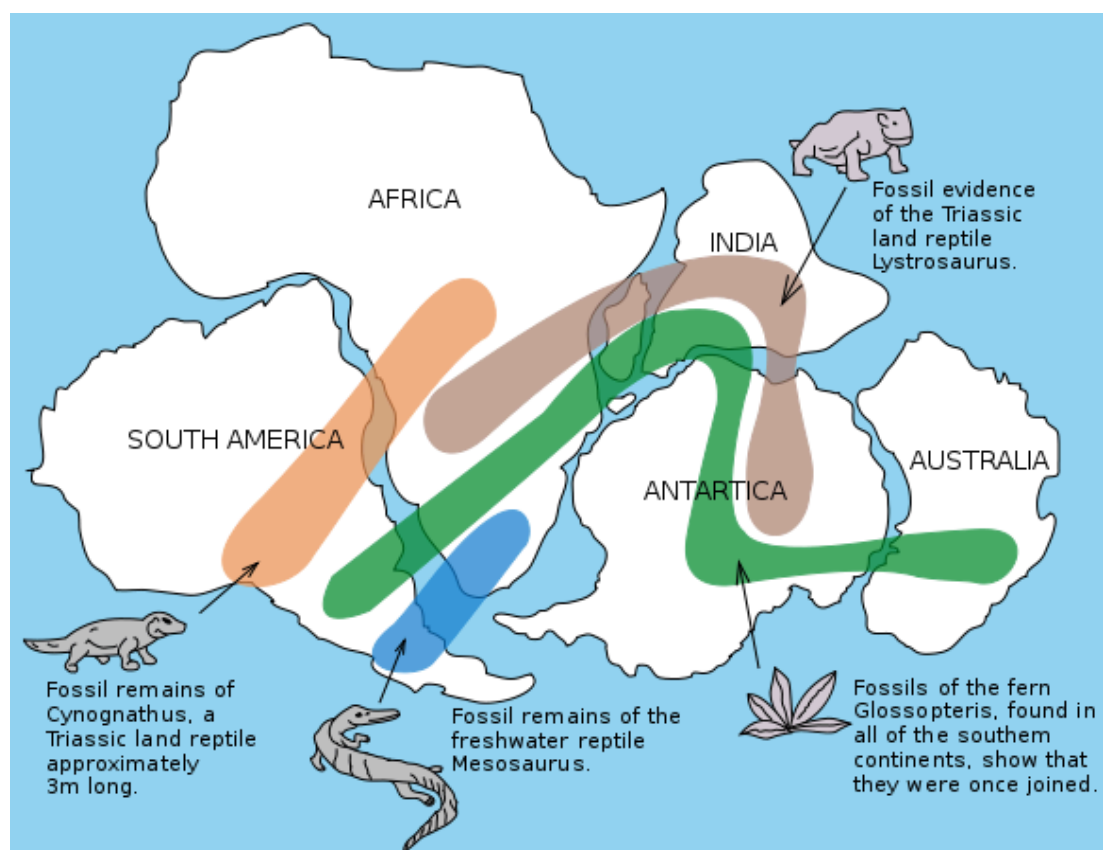


Age of Oceanic Lithosphere by Muller, R.D., M. Sdrolias, C. Gaina, and W.R. Roest,
https://commons.wikimedia.org/wiki/File:Age_oceanic_lithosphere,_Muller_et_al.,_2008.jpg, CC BY-SA

Fossil Evidence for Plate Movement

Fossil evidence for plate movement include the presence of similar or identical species on continents that are now great distances apart. For example, fossils of the therapsid *Lystrosaurus* have been found in South Africa, India, and Antarctica, alongside members of the *Glossopteris* flora, whose distribution would have ranged from the polar circle to the equator if the continents had been in their present position; similarly, the freshwater reptile *Mesosaurus* has been found in only localized regions of the coasts of Brazil and West Africa.

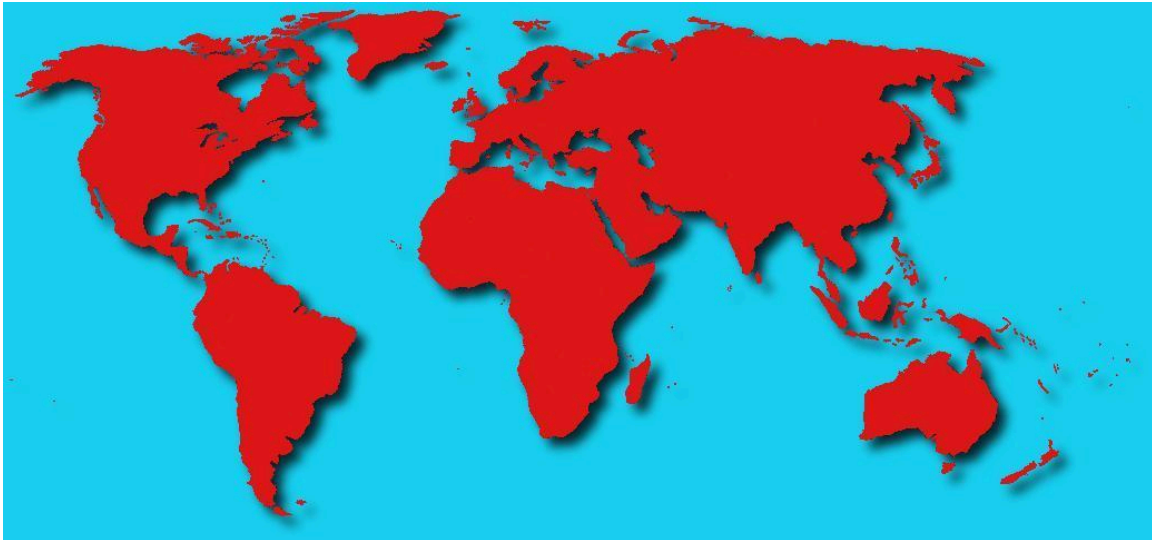
Additional evidence for plate movement is found in the similar geology of adjacent continents, such as the eastern coast of South America and the western coast of Africa which contain rocks of similar ages and types. The polar ice cap of the Carboniferous Period covered the southern end of Pangaea (when all the continents were one large land mass). Glacial deposits of the same age and structure as well as scratches, or grooves, in the rocks are found on many separate continents which would have been together in the supercontinent of Pangaea.



CC0

7.2.5 Patterns in Plate Tectonics

Putting It Together



World Map 3D by kcp4911, CC BY

Alfred Wegener proposed a theory in the early 1900's. He suggested that continents moved, drifted, from their previous locations to their current location. At one point in time, all of the continents were once connected in one large land mass.

Writing Performance Task:

In the task that follows, you analyze and interpret data about Wegner's continental drift theory and modern day plate tectonics theories. You will use the patterns that Wegner and modern day scientists have observed to explain how these theories fit into what we know about plate tectonics today.

Use the following passage and the picture above to complete your task.

Alfred Wegner's Continental Drift Theory

Alfred Wegener (1880-1930) was a German meteorologist and geophysicist who proposed the theory of continental drift in 1912. His theory was based on

evidence from fossils, geological features, and rock strata found on continents that were separated. For example, Wegener found fossils of identical plants and animals on opposite sides of the Atlantic, and noticed that Africa and South America fit like puzzle pieces. Using the evidence that he observed he came up with the theory that the continents were once a large continent and have been moving away from each other. He called the ancient continent "Urkontinent," which is German for "first or original continent". Today, most scientists call this continent Pangaea, which is Greek for "all lands". Scientists at the time thought that his theory was wrong. However, modern day scientists have used these theories to come up with a new theory called plate tectonics.

In the task that follows, you will be analyzing and interpreting data about Wegener's continental drift theory and modern day plate tectonics theories. You will be using the patterns that Wegener and modern day scientists have observed to explain how these theories fit into what we know about plate tectonics today.

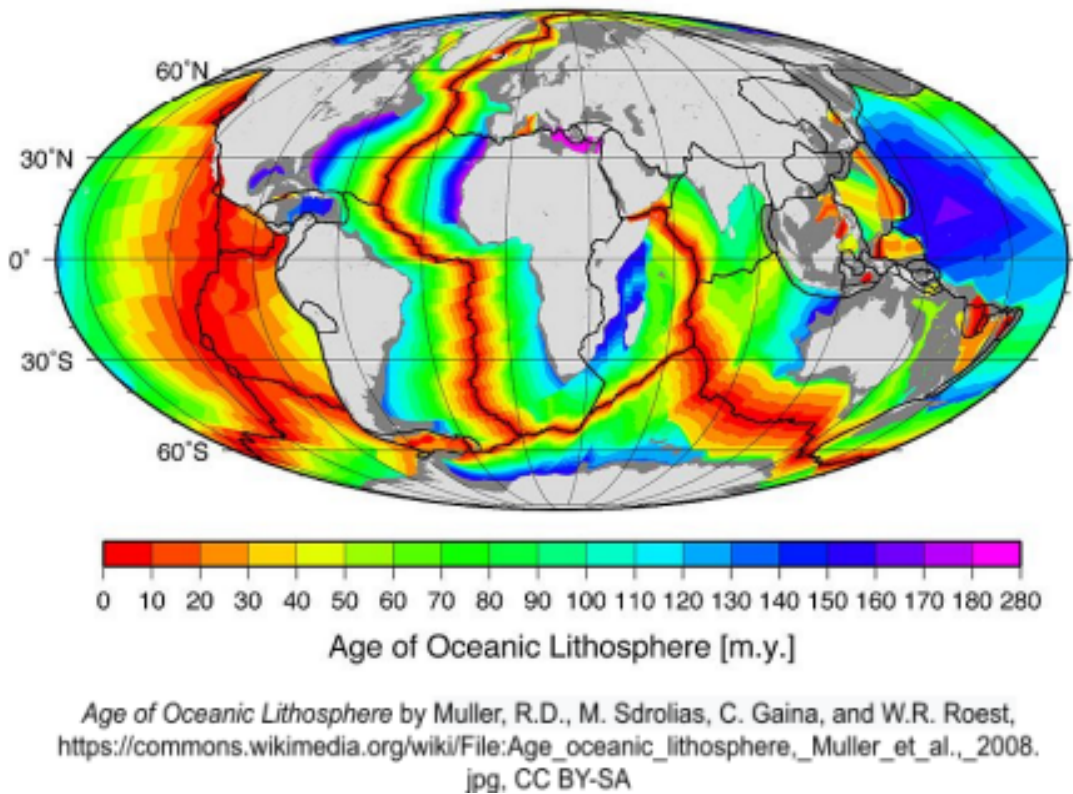
Gather:

- A. What are the patterns you observe in the image above?

- B. How could these patterns provide evidence to support Alfred Wegener's claim?

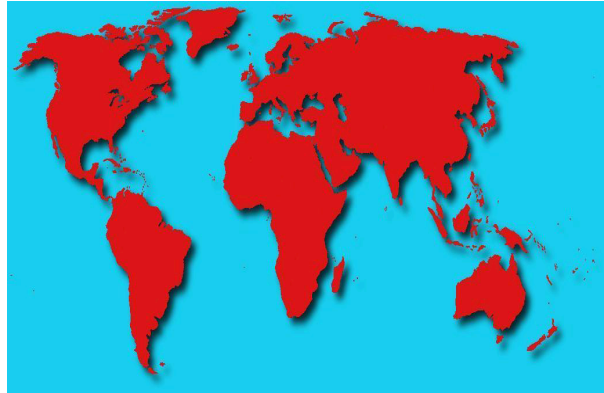
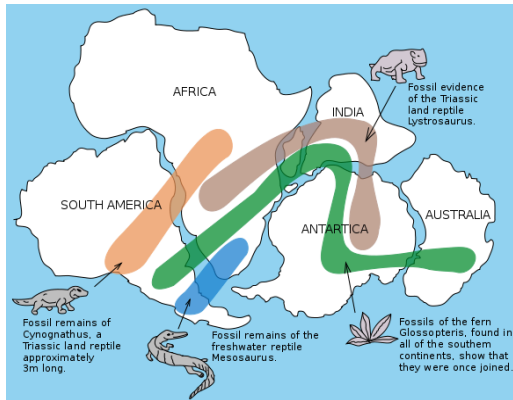
- C. What are the patterns scientists use as evidence to prove the continents are moving?

Reason:



Using the picture above, explain what patterns in the data would tell modern day scientists that the plates are moving and the surface of the Earth is changing?

Communicate:



A. Construct an argument using these two pictures above, to support the evidence of Alfred Wegener's claim that continents were once connected into one large land mass.

B. How does his theories support modern day plate tectonics theories?

7.2.6 How Old is the Earth

Phenomenon



You and your family went on a hike in a canyon similar to the one pictured above. The walls of the canyon had layers of different colored sedimentary rocks. Some of these layers looked older than others. The layers appeared to be made up of different materials, such as larger pieces of rock inside the layer or pieces of rock so small that it made it look like mud. A few layers even had some shells sticking out of the rock. The canyon had a v-shape to it with a river running through it.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.2.6 How Old is the Earth

Make an argument from evidence for how the geologic time scale shows the age and history of Earth. Emphasize scientific evidence from rock strata, the fossil record, and the principles of relative dating such as superposition, uniformitarianism and recognizing unconformities. (ESS1.C)



In this section, focus on how scientists use the geologic time scale and to make an argument for the age of the earth.

Clues from Fossils

Fossils are our best form of evidence about Earth's history of life. Fossils give us clues about past climates, the motions of plates, and other major geological events. Scientists use what we know about the present to understand the past.

What we know about a type of organism that lives today can be applied to past environments as well as ancient organisms. We call this principle uniformitarianism. Scientists assume that natural laws and processes that operate on Earth today, operated the same way back millions of years ago.

History of Life on Earth

The fossil record illustrates how life on Earth has changed over time. Fossils in relatively young rocks resemble the types of animals and plants that are living today. In general, fossils in older rocks are less similar to modern organisms.

We would know very little about the organisms that came before us if there were no fossils. Modern technology has allowed scientists to reconstruct images and learn about the biology of extinct animals like dinosaurs.

Environment of Deposition

Geologists can determine whether a region was terrestrial (on land), freshwater, or marine (ocean) or even if the water was shallow or deep by what type of organism created the fossil.

Geologists can further find clues about the original environment by studying the type and structure of the rock in which the fossil was found. The type of rock may give clues to whether the rate of sedimentation was slow or rapid, which scientists can infer from the rate of erosion and available materials.

The amount of wear and breakage of a fossil allows scientists to learn about what happened to the region after the organism died; for example, whether it was exposed to wave action.

Geologic History



Fossils in a beach wall, by Brocken Inaglory, CC BY-SA

The presence of marine organisms in a rock indicates that the area where the rock was deposited was once on the bottom of the ocean. Sometimes fossils of marine organisms are found on tall mountains indicating that rocks that formed on the seabed were pushed up, uplifted. The image to the right is an example of what marine organisms fossils may look like in rock that has been uplifted.

The photo on the next page is a sand dune in Coral Pink Sand Dunes State Park, Utah. Here wind has caused cross-bedding in sand. Cross-bedding is due to changes in wind direction. There are also ripples caused by the wind waving over the surface of the dune.



Sand dune in Coral Pink Sand Dunes State Park, Utah.

Ck12.org, CC BY-SA

This doesn't look exactly like the outcrop of Navajo sandstone found in Zion National Park, but if you could cut a cross-section into the face of the dune it would look very similar.

Since we can observe wind forming sand dunes with these patterns now, we have a good explanation for how the Navajo sandstone formed. The Navajo sandstone is a rock formed from ancient sand dunes. The rock shows that the ancient wind direction changed from time to time.

This is just one example of how geologists use observations they make today to unravel what happened in Earth's past. Rocks formed from volcanoes, oceans, rivers, and many other features are deciphered by looking at the geological work those features do today.

Sedimentary Rock Rules

Sedimentary rocks follow certain rules.

1. **Superposition:** Sedimentary rocks are formed with the oldest layers on the bottom and the youngest on top. The rocks that got there first will be located at the bottom of the layers.

2. Sediments are deposited horizontally, so sedimentary rock layers are originally horizontal. For example, some volcanic rocks, such as ash, fall and cover the ground horizontally.
3. Unconformities are gaps in time shown in the geologic rock record. This means older sedimentary rocks layers are in contact with younger sedimentary rock layers and some layers are missing due to weathering and erosion.

Since sedimentary rocks follow these rules, they are useful for seeing the effects of stress and other geologic processes on rocks. Sedimentary rocks that are not horizontal must have been deformed by these processes.

You can trace the deformation a rock has experienced by seeing how it differs from its original horizontal, oldest-on-bottom position. This deformation produces geologic structures such as folds, joints, and faults.

Unconformities

An unconformity represents time during which no sediments were preserved in a region. The local record for that time interval is missing and geologists must use other clues to discover that part of the geologic history of that area. The image below is an example of an unconformity discovered by James Hutton in the 1700's.



Hutton's Unconformity is a name given to various famous geological sites in Scotland identified by the 18th-century Scottish geologist James Hutton as places where the junction between two types of rock formations can be seen. This geological phenomenon marks the location where rock formations created at different times and by different forces adjoin.

Using a combination of superposition, uniformitarianism and recognizing unconformities, as well as specific fossils and layers of rock, geologists have constructed a well-defined timeline of Earth's relative geologic history. With information gathered from all over the world, estimates of rock and fossil ages have become increasingly accurate.

7.2.6 How Old is the Earth

Putting It Together



Rafters in Grand Canyon National Park, NPS Photo / Mark Leliouch Public Domain

You and your family went on a hike in a canyon similar to the one pictured above. The walls of the canyon had layers of different colored sedimentary rocks. Some of these layers looked older than others. The layers appeared to be made up of different materials, such as larger pieces of rock inside the layer or pieces of rock so small that it made it look like mud. A few layers even had some shells sticking out of the rock. The canyon had a v-shape to it with a river running through it. The guide on your hike explained that in order to see the different layers in the canyon, the river cut through the sedimentary rocks to its current location.

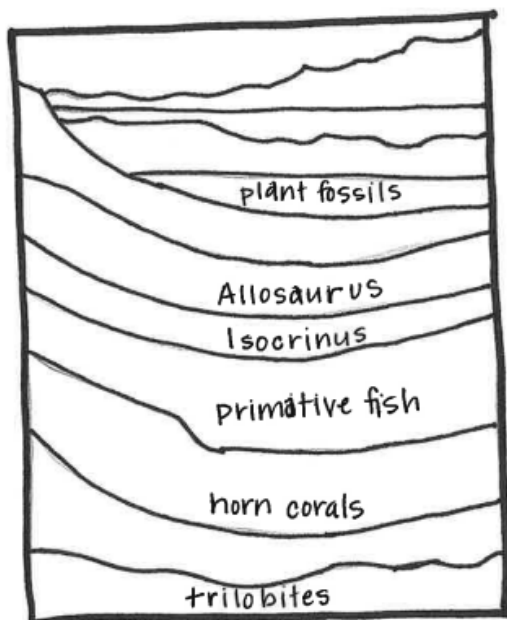
Writing Performance Task:

In the tasks that follow, you will be engaging in an argument using evidence you have gathered to explain how the layers and features of the earth are formed and how you would know the ages of the layers, features and fossils.

Gather:

- A. Which layer in the canyon was the oldest? Explain your answer.
- B. Which layer was the youngest? Explain your answer.
- C. How could you tell if an unconformity is present in the canyon?

Reason:



Look at this picture of the layers of rock. The layers have fossils in them. List the fossils from oldest to youngest. Explain why you put the fossil in that order.

Communicate:



Construct an argument from the evidence you gathered in the chapter to explain how the layers in the canyon were formed, how the canyon was cut from the layers and how long it took for the canyon to form.

Strand 3: Structure and Function of Life

Chapter Outline

- 3.1 CELLS ARE THE BUILDING BLOCKS OF LIFE (7.3.1)
- 3.2 FUNCTIONS OF CELL PARTS (7.3.2)
- 3.3 ORGANIZATION OF THE HUMAN BODY (7.3.3)

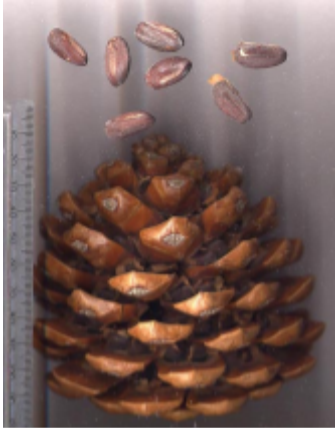


(Pixabay.com. CC0)

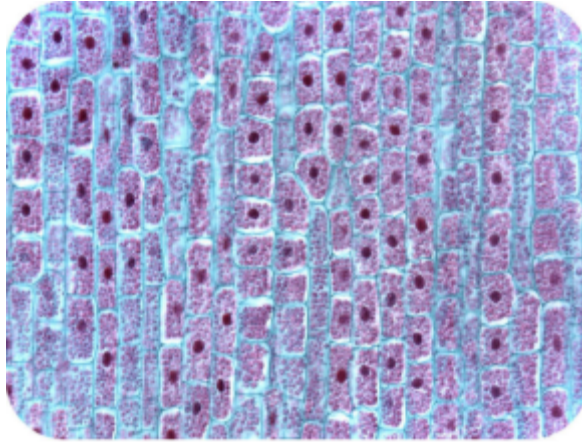
All living things (or things that were once living) are made of smaller structures called cells, which function to meet the needs of survival. The basic structural unit of all living things is the cell. Parts of a cell work together to function as a system. Cells work together and form tissues, organs, and organ systems. Organ systems interact to meet the needs of the organism.

7.3.1 Cells are the Building Blocks of Life

Phenomenon



Pinus pinea (Stone Pine) cone with pine nuts by MPF, CC BY-SA



Ck12.org, CC BY-SA



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Seeds from a pinecone and alloy metals such as coins both look very different when viewed under a microscope. When living things are viewed under a microscope, you can see they are each made of tiny compartments called cells. Non-living things are not.

Observations and Wonderings

What do you observe about the two different types of things in the picture?

What do you wonder about the two things being different?

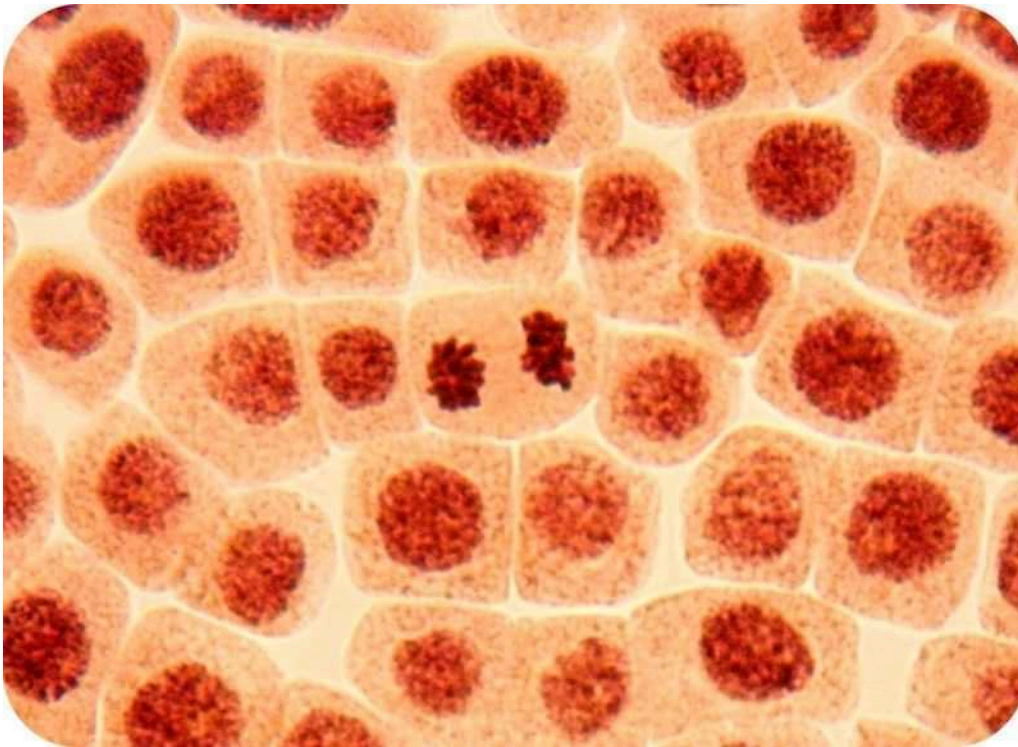
7.3.1 Cells are the Building Blocks of Life

Plan and carry out an investigation that provides evidence that the basic structures of living things are cells. Emphasize that cells can form single-celled or multicellular organisms and that multicellular organisms are made of different types of cells. (LS1.A)



In this section, focus on understanding how the structure and function of the tiny cells contribute to the structure and function of the whole organism

Introduction to Cells



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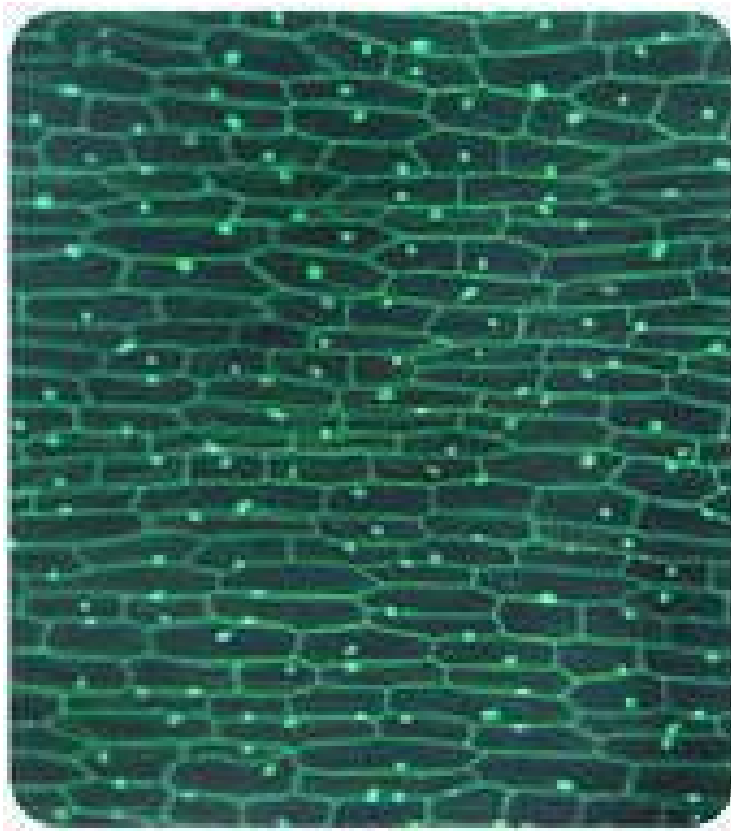
Cells make up all living things, including your own body. The image to the left shows a group of cells. Not all cells look alike. Cells can differ in shape and sizes. And the different shapes usually mean they do different things.

A cell is the smallest structural and functional unit of an organism. Some organisms, like bacteria, consist of only one cell. Large organisms, like humans,

consist of trillions of cells. Compare a human to a banana. On the outside, they look very different, but if you look close enough you'll see that their cells are actually very similar.

Observing Cells

Most cells are so small that you cannot see them without the help of a microscope. It was not until 1665 that English scientist Robert Hooke invented a basic light microscope and observed cells for the first time, by looking at a piece of cork, which he got from a tree. You may use light microscopes in the classroom. You can use a light microscope to see cells like the image below.



The outline of onion cells are visible under a light microscope.

Ck12.org, CC BY-SA

Cell Theory

In 1858, after using microscopes much better than Hooke's first microscope, Rudolf Virchow developed the hypothesis that cells only come from other cells. For example, bacteria, which are single-celled organisms, divide in half (after they grow some) to make new bacteria. In the same way, your body makes new cells by dividing the cells you already have. In all cases, cells only come from cells that have existed before. This idea led to the development of one of the most important theories in biology, the cell theory.

Cell theory states that:

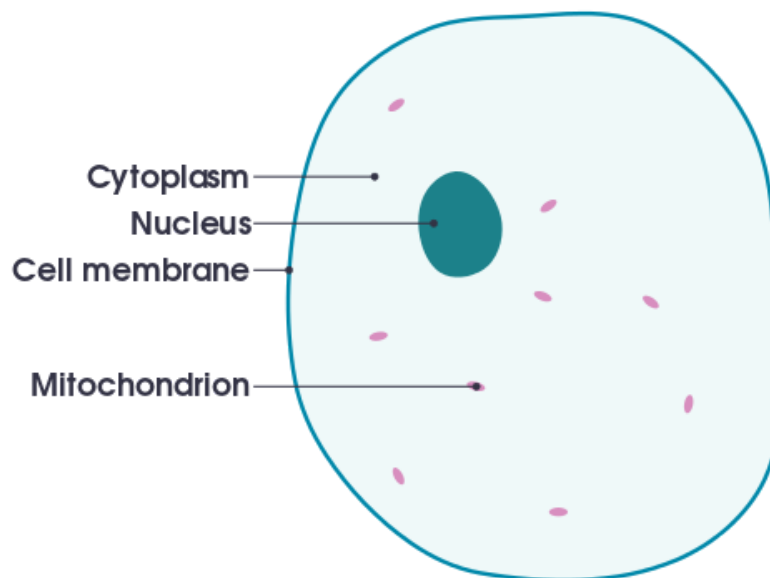
1. All organisms are composed of cells.
2. Cells are alive and the basic living units of organization in all organisms.
3. All cells come from other cells.

As with other scientific theories, many hundreds, if not thousands, of experiments support the cell theory. Since Virchow created the theory, no evidence has ever been identified to contradict it.

Single-celled vs Multicellular Organisms

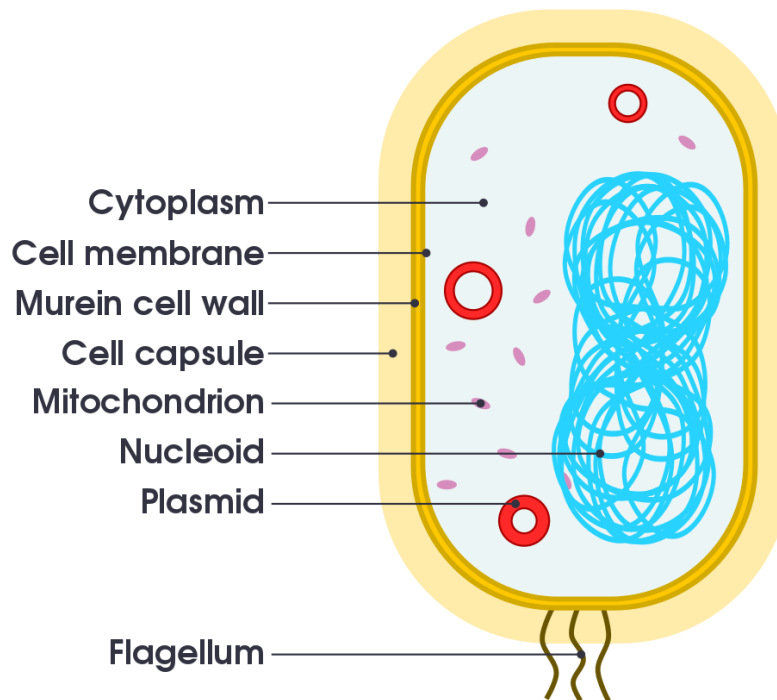
Single-celled (unicellular) organisms like bacteria are composed of just one cell, whereas multicellular organisms can be composed of trillions of cells. Multicellular organisms include protists (though single-celled protists also exist), fungi, plants and animals. Most plant and animal cells are between 1 and 100 μm (micrometer) in size and therefore can only be observed under the microscope.

The one cell of a unicellular organism must be able to perform all the functions necessary for life. These functions include metabolism, homeostasis, and reproduction. Specifically, these single cells must transport materials, obtain and use energy, dispose of wastes, and continuously respond to their environment. The cells of a multicellular organism also perform these functions, but they may do so in collaboration with other cells.



Simple diagram of animal cell

by domdomegg, CC-BY



Simple diagram of bacterium
by domdomegg, CC-BY

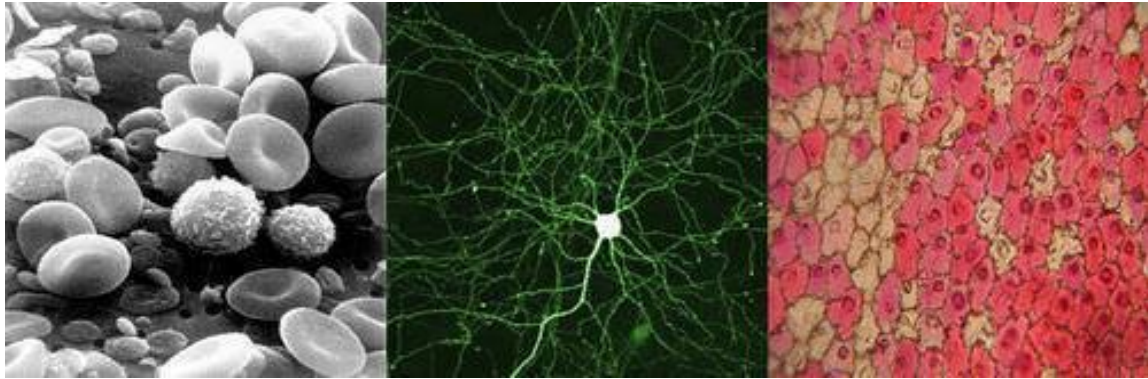
Compare and contrast the unicellular organism to the right and the cell found in a multicellular organism above. What similarities and differences do you see?

Specialized Cells for Multicellular Organisms

Although cells share many of the same features and structures, they also can be very different. Each cell in your body is designed for a specific task. In other words, the cell's function is partly based on the cell's structure. For example:

- Red blood cells are shaped with a pocket that traps oxygen and brings it to other body cells. These cells also have a large surface area that aids in oxygen transfer.
- Nerve cells are long and stringy in order to form a line of communication with other nerve cells, like a wire. Because of this shape, they can quickly send signals, such as the feeling of touching a hot stove, to your brain.
- Skin cells are flat and fit tightly together to protect your body.

As you can see in the images below, cells are shaped in ways that help them do their jobs. Multicellular (many-celled) organisms have many types of specialized cells in their bodies.



ck12.org, CC BY-SA

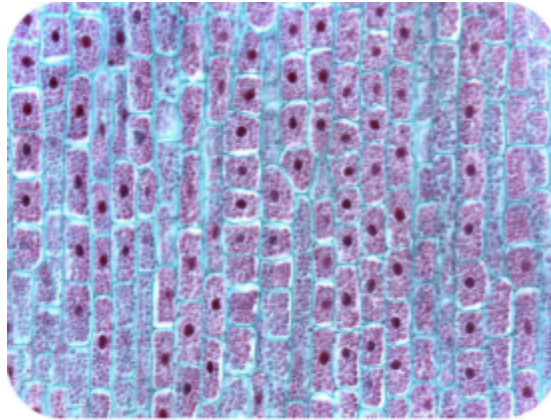
Red blood cells (*left*) are specialized to carry oxygen in the blood. Neurons (*center*) are shaped to conduct electrical impulses to many other nerve cells. These epidermal cells (*right*) make up the “skin” of plants. Note how the cells fit tightly together.

7.3.1 Cells are the Building Blocks of Life

Putting It Together



Pinus pinea (Stone Pine) cone with pine nuts by MPF, CC BY-SA



Ck12.org, CC BY-SA



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Seeds from a pinecone and alloy metals such as coins both look very different when viewed under a microscope. When living things are viewed under a microscope, you can see they are each made of tiny compartments called cells. Non-living things are not.

Writing Performance Task:

In the tasks that follow, you will construct an explanation about multicellular vs unicellular organisms. You will observe the structures of different organisms to determine if they are multicellular or unicellular organisms. You will also provide evidence that all living organisms are made of cells.

Gather:

- A. The smallest unit of an organism is the _____
- B. Using the images below, determine if each organism is unicellular or multicellular.

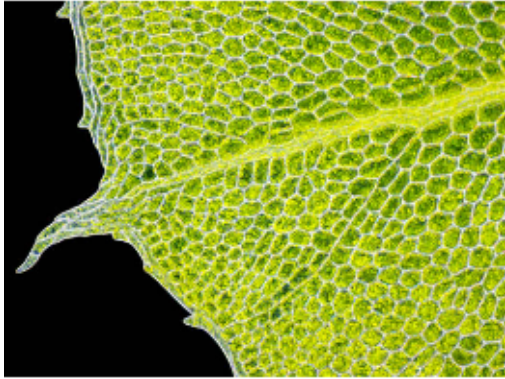


Image A

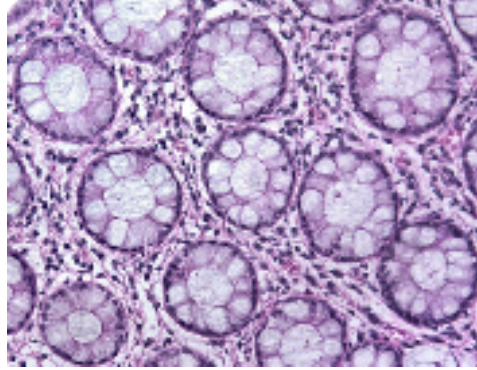


Image B



Image C

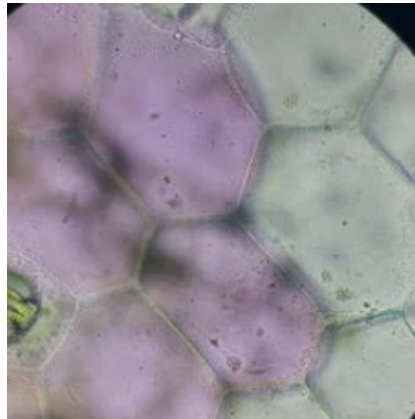


Image D

Images used free from Pexels

- C. Which organism(s) are unicellular: _____
- D. Which organism(s) are multicellular: _____

Reason:

Compare and contrast the similarities and differences between unicellular organisms and multicellular organisms:

Similarities between unicellular and multicellular	Differences between unicellular and multicellular

Communicate:

- A. Multicellular organisms are made of many different types of cells. Why do they need these different types of cells?

- B. Provide evidence to support the statement that all living things are made up of cells.

7.3.2 Function of Cell Parts

Phenomenon



All living things must have energy to survive. The sheep in this picture are eating grass to get energy to live. Grass does not eat, it converts sunlight energy into chemical energy, in the form of sugar. To do this the two organisms need different bodies and different cells but also have many things in common.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.3.2 Functions of Cell Parts

Develop and use a model to describe the function of a cell in living systems and the way parts of cells contribute to cell function. Emphasize the cell as a system, including the interrelating roles of the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall. (LS1.A)

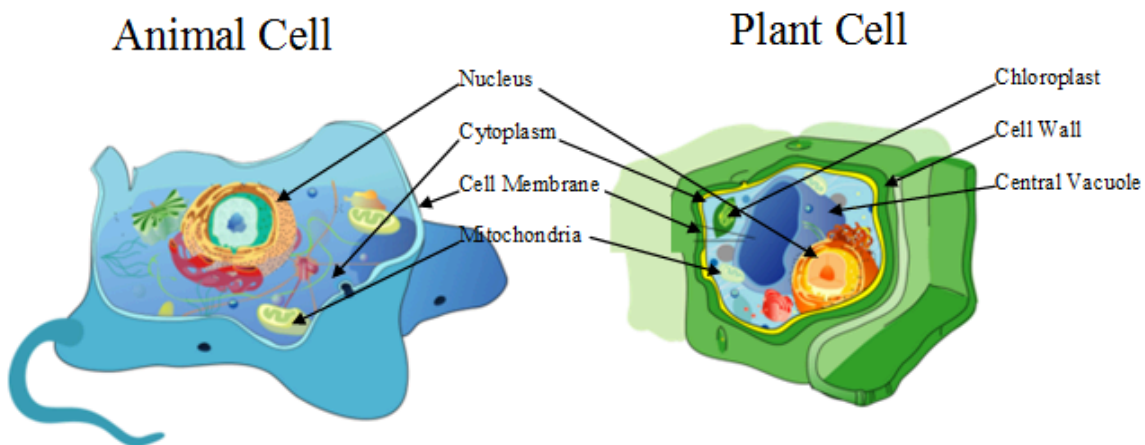


In this section, focus on understanding how different cell parts contribute to the function of the cell.

Organelles

Cells are defined as the basic unit of all living things. This means that the cell is the smallest unit that can still be considered living. Cells are a working system of parts just as a bicycle is a working system of parts. You can break a bicycle down into smaller parts, but it will no longer function as a bicycle. If a cell were broken down further, it would no longer be considered a living thing.

But what makes up a cell? Cells are made up of smaller structures called organelles. Organelles are common to most cells. The word organelle means “little organs”. Each organelle has its own function or job in the cell to keep the cell alive. The following information describes the structure and function of some organelles in cells:



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Cell Membrane

Magnified Cell Membrane

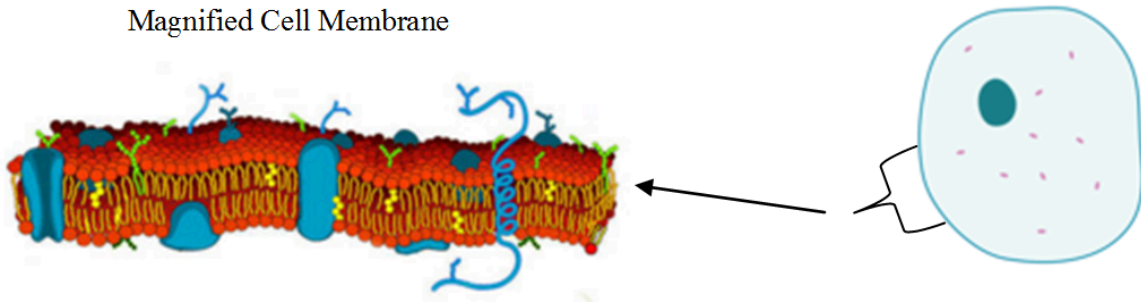
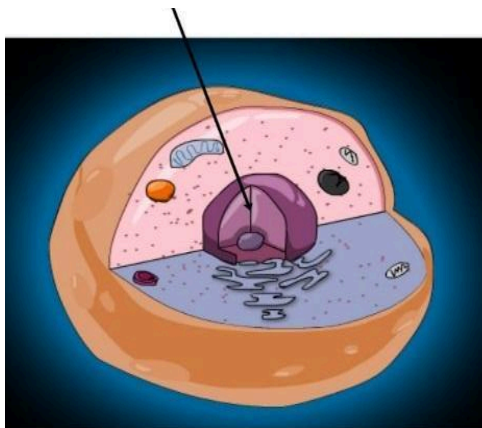


Image adapted from CK-Foundation, CC BY

The cell membrane is the layer surrounding the cell. The function or job of the cell membrane is to hold all of the cell's contents together and to control what goes in and out of the cell. The cell membrane is semipermeable, which means that some things can freely cross it and some things cannot. This helps the membrane control what can or cannot cross into and out of the cell. Food, water, oxygen and waste products are examples of particles that need to pass the membrane to get into and out of the cell. Both plant and animal cells have a cell membrane. Plants also have another layer called the cell wall that you will learn about later.

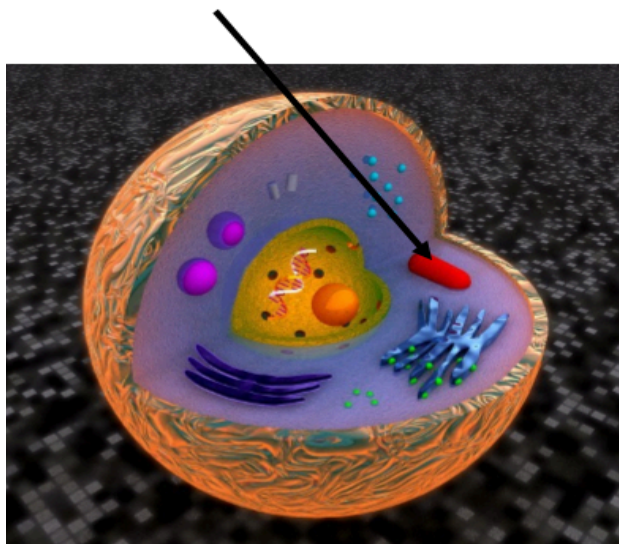
Nucleus



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The nucleus is the control center of the cell. It contains the genetic information (DNA) and controls all the activities of the cell.

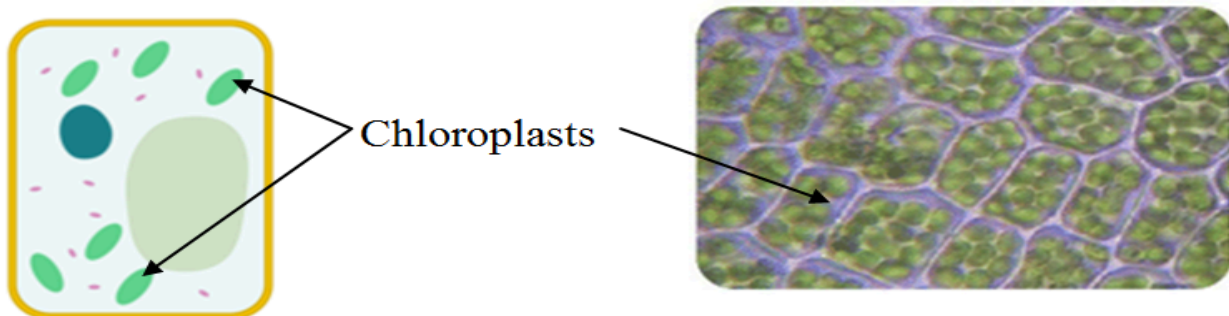
Mitochondria



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All cells need energy to survive. The mitochondria is sometimes called the powerhouse of the cell. In the mitochondria, small molecules of food are broken apart. The energy that was holding the molecules together is released for our use. Food is the energy source for our bodies. Just as we use the stored energy in wood to make a fire to heat some water, the food that we eat needs to be broken down in order to release energy so that our bodies can function. Mitochondria are responsible for doing this in cells. The process whereby food is broken down to release energy is called cellular respiration. Both plant and animal cells break down food particles to create energy, plant cells can make the food particles in chloroplasts, animals must eat organisms that have chloroplasts or eat other animals that ate organisms with chloroplasts.

Chloroplast

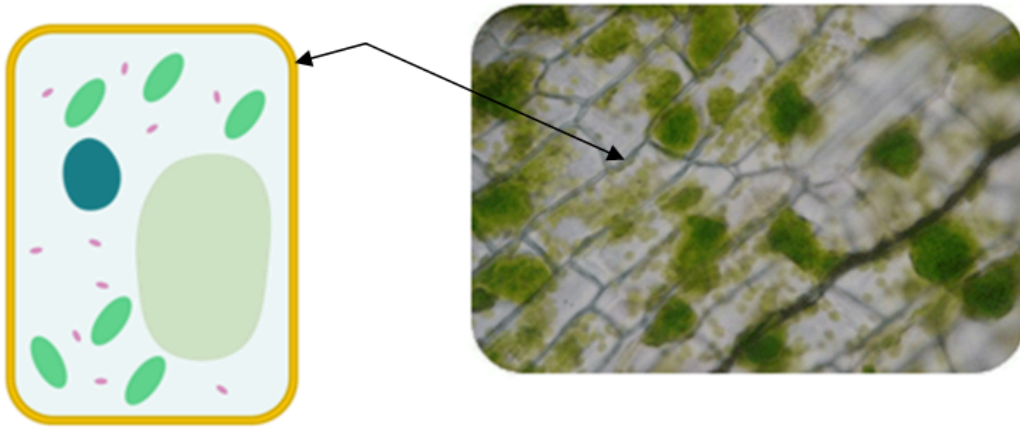


found in plant cells and some protists, but not in animal cells. These green structures make food for the plant by converting the energy of sunlight into sugar using carbon dioxide and water. Plant cells still have mitochondria too, after

photosynthesis, they break down the food particles made by chloroplasts using their mitochondria.

Cell Wall

Plant cells need a cell wall. The cell wall is a rigid outer barrier that supports and protects the cell. Plants do not have a skeleton to offer the strength and support like an animal does. Also because of the cell walls plants are more rigid and don't move in as many ways as animals.



The cell wall in plant cells is the outermost layer of the cell.

ck12.org, CC BY-SA

The Cell as a System

Each organelle in the cell plays a key role in helping the cell to survive. The nucleus tells the organelles what to do and when to do it. The cell membrane allows materials in and out that the organelles need to do their jobs. The chloroplasts in the plant cell produce the food that plants need to survive. The mitochondria takes the food that is produced by the chloroplasts or let in by the cell membrane and releases the energy stored inside the food. The energy is then used by the cell to do other jobs. The cell wall in plants helps protect the cell and provides strength for the plant to grow tall. How are these functions of the organelles similar to the functions of other systems you know?

How are plant and animal cells different?

Even though plants and animals are both made of cells, plant cells differ in some ways from animal cells.

First, in addition to a cell membrane, plant cells have a cell wall that supports and makes the cell somewhat rigid. Plant cells need this cell wall because they do not have a skeleton to offer the strength and support that an animal does. A cell wall gives the plant cell strength and protection. It is the strength of trillions of cell

walls in trees that make them strong enough to grow as tall as they are. Animals do not need cell walls, in fact rigid cell walls would make it harder for them to move around to find food. They only have a cell membrane.

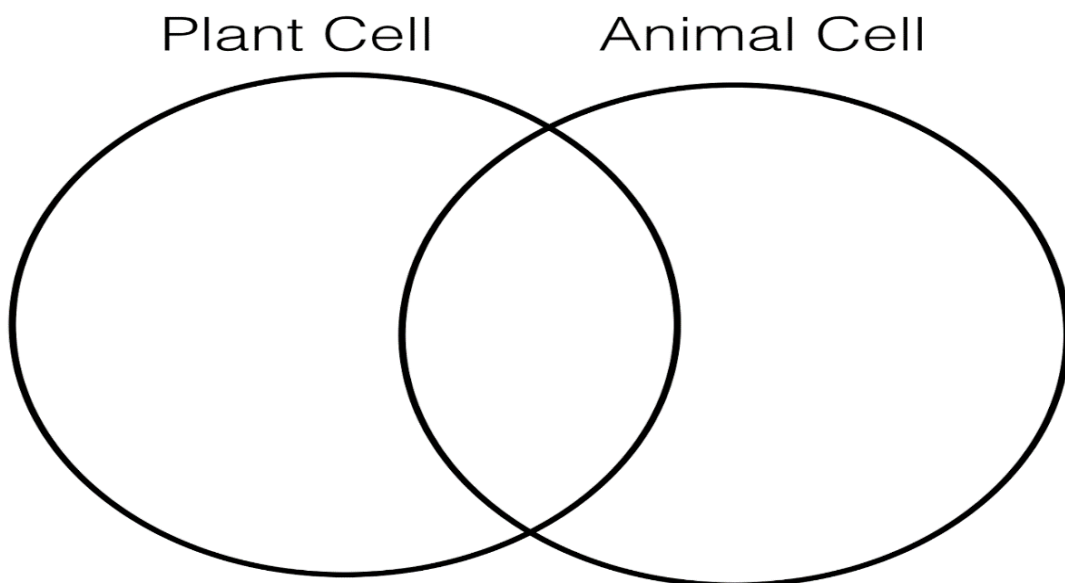
Second, plant cells have chloroplasts that capture the sun's energy to convert carbon dioxide and water to sugar. They make their own food. Since animals have to get food to eat from other sources, they do not need chloroplasts. Both plants and animals do have mitochondria to break apart the sugar molecules made in chloroplasts into energy that the cell can use.

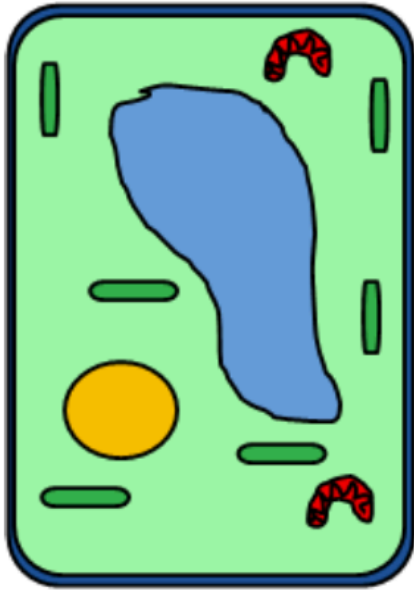
Think like a Scientist

Fill in the table below. Put a checkmark for each organelle/structure that is found in each cell type.

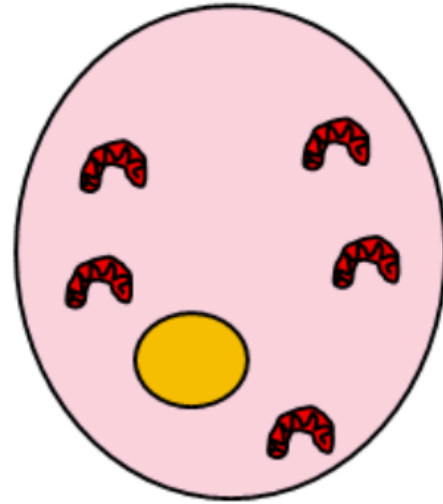
Organelle/Structure	Plant Cell	Animal Cell
Cell Wall		
Cell Membrane		
Nucleus		
Mitochondria		
Chloroplast		

Fill out the following Venn diagram comparing and contrasting plant cells and animal cells.





CC0 by Authors



Identify each structure and explain what the function of each structure is.

Nucleus

Mitochondria

Chloroplast

Cytoplasm

Vacuole

Cell Membrane

Cell Wall

7.3.2 Functions of Cell Parts

Putting It Together



Sheep Around A Tree by Henry Burrows, CC BY-SA

Grass doesn't eat like the sheep in the image above do. Grass uses chloroplasts in each cell to capture sunlight energy and convert it into chemical energy in the form of sugar. Because Grass can do this better by staying in one place and getting sunlight they have a body with roots that keep them in one place. Sheep need to be able to move because they have to find new or different grasses to get the sugars they need from those plants. Both Sheep and Grass have mitochondria that convert the sugars into energy the cells can use. The needs of the organism are different because their cells are different.

Writing Performance Task:

In the tasks that follow, you will be identifying the structures and functions of plant and animal cells and create an analogy of another system that carries out similar functions.

Gather:

- A. What do you think some of the things every cell in an organism must do?
- B. What structures in a cell might help them do the things they need to?
- C. Would these structures be different in plants, animals and single celled organisms? List at least **one** structure that is different and which type of cell it is located in

Reason:

- A. What cell structures are unique to plants? Why do you think plants might need these structures?
- B. What cell structures are common to both plants and animals? Why do you think there are parts that can function in both types of cells?

Communicate:

Cell Structure (organelle)	Function
Cell Membrane	Allows materials into and out of the cell.
Cell Wall	Provides a rigid outer layer of a plant cell
Chloroplasts	Make food for the plant cells using sunlight energy
Nucleus	Control center and genetic information
Vacuole	Storage tank and pressure
Mitochondria	Makes energy from food
Cytoplasm	Gel-like fluid that contains the organelles

- A. Using the data from the chart above, develop a model of a system that has to function similar to the cell. Your model should compare a cell to another system that carries out the same functions. For example: A cell is like a school, the nucleus would be the office. When you create your model, describe how all of the system parts function together and help the system as a whole to function. Be sure to label the parts of your system.

[illegible]

- B. Describe the contributions the mitochondria and chloroplasts make to a cell's energy requirements, including which cells they are found in.
- C. Describe how the cell membrane and cell wall functions to support and protect a cell, including which cells they are found in.

7.3.3 Organization of the Body

Phenomenon



CC0

After running the mile in PE, this student is sweating. He was not sweating before.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.3.3 Organization of the Body

Construct an explanation using evidence to explain how body systems have various levels of organization. Emphasize understanding that cells form tissues, tissues form organs, and organs form systems specialized for particular body functions. Examples could include relationships between the circulatory, excretory, digestive, respiratory, muscular, skeletal, and nervous systems. Specific organ functions will be taught at the high school level. (LS1.A)



In this section, focus on understanding how systems that have specific functions work together to perform all the functions of life.

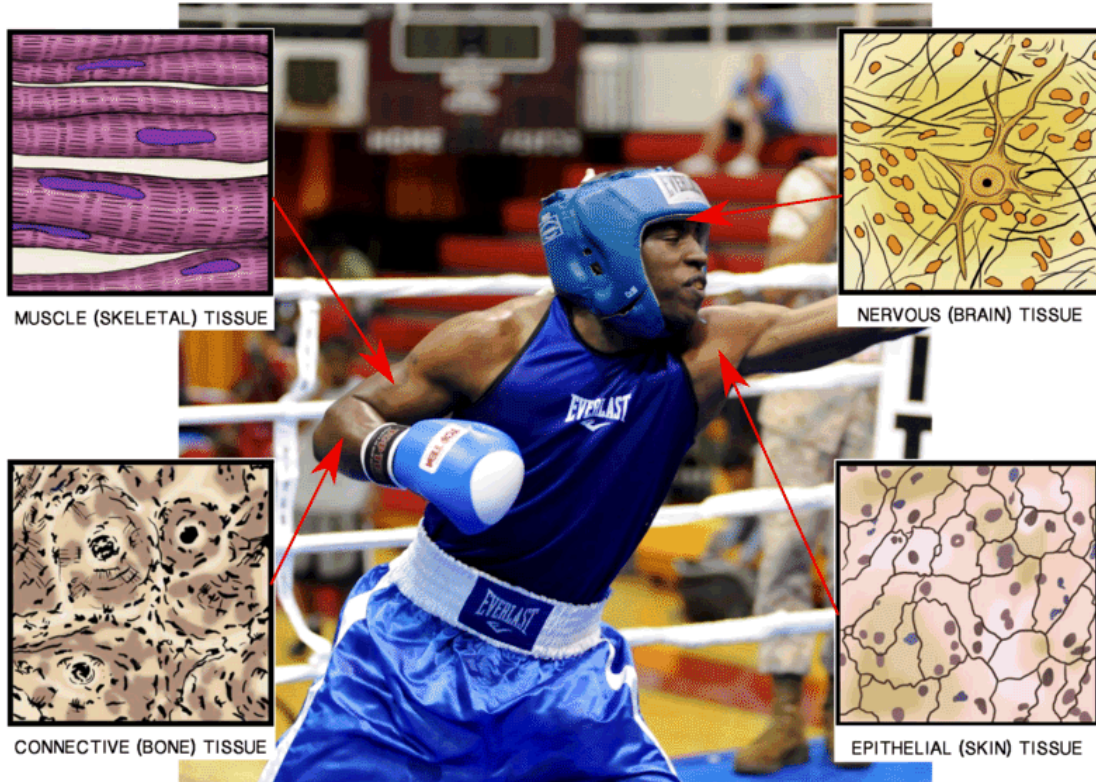
Organization of Your Body: Cells, Tissues, Organs

Ck12.org, CC BY-SA

Cells, like these nerve cells in the image to the left, do not work in isolation. To send orders from your brain to your legs, for example, signals pass through many nerve cells. These cells work together to perform a similar function. Just as muscle cells work together, bone cells and many other cells do as well. A group of similar cells that work together is known as a tissue.

Cells Form Tissues

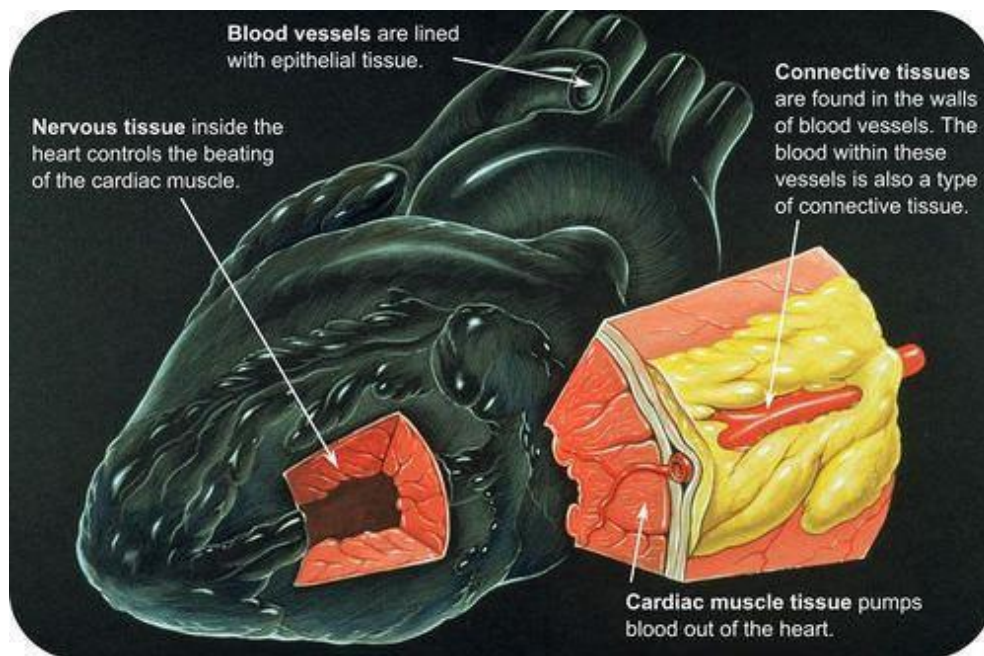
A group of cells that work together form a tissue. Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is pictured in the picture on the next page.



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Groups of Tissues Form Organs

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An organ is a structure made of two or more tissues that work together. The heart is made up of the four types of tissues.



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Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together form an organ system. Together, your heart, blood, and blood vessels form your circulatory system.

What other organ systems can you think of?

Organ Systems Work Together

Seven of your body's organ systems are shown in the table below. Your organ systems do not work alone in your body. They must all be able to work together.

Your skeletal and muscular system work together so you can dance. Your nervous system and muscular system work together to help you read this book.

Your integumentary, muscular, and nervous systems work together to release sweat to help cool your body down after exerting energy in exercise.

One of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the circulatory and respiratory systems, all work together to do this.

Organ System	Major Tissues and Organs	Function
Circulatory	Heart; blood vessels; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves waste and carbon dioxide away from cells.
Excretory	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water.
Respiratory	Trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around the body) or blood and air (lungs).
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons	Involved in movement and heat production.
Skeletal	Bones, cartilage; ligaments	Supports and protects soft tissues of the body; produces blood cells; stores minerals.
Nervous	Brain, spinal cord; nerves	Collects, transfers, and processes information.

Systems Working Together Form an Organism

When body systems interact you get an organism. Though these systems seem to function alone, they need to work together to make a living organism. If one of the systems is not working properly, it can cause illness and death to the organism. All plants and animals are examples of organisms.



7.3.3 Organization of the Body

Putting It Together



CC0

After running the mile in PE, this student is sweating. He was not sweating before.

Writing Performance Task:

In the tasks that follow, you will gather information about the structure and function of body systems and construct an explanation of how they work together to explain the phenomenon.

Gather:

- A. What are the basic levels of organization in living things from simplest to most complex
- B. Name at least two of the organ systems in the human body
- C. What are the functions of the excretory and muscular systems?

Reason:

- A. Looking at the function of the digestive system given in the table, what is another system that could work closely with it and how?
- B. Think of an organ, for example the heart. How does its shape and location in the body help support its function?

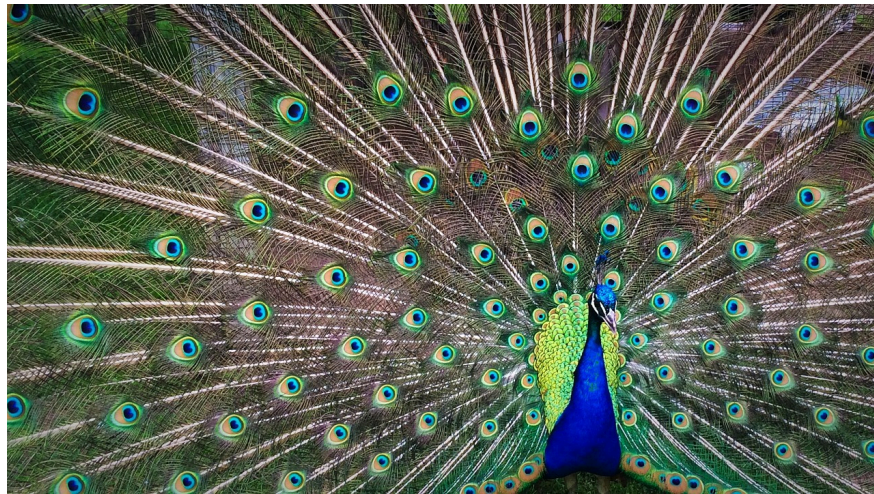
Communicate:

Please choose **two** systems to construct an explanation about how the body systems work together to keep the boy's body cool. They Include the names and functions of relevant systems and how they interact. Include each level of organization, starting with cells, and how it builds up to the systems involved.

Strand 4: Reproduction and Inheritance

Chapter Outline

- 4.1 TYPES OF REPRODUCTION (7.4.1)
- 4.2 ADAPTATIONS FOR REPRODUCTION (7.4.2)
- 4.3 MUTATIONS (7.4.3)
- 4.4 GENETIC CHANGES CAUSED BY HUMANS (7.4.4)



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The great diversity of species on Earth is a result of genetic variation. Genetic traits are passed from parent to offspring. These traits affect the structure and behavior of organisms, which affect the organism's ability to survive and reproduce. Mutations can cause changes in traits that may affect an organism. As technology has developed, humans have been able to change the inherited traits in organisms which may impact society.

7.4.1 Types of Reproduction

Phenomenon



Brent Myers CC-BY

Above is a picture of a desert grassland whiptail. All members of this species are females! There are no males in the population and yet the females lay eggs and have offspring. This is unusual because in most species females must mate with a male in order to produce fertile eggs and offspring.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.4.1 Types of Reproduction

Develop and use a model to explain the effect that different types of reproduction have on genetic variation, including asexual and sexual reproduction. (LS1.B, LS3.A, LS3.B)



In this section, analyze how the number of parents an organism has can affect its genetic variation.

Heredity: Passing on Traits

Have you ever wondered why some people throw a baseball with their left hand when most others use their right hand? Why do some people have curly hair and others do not? Why are some tulips red and other tulips white? The answer to these questions is heredity. Heredity is the passing of traits and characteristics from parents to their offspring. Genetics is the study of how traits are passed from parents to their offspring.

DNA, Genes, Chromosomes

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To understand genetics, you need to understand what causes the traits that are expressed or shown in an organism. The information used to code all the traits

are located on structures called chromosomes. Chromosomes are located in the nucleus of every cell in your body.

You have probably heard the phrase, “It’s in your genes.” Genes are tiny sections of chromosomes that contain codes for the traits that we carry. A single chromosome can contain thousands of genes, making it responsible for controlling certain traits that appear in an individual.

Chromosomes and genes are composed of DNA. When you build a house, you need a blueprint, or a set of instructions that tells you how to build it. DNA is like the blueprint for living organisms. Genes on the DNA are instructions for building proteins. These proteins tell your cells what to do and what to become. The proteins also build what your body looks like. Changes in the DNA sequence (blueprint) account for the differences in traits among the various species of living things.

Reproduction

Animals and other organisms cannot live forever. Organisms must reproduce so their species will survive. What does it mean to reproduce? Reproduction is the ability to create offspring (“children”). Reproduction is one of the basic characteristics of life. Two methods of reproduction are:

1. Asexual reproduction, the process of forming a new individual from a single parent.
2. Sexual reproduction, the process of forming a new individual from two parents.

There are advantages and disadvantages to each method, but the result is always the same: a new life begins.

Asexual Reproduction

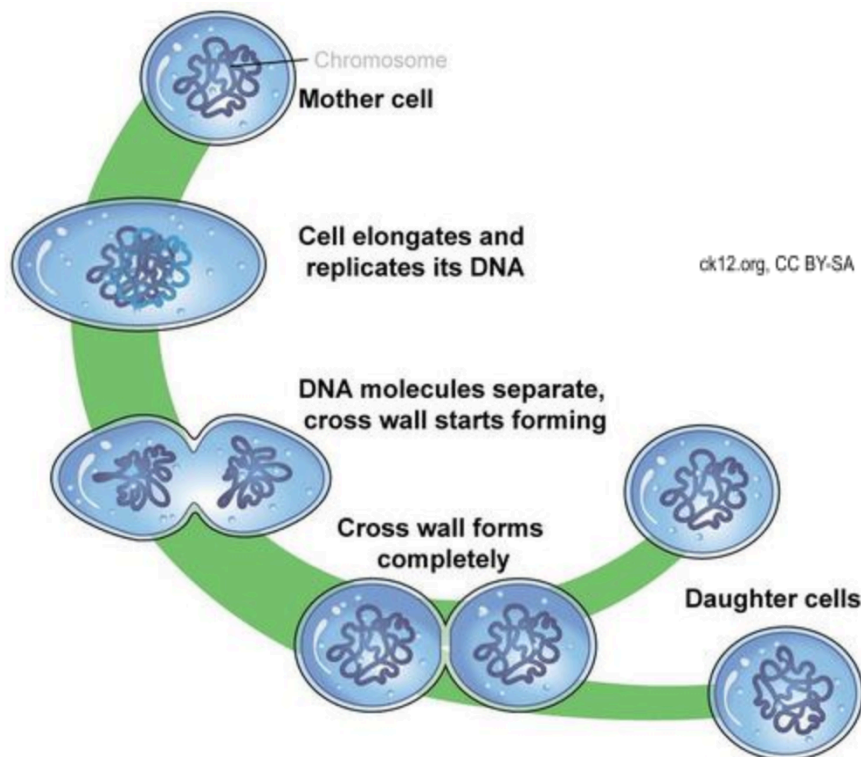
Asexual reproduction is reproduction where the offspring arises from a single organism. There is one parent and typically two offspring. All bacteria reproduce asexually. Other simple unicellular organisms such as protists also reproduce asexually. Having just one parent is possible in complex organisms as well. Some insects, fish, and reptiles reproduce asexually. With asexual reproducers, the offspring have a single parent and share the exact same genetic material as the parent.

The advantage of asexual reproduction is that it can be very quick and easy. Asexual reproduction does not require the mating of a male and female organism. Organisms that reproduce asexually do not have to find a mate which can cost the organism time and energy. The disadvantage of asexual reproduction is that organisms do not receive a mix of traits from both parents.

An organism that is born through asexual reproduction only has the DNA from the one parent. In fact, the offspring is genetically an exact copy of the parent. This results in offspring that have the exact same traits as the parent. This can cause problems for the individual. For example, if the parent has a gene that causes a particular disease, the offspring will also have the gene that causes that disease. Organisms produced sexually may or may not inherit the disease gene because they receive a mix of their parents' genes.

Types of organisms that can reproduce asexually include:

1. Bacteria reproduce through binary fission, where they grow and divide in half. First, their DNA replicates and the cell enlarges. The cell then divides into two cells as new membranes form to separate the two cells. After cell division, the two new cells each have identical DNA. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an invertebrate animal species, can divide in two. Each half regenerates into a new flatworm identical to the original, a process called fragmentation.
3. Different types of insects, fish, and lizards can reproduce asexually through a process called parthenogenesis. Parthenogenesis happens when an unfertilized egg cell grows into a new organism. Parthenogenesis is common in honeybees. In a hive, the sexually produced eggs become workers, while the asexually produced eggs, produced by parthenogenesis, become drones.



Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

Sexual Reproduction

During sexual reproduction, two parents are involved. Most organisms, including plants, have both males and females, with the male producing sperm and the female producing eggs. When a sperm and egg meet during fertilization, a zygote, the first cell of a new organism, is formed. This process combines the genetic material (DNA) from both parents. The resulting organism will be genetically unique, because they will have a mix of its parent's traits.



During sexual reproduction, a sperm fertilizes an egg.

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Animals produce sex cells called eggs or sperm, which contain genetic material from the parent. Sex cells have half the amount of the genetic material of a regular body cell. In humans, sex cells have one set of 23 chromosomes. Normal human cells have 46 chromosomes, 23 of these chromosomes came from the individual's mom and 23 came from the individual's dad. These two sets

of chromosomes combine in the new human, giving him or her traits from both parents.

Plants can also reproduce sexually, but their reproductive organs are different from animals'. Plants that have flowers have their reproductive parts in the flower. The sperm is contained in the pollen, while the egg is contained in the ovary, deep within the flower. Many plants need pollinators, like butterflies and honeybees, to bring the pollen from one flower to another flower, to fertilize the egg. The egg grows into an embryo inside of a seed. When the seed is planted, the embryo grows into a new plant that has a combination of traits from both of its parents.

Check This Out



Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

ck12.org, CC BY-SA



Aspen trees can be found in the mountains in Utah. Aspen trees can reproduce sexually by creating pollen and eggs, but aspen trees can also reproduce asexually. They can send up new stems from their roots. This stem becomes a new tree. Because it was created from the roots of the parent tree, it has the exact same DNA and traits as the parent tree. How could scientists test whether a group of aspen trees were made through sexual or asexual reproduction?

Some other organisms that reproduce both asexually and sexually are starfish, hydra, sponge, and some plants and fungi.

One possible way to model sexual reproduction is through the use of Punnett squares.

A Punnett square is a special tool derived from the laws of probability. It is used to predict the possible offspring from a cross, or mating between two parents.

An example of a Punnett square (Figure to the right) shows the results of a cross between two purple flowers in a pea plant that each have one dominant gene (*B*) and one recessive gene (*b*).

		 pollen ♂	
		B	b
 pistil ♀	B	 BB	 Bb
	b	 Bb	 bb

The Punnett square of a cross between two purple flowers (Bb). A Punnett square can be used to calculate what percentage of offspring will have a certain trait.
(ck12.org, CC BY-SA)

To create a Punnett square, perform the following steps:

1. Take the genes from the first parent and place them at the top of the square (B and b).
2. Take the genes from the second parent and line them up on the left side of the square (B and b).
3. Pull the genes from the top into the boxes below.
4. Pull the genes from the side into the boxes next to them.

The possible offspring are represented by the letters in the boxes, with one gene coming from each parent.

Results:

- Top left box: BB , or purple flowers
- Top right box: Bb , or purple flowers
- Lower left box: Bb , or purple flowers
- Lower right box: bb , or white flowers

Only one of the plants out of the four, or 25% of the plants, has white flowers (bb). The other 75% have purple flowers (BB , Bb), because the purple gene (B) is the dominant gene. This shows that the color purple is the dominant trait in pea plants.

What would a Punnett square for asexual reproduction look like, since there is only one parent?

100% of the offspring in asexual reproduction will inherit the same genes from the parent organisms, since they are not able to inherit traits from another parent.

Since the model does not give us very much helpful information, Punnett squares are not used to model asexual reproduction.

7.4.1 Types of Reproduction

Putting It Together



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Above is a picture of a desert grassland whiptail. All members of this species are females! There are no males in the population and yet the females lay eggs and have offspring. This is unusual because in most species females must mate with a male in order to produce fertile eggs and offspring. Let's revisit this.

Focus Questions:

1. In typical organisms that reproduce sexually, what portion of their genetic material comes from each parent? Is it the same portion for each offspring from both parents?
2. How do we get the wide array of variation in a population?
3. With asexually reproducing organisms what portion of their genetic material is similar to the parent?

Final Task:

Use a Venn diagram as a model to explain the differences and similarities between asexual and sexual reproduction. Pay special attention to what effect these types of reproduction have on offspring.

7.4.2 Adaptations for Reproduction

Phenomenon



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If you go to a flower store, you will see flowers in many different bright colors, many different scents, and many shapes. Each flower has a specific reason for being that way. On plants that have flowers, the flowers play a role in reproduction.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.4.2 Adaptations for Reproduction

Obtain, evaluate, and communicate information about specific animal and plant adaptations and structures that affect the probability of successful reproduction. Examples of adaptations could include nest building to protect young from the cold, herding of animals to protect young from predators, vocalization of animals and colorful plumage to attract mates for breeding, bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury. (LS1.B)



In this section, focus on understanding how the different structural adaptations increase the organism's reproduction rates and offspring survival.

Reproduction

In the previous section, you learned that organisms need to reproduce in order to ensure that their species continues to live on the Earth. Successful reproduction can be described as having offspring that also live long enough to reproduce. Animals and plants have a number of strategies and adaptations that increase the odds for successful reproduction.

Plant Reproductive Adaptations

Some flowers have very strong scents. Others have sweet nectar. These traits attract animals. The animals they attract may include insects, birds, mammals, and even reptiles. Why do you think it is important for plants to attract animals?

Animals are able to transfer pollen from one plant to another and carry seeds from one place to another. While visiting a flower, an animal picks up pollen. The animal then travels to another flower and transfers the pollen to fertilize the egg resulting in offspring.

Some plants utilize their fruit to attract animals to transport the seeds they create to another location. When a horse eats an apple, it does not digest the apple seeds. As the horse travels and eliminates waste, the seeds are dispersed over a

large area. Other plants developed additional traits that aid in reproduction through seed dispersal.



Dandelion seeds



Maple Tree seeds



Burdock seeds

Dandelion seeds have tiny "parachutes." Maple seeds have "wings" that act like little gliders. Burdock seeds are covered with tiny hooks that cling to animal fur.

(ck12.org, CC BY-SA)

Some plants rely on seeds getting stuck in animal fur. Once stuck, the seeds are carried off to another location. Eventually, the seeds fall off and grow into a new plant.

Other plants developed traits to better disperse their seeds using the wind. With time, plants develop better and better traits to help them reproduce.

Animal Reproductive Adaptations

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Some of the most important animal adaptations involve mating. Mating is the pairing of an adult male and female to produce young. Adults that are most successful at attracting a mate are most likely to have offspring. Traits that help animals attract a mate and have offspring increase their ability to survive. As the genes that encode these traits are passed to the next generation, the traits will become more common in the population.

In many species, females choose the male they will mate with. For their part, males try to be chosen as mates. They show females that they would be a better mate than the other males. To be chosen as a mate, males may perform courtship behaviors. These are special behaviors that help attract a mate. Male courtship behaviors get the attention of females and show off a male's traits. These behaviors are often observed as direct competition between males.

Different species have different courtship behaviors. One example is a peacock raising his tail feathers. The colorful peacock is trying to impress females of his species with his beautiful feathers. Another example of courtship behavior in birds is the blue-footed booby. He is doing a dance to attract a female for mating. During the dance, he spreads out his wings and stamps his feet on the ground. You can watch the following video of a blue-footed booby doing his courtship dance at: <http://go.uen.org/aYE>

Courtship behaviors occur in many other species. For example, males in some species of whales have special mating songs to attract females as mates. Frogs croak for the same reason. Male deer clash antlers to court females. Male jumping spiders jump from side to side to attract mates.

Adaptations for Caring for Young

In most species of birds and mammals, one or both parents care for their offspring. Caring for the young may include making a nest or other shelter. It may also include feeding the young and protecting them from predators. Caring for offspring increases their chances of surviving. Birds called killdeer have an interesting way of protecting their chicks. When a predator gets too close to her nest, a mother killdeer pretends to have a broken wing. The mother walks away from the nest holding her wing as though it were injured. The predator thinks she is injured and will be easy prey. The mother leads the predator away from the nest and then flies away.



This mother killdeer is pretending she has a broken wing. She is trying to attract a predator's attention in order to protect her chicks. This behavior puts her at risk of harm. How can it increase her fitness?

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In most species of mammals, parents also teach their offspring important skills. For example, meerkat parents teach their pups how to eat scorpions without being stung. A scorpion sting can be deadly, so this is a very important skill. Teaching the young important skills makes it more likely that they will survive. This is especially important for many species of birds and mammals, because they have fewer offspring than other types of animals.

To obtain additional information regarding animal reproductive adaptations you can search for videos:

- Search for Behavior on a Sage Grouse
- Elk Fighting in River

7.4.2 Adaptations for Reproduction

Putting It Together



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If you go to a flower store, you will see flowers in many different bright colors, many different scents, and many shapes. Each flower has a specific reason for being that way. On plants that have flowers, the flowers play a role in reproduction.

Focus Questions

1. What are some examples of physical adaptations that help organisms reproduce?
2. What are some examples of behavioral adaptations organisms use to help them increase their chances of mating?
3. Why are so many adaptations focused on reproduction?

Final Task

Pick an organism you find interesting. Identify at least 5 traits or adaptations it has that help it survive. Find 5 traits or adaptations that specifically help the organism reproduce. Describe your findings in a presentation, poster, or paragraph.

7.4.3 Mutations

Phenomenon



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This baby was born with 2 thumbs on one hand. This trait was not inherited (passed down from parents). As you read the following section, think of where she would have gotten this trait.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.4.3 Mutations

Develop and use a model to describe why genetic mutations may result in harmful, beneficial, or neutral effects to the structure and function of the organism. Emphasize the conceptual idea that changes to traits can happen because of genetic mutations. Specific changes of genes at the molecular level, mechanisms for protein synthesis, and specific types of mutations will be introduced at the high school level. (LS3.A, LS3.B)



In this section, focus on understanding which mutations will be helpful, harmful or neutral to the organism's life.

Mutations

The process of DNA replication before a cell divides is not always 100% accurate. Sometimes the wrong code is inserted in the new strand of DNA. This wrong code could become permanent. A permanent change in the sequence of DNA is known as a mutation. Once DNA has a mutation, that mutation will be copied each time the DNA replicates. After cell division, each resulting cell will carry the mutation and the resulting trait.

Are Mutations Good or Bad?

A mutation in the DNA may have no effect. However, sometimes a mutation can cause a protein to be made incorrectly. A defect in the protein can affect how well the protein works, or whether it works at all.



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Usually the loss of a protein function is detrimental to the organism and makes it harder to survive. This rare albino alligator has the mutation for albinism.

Albinism is a mutation in a gene for melanin, a protein found in skin and eyes. Such a mutation may result in no melanin production at all or a significant decline in the amount of melanin. The resulting color will make it harder for the alligator to camouflage with its surroundings. This mutation has a negative impact on the alligator's chance for survival.



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This rabbit also has the mutation for albinism. If this population of rabbits lives in a dark forest this mutation would be harmful. However, would this mutation be harmful if the population of rabbits lived in the snowy arctic? In rare circumstances a mutation can help an organism survive in their environment.

For example, humans have the ability to see more colors than other animals. This ability is the result of a mutation that occurred a long time ago. Organisms that have those beneficial mutations are more likely to survive and pass the mutation to future generations.

Sometimes the resulting trait does not help or harm the organism, it is neutral. For example, heterochromia is a mutation that causes two different colored eyes (pictured to the side). Having two different colored eyes does not help or harm the organism's chance of survival so it would be considered a neutral mutation.

Causes of Mutations



Some mutations are not caused by errors in DNA replication. Mutations can happen spontaneously, and they can be caused by mutagens (something that causes genetic mutation) in the environment. Some chemicals, such as those found in tobacco smoke, can be mutagens. Sometimes mutagens can also cause cancer. Tobacco smoke, for example, is often linked to lung cancer.

7.4.3 Mutations

Putting It Together



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This baby was born with 2 thumbs on one hand. This trait was not inherited (passed down from parents). This trait was likely caused by a mutation in the DNA contained in the nucleus of the cells in this person. A slight change in the order of the chemicals that make up chromosomes could cause an extra finger or toe to grow. These changes occur as copying errors when cells divide. They can be harmful, beneficial, neutral or to the organism.

Focus Questions:

1. Describe different environments where this mutation would be harmful, beneficial, and neutral to the person.
2. When organisms reproduce sexually there is a random assortment of the genes each parent has, this can cause variations to the offspring. How is a mutation different?
3. How does mutation play a role in survival of sexually reproducing organisms? In Asexually reproducing organism?

Final Task:

Develop a model, flow chart or diagram that explains the effect a mutation in a parent has on the traits of the offspring.

7.4.4 Genetic Changes Caused by Humans

Authentic Situation



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Dogs come in many shapes and sizes. Each breed of dog has different personalities, demeanors and talents. For hundreds of years humans have been breeding dogs to have specific physical characteristics and behavioral traits we find beneficial. Many designer breeds such as: labradoodles, puggles, and schnoodles are the result of humans breeding for newly desired traits to match our modern needs.

Observations and Wonderings

What is the problem or goal in this situation?

What are possible criteria (positive outcomes) to this situation?

What are constraints (limitations) with this situation?

7.4.4 Genetic changes caused by Humans

Obtain, evaluate, and communicate information about the technologies that have changed the way humans affect the inheritance of desired traits in organisms. *Analyze data from tests or simulations to determine the best solution to achieve success* in cultivating selected desired traits in organisms. Examples could include artificial selection, genetic modification, animal husbandry, and gene therapy. (LS4.B, ETS1.A, ETS1.B, ETS1.C)



In this section, focus on understanding how Inherited differences among individuals in a population give some individuals a benefit.

Engineering Design

This is an engineering standard. Refer to page 10 to read about engineering design. Which type of engineering task is utilized in this SEEd Standard?

Artificial Selection



Dairy cows like this Holstein are carefully bred for traits that will give them better strength and produce more milk.

Artificial selection occurs when humans select which plants or animals to breed in order to pass on specific traits to the next generation. Two organisms with desirable traits are crossed to produce offspring with those same traits. By selecting and crossing individuals with the traits we want for several generations, scientists are able to increase the chance that the offspring will have those desirable traits.

One of the areas where artificial selection gives the most benefit is in farming and ranching. For example, farmers practice animal husbandry

where a farmer may choose to breed only cows that produce the most milk. Farmers would also avoid breeding cows that produce less milk. In this way,

selective breeding of the cows would increase milk quality and/or quantity. By selecting the individuals with the traits we want for reproduction, farmers can improve the quality of their animals.

Plants can also be selectively bred. Fruits and vegetables are bred to increase size, flavor, and production. Almost every fruit or vegetable you eat has been improved in size, abundance, flavor or nutrition by being artificially bred by humans. For example, generations of farmers have harvested corn with the largest kernels to produce the corn we have today.



Teosinte ear (*Zea mays ssp mexicana*) on the left, maize ear on the right, and ear of their F1 hybrid in the center (photo by John Doebley), CCBY

Over time, selective breeding has modified teosinte's few fruit cases (left) into modern corns rows of exposed kernels (right). Selective breeding of crops such as corn and wheat gave early humans the freedom to develop civilizations.

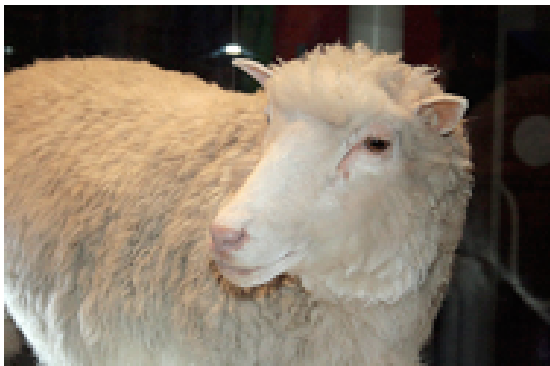
Genetic Modification

Genetic engineering is a research field that tries to find ways to change the genetics of living organisms so that the organisms have more desirable traits to people.

This technology has led to less crop damage and increased farm production. This allows farmers to produce more food on less land. Crops have also been engineered that produce better tasting food with a longer shelf life.

Farming is not the only field that benefits from genetic engineering. Advances in medical research have improved life for people with certain diseases. Diabetes is a disease that limits the body's ability to create or use an important hormone called insulin. Insulin is important because it helps to remove sugar from the bloodstream and put it in cells where it can be used by the mitochondria to produce energy. Until a few years ago, insulin was extracted from non-human sources. It worked, but was not a perfect solution to the problem. In recent years scientists have found ways to engineer (create) human insulin using bacteria. The human gene that produces insulin is inserted into bacteria. The bacteria then produce human insulin as they reproduce. The insulin is then harvested from the bacteria and used in patients so that people with diabetes can have a more normal life.

What Cloning Is and What Cloning Is Not



Dolly, a sheep, was the first
mammal to be cloned.

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Several years ago, researchers shocked the world when they announced that a sheep had been cloned. A clone is an exact genetic duplicate of a living organism, like an identical twin, but born at different times. DNA from a cell from

one female is inserted into an empty egg cell from a different female. Because a complete set of DNA is injected, the cell is tricked into thinking it has been fertilized. It then grows and develops inside the host mother's womb. Scientists cannot and probably will never be able to send an organism through a machine and have a clone walk out the other side like you see in some movies. Clones have to grow, develop, and learn just as any other living thing does. Even though the clones have identical DNA, the expression of the clone's traits would be subject to the environment in which it was raised.

Gene Therapy

Gene therapy is the insertion of genes into a person's cells to cure a genetic disorder. Gene therapy could not be used to cure diseases that are caused by viruses, like AIDS. It only works to fix disorders caused by a faulty gene. The patient would have had this disorder from birth.

Gene therapy uses a vector, or carrier molecule, for the gene. The vector helps incorporate the desired gene into the patient's DNA. Usually this vector is modified viral DNA in which the viral genes have been removed. Don't worry, the virus used in gene therapy has been deactivated, meaning it is not harmful to the human body. Though gene therapy is still in experimental stages for diseases like hemophilia and cystic fibrosis, the common use of this therapy may occur during your lifetime. As more research is done and technology improves, scientists will continue to learn more about the genetics of living things and find new ways to improve life on earth.

7.4.4 Genetic Changes

Putting It Together



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Dogs come in many shapes and sizes. In order to get the very best traits of these two dogs we would need to breed them. During each generation we would pick the animals with the traits we liked best and breed them back to each other. Careful record keeping would allow us to identify which traits are being passed on and help us make future breeding decisions. In a matter of a dozen generations we could have dogs with the traits we are looking for. Humans do this with livestock, pets and crops.

Focus Questions:

1. How have humans affected the inheritance of desired traits in organisms?
2. Flounder fish live in water with very cold temperatures. Why might scientists want to combine the genes from a flounder fish and a strawberry? How would they do this?
3. Think of an example of selective breeding in an animal or plant we use regularly. How has it helped humankind?

Final Task:

You want to win the State Fair giant pumpkin contest. Using your knowledge of artificial selection, construct an explanation as to what you can do to win the contest.

Strand 5: Changes in Species over Time

Chapter Outline

- 5.1 DEVELOPING TRAITS THAT AFFECT SURVIVAL (7.5.1)
- 5.2 CHANGES TO LIFE OVER TIME (7.5.2)
- 5.3 CONNECTING MODERN ORGANISMS TO ANCIENT ORGANISMS (7.5.3)
- 5.4 COMPARATIVE EMBRYOLOGY (7.5.4)



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Genetic variation and the proportion of traits within a population can change over time. Additional evidence of change over time can be found in the fossil record, anatomical similarities and differences between modern and ancient organisms and in embryological development.

7.5.1 Developing Traits that Affect Survival

Phenomenon



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Temperatures in Finland, a country near the North Pole, have been rising in recent years. Tawny Owls in Finland used to be found most often with gray feathers. In the last 30 years, brown feathers have become more and more common in the Tawny Owl.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.5.1 Developing Traits that Affect Survival

Construct an explanation that describes how the genetic variation of traits in a population can affect some individuals' probability of surviving and reproducing in a specific environment. Over time, specific traits may increase or decrease in populations. Emphasize the use of proportional reasoning to support explanations of trends in changes to populations over time. Examples could include camouflage, variation of body shape, speed and agility, or drought tolerance. (LS4.B, LS4.C)



In this section, focus on identifying additional cause and effect relationships between an organism's traits and the environment in which it lives.

Adaptation and Evolution of Populations

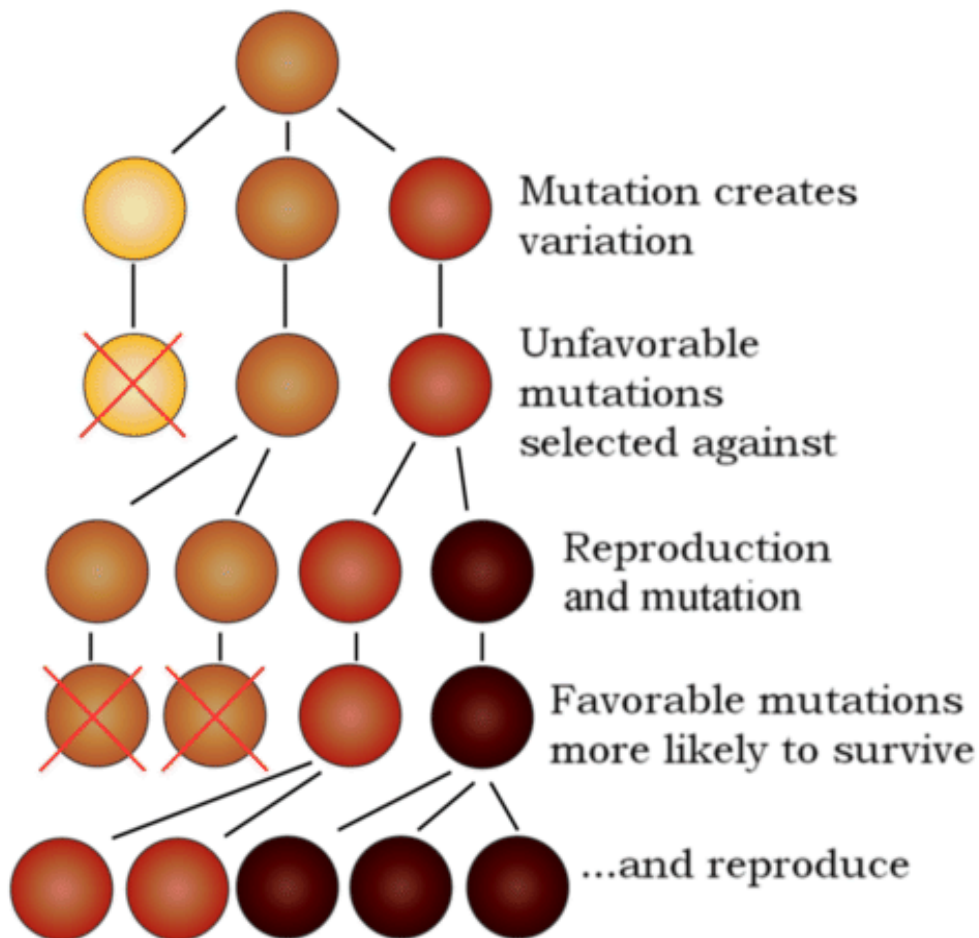
Look at the picture of the moth. An organism that blends with its background is more likely to avoid predators. If it survives, it is more likely to pass on this beneficial trait to its offspring. This moth appears to be well adapted to its environment. It is less likely to be eaten by a bird than a dark colored moth on the tree.



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Mutations and Variation

Even though they may look very similar, most organisms of the same species have some physical differences. This is because their genes are different. These differences in traits are called variations. For example, there are lots of variations in the color of human hair. Hair can be blonde, brown, black, or even red. Hair color is a trait determined by genes. At some time in the past, a variation probably came from a mutation. Mutations are natural changes to DNA. Some are harmful, but many are neutral and some are beneficial. If a mutation is harmful, the organism may not live long enough to reproduce. If the mutation is beneficial, that organism may have a better chance to survive. An organism that survives is likely to have offspring. If it does, it may pass the mutation onto its offspring.



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Genetic mutation is central to the creation of biological diversity.

Adaptations



Ck12.org, CC BY-SA
Cacti have thick, water-retaining bodies that help them conserve water.

Traits that help organisms survive and reproduce are called adaptations. Many adaptations protect organisms from the external environment; however, adaptations that are beneficial in one environment may not be beneficial in another.



Poison dart frogs have toxins in their skin. Their bright colors warn potential predators not to take a bite.

How Adaptations Develop

Think about a population of oak trees. Imagine that a fungus has arrived from Asia to North America. Most of the North American oak trees are killed by the fungus. But a few oak trees have a mutation in their DNA that gave them the ability to survive the fungus. Those oak trees are better adapted to the new environment than the others, and have a better chance of surviving. If they survive to reproduce, their offspring may inherit that favorable mutation. Eventually, the population of oak trees will change so that most trees will have the trait to survive the fungus. Over time, traits that help an organism survive become more common. Traits that hinder survival eventually disappear.

Other adaptations help an organism move or gather food. Reindeer have sponge-like hooves that help them walk on snowy ground without slipping and falling. Fish at the bottom of the ocean are tiny and use very little energy because there is very little food. Organisms can have special features that help them avoid being eaten. Some plants have poisonous or foul-tasting substances in them that keep animals from eating them. Their brightly colored flowers serve as a warning. Skunks release a nasty odor to protect them from predators.

Charles Darwin



In the 19th century, an English natural scientist named Charles Darwin set out to answer the following questions:

- Why are organisms different?
- Why are organisms similar?
- Why are there so many different types of organisms?

Darwin was the first to write and publish a book on how environments could influence the diversity of species. His book, “The Origin of Species,” describes the observations and evidence that he collected over 20 years of research, beginning with a five-year voyage around the world on a British research ship, the HMS Beagle.



Darwin's Travel Route

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Aboard the Beagle, Darwin visited the Galápagos Islands, a group of 16 volcanic islands near the equator, about 600 miles from the west coast of South America. The islands are famous for many species of organisms that are found nowhere else in the world.

On the Galapagos, Darwin observed that the same kind of animal differed from one island to another. For example, the iguanas (large lizards) differed between islands. The members of one iguana species spent most of their time in the ocean, swimming and diving underwater for seaweed, while those of other iguana species lived on land and ate cactus. Darwin wondered why there were two species of iguana on the same set of islands that were so different from one another. What do you think?



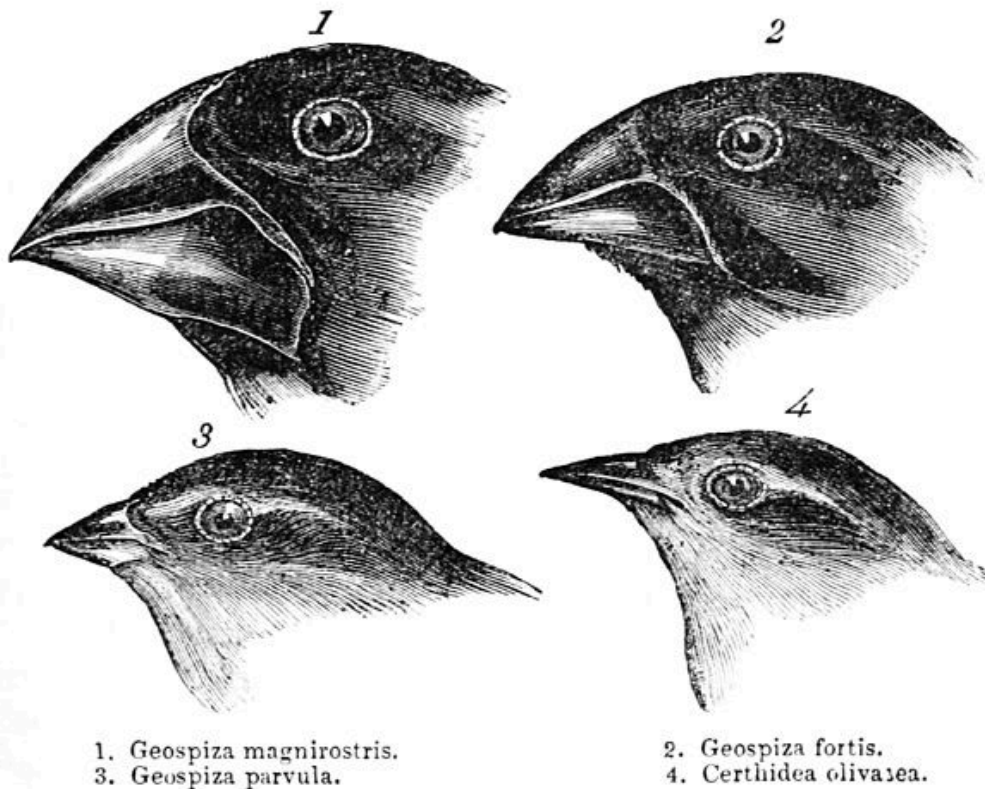
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CC0

In the images above you can see how similar and different a land iguana (top image) is to a marine iguana (bottom image).

Darwin's Finches



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The most studied animals on the Galápagos are finches, a type of bird pictured above. When Darwin first observed finches on the islands, he did not even realize they were all finches. But when he studied them further, he realized they were related to each other. Each island had a unique type of finch. The birds on different islands had many similarities, but their beaks differed in size and shape.

The birds came from the same finch ancestor. They evolved as they adapted to different food resources on different islands. The first bird in the picture above uses its large beak to crack open and eat large seeds. Bird #3 is able to pull small seeds out of small spaces.

In his diary, Darwin pointed out how each animal is well-suited for its particular environment. The shapes of the finch beaks on each island were well-matched with the seeds available on that island, but not the seeds on other islands. For example, a larger and stronger beak was needed to break open large seeds on one island and a small beak was needed to eat the small seeds on a different island.

Natural Selection

Darwin summarized his observations and ideas as the principle of natural selection. This principle is one of the most important ideas in life science. Simply stated, an individual in a species that has traits (genes) that are best suited to survive changes in the environment are the ones that live and reproduce. This increases the presence of those traits (genes) in the species until it eventually becomes a characteristic of that species.

Natural selection occurs when:

1. There is some variation in the inherited traits of organisms within a species.
2. Some of these traits will give individuals an advantage over others in surviving and reproducing.
3. These individuals will be likely to have more offspring and pass on the beneficial trait.

Survival of the Fittest

Some people refer to natural selection as “survival of the fittest.” This does not refer to the fastest, strongest, or biggest but rather to the organism that is most “fit” for their environment. Both predators and prey have adaptations that help them survive in their environment. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey is camouflage, the ability of an organism to blend in with its environment because of its inherited traits.

Imagine how in winter, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Natural selection suggests that white fur is a beneficial trait that improves the chance that a rabbit will survive, reproduce and pass the trait of white fur to its offspring. Over time, dark fur rabbits will become uncommon. Most of the rabbits in the population will adapt to have white fur.

In winter, the fur of Arctic hares turns white. The camouflage may make it more difficult for foxes and other predators to locate hares against the white snow. Some additional examples are shown in the picture below.



Ck12.org, CC BY-SA



Camouflage in Predator and Prey Species.

ck12.org, CC BY-SA

Can you see the crab in the photo on the left? It is camouflaged with algae. The praying mantis in the middle photo looks just like the dead leaves in the background. Can you tell where one zebra ends and another one begins? This may confuse a predator and give the zebras a chance to run away. These traits show how natural selection has worked over a very, very long time.

7.5.1 Developing Traits that Affect Survival

Putting It Together



Pixabay.com, CC0

The Tawny Owl in Finland is experiencing a change in its environment. This is making some individuals thrive and others to struggle. Those individuals that are best suited for the new environment will produce more offspring with their traits. This changes the population.

Focus Questions:

1. Why are some traits beneficial and others not, or even harmful?
2. As conditions change what happens to the populations of organisms in that environment?
3. In a population responding to a changing environment what happens to the genes and the traits they cause?

Final Task:

Think back to the Tawny Owl living in the rising temperatures of Finland. Construct an explanation for why this population of owls is seeing a rise in brown feathers over gray and compare it to your original explanation. How did your thinking change?

7.5.2 Changes to Life over Time

Phenomenon



Dinosaurious Park, Utahraptor by HombreDHojalata, CC BY-SA

The Utahraptor was discovered in 1991 near Moab, UT. Scientists have measured that the Utahraptor is the largest raptor that ever lived in Utah. The Utahraptor and many of the other raptors have common traits. Many of these traits are found in modern birds. When you look at layers of rocks you can see a variety of fossils showing different species at consecutive layers that provide evidence that there has been change over time.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.5.2 Changes to Life over Time

Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth, under the assumption that natural laws operate today as in the past. (LS4.A, ESS2.E)



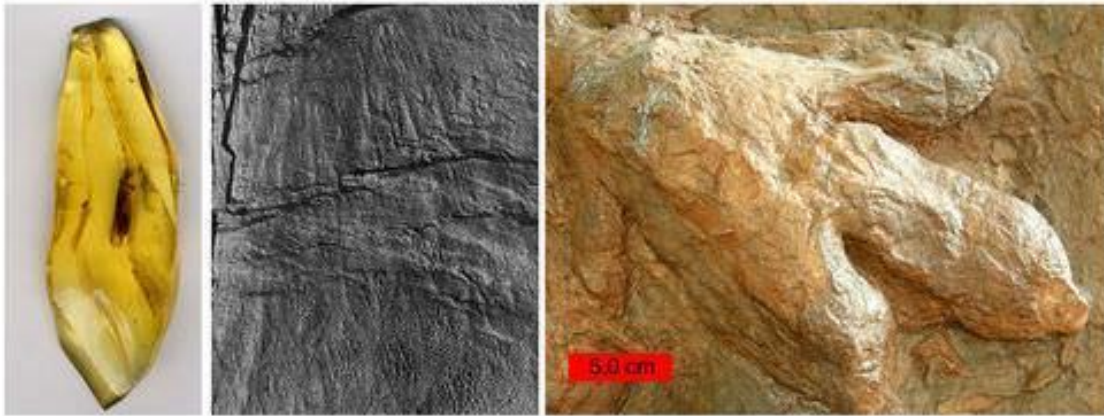
In this section, focus on analyzing and interpreting data from patterns found in fossils and the rock layers showing how Earth has changed throughout its history.

The Fossil Record



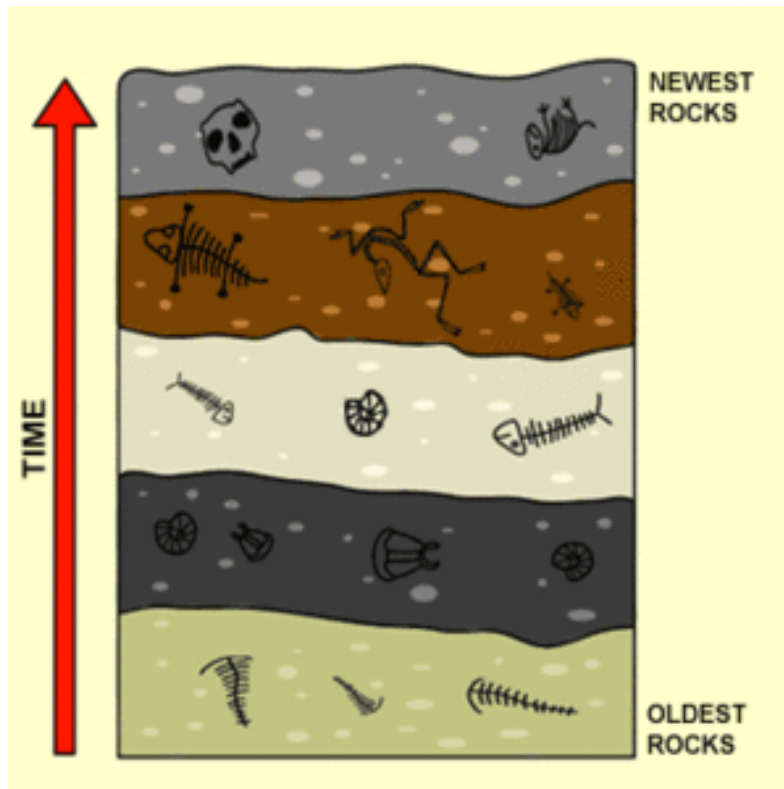
What is on this rock? This rock contains a portion of a fossilized tree fern. Scientists study fossils of plants, animals, and other organisms in order to better understand what life was like on Earth many years ago and how it has changed over time. Fossils are important evidence for the theory of evolution.

Fossils are the preserved remains of animals, plants, and other organisms from the distant past. Because most parts of organisms decompose rapidly following death, fossilization usually preserves only hard body parts like bones, teeth. Other fossils include footprints, burrows, droppings, eggs, nests, and other types of impressions. Animals and plants were also trapped and preserved in sap called amber.



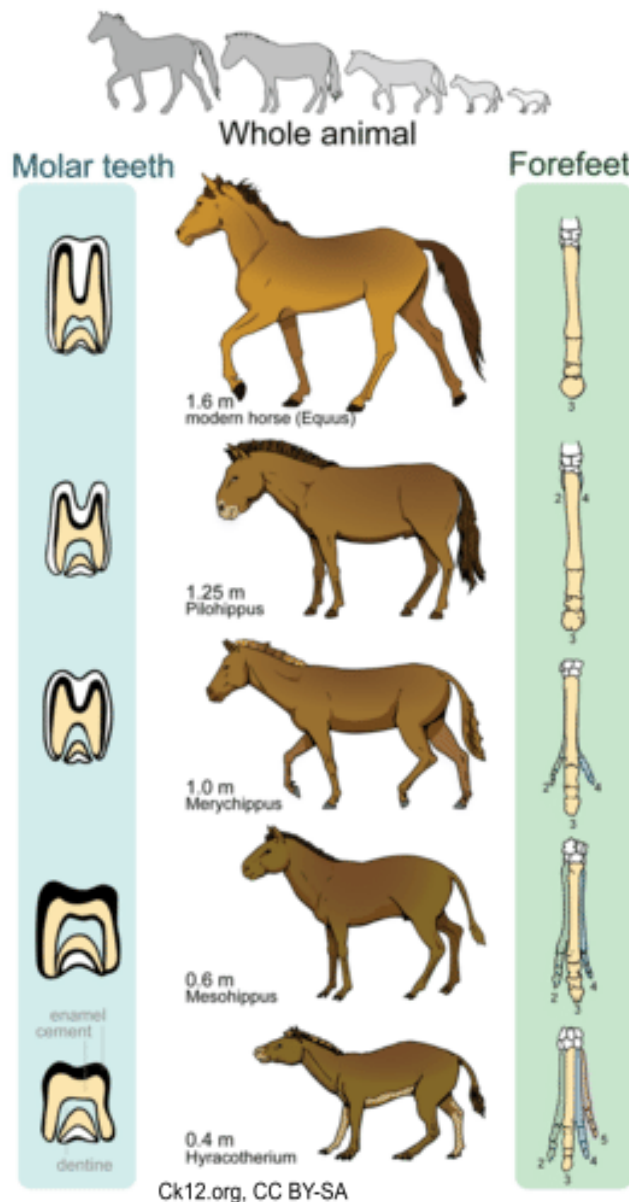
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Different types of fossils reveal the history of life. From left to right:
Amber preserves an insect intact. Stone etches impressions of
Edmontosaurus skin. Rock echoes a dinosaur's footprint.



Paleontologists are scientists who study fossils to learn about life in the past. Fossils are found in rocks. There are many layers of rock in the Earth's surface. Newer rock layers form on top of the older layers so the deepest rock layers are the oldest. Therefore, you can tell how old a fossil is by observing in which layer of rock it was found. The fossils and the order in which fossils appear in the rock is called the fossil record. The fossil record provides evidence for when organisms lived on Earth, how species evolved, and how some species have gone extinct.

Evidence of Animal Evolution



Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones.

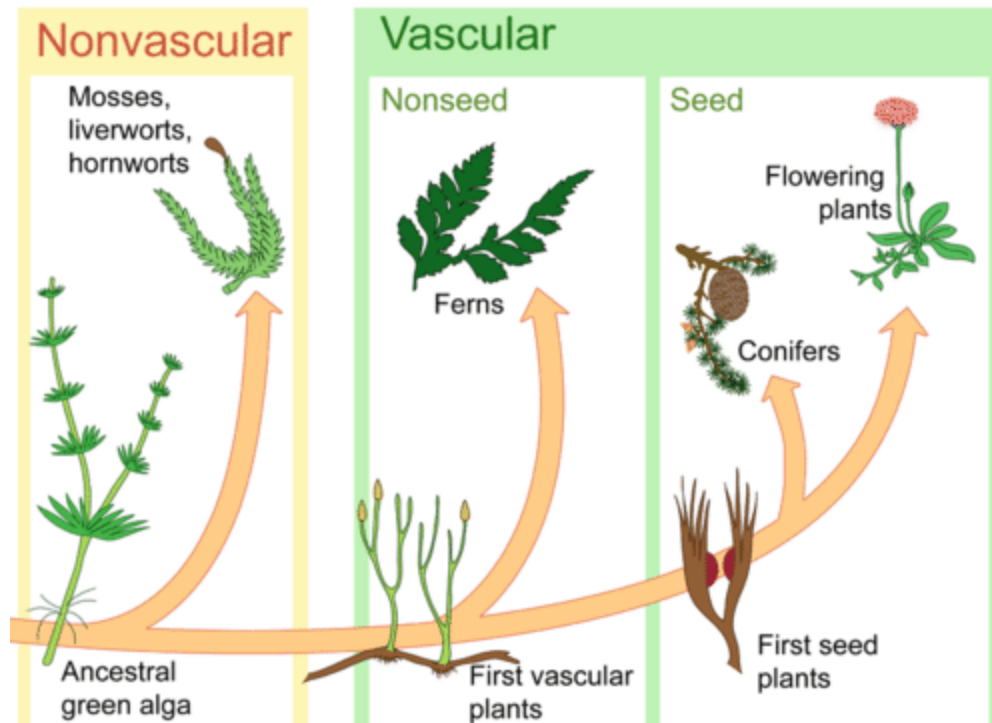
The oldest horse fossils show what the earliest horses were like. They were about the size of a fox, and they had four long toes. Additional evidence in the rock layers shows they lived in wooded marshlands, where they probably ate soft leaves. Through time, the climate became drier, and grasslands slowly replaced the marshes. Later fossils show that horses changed as well.

- They became taller, which would help them see predators while they fed in tall grasses.
- They evolved a single large toe that eventually became a hoof. This would help them run swiftly and escape predators.
- Their molars (back teeth) became longer and covered with cement. This would allow them to grind tough grasses and grass seeds without wearing out their teeth.

Similar fossil evidence demonstrates the evolution of the whale, moving from the land into the sea.

Evidence of Plant Evolution

Evolution of plants can also be found in the fossil record. As shown in the figure below, plants are thought to have evolved from an aquatic green algae protist. Later, they evolved important adaptations for land, including vascular tissues, seeds, and flowers. Each of these major adaptations made plants better suited for life on dry land and much more successful.



Ck12.org, CC BY-SA

From a simple, green algae ancestor that lived in the water, plants eventually evolved several major adaptations for life on land.

7.5.2 Changes to Life Over Time

Putting It Together



*Dinosaurious Park, Utahraptor by HombreDHojalata,
CC BY-SA*

The Utahraptor was discovered in 1991 near Moab, UT. Scientists have measured that the Utahraptor is the largest raptor that ever lived in Utah. The Utahraptor and many of the other raptors have common traits. Many of these traits are found in modern birds. When you look at layers of rocks you can see a variety of fossils showing different species at consecutive layers that provide evidence that there has been change over time.

Focus Questions:

1. What evidence could scientists use to make the claim that modern birds share ancestry with dinosaurs like the Utahraptor?
2. What other characteristics about the Utahraptor could be inferred based on the evidence collected?
3. What other examples of changes in organisms would be helpful to understand?

Final Task

Create a list of evidence that organisms have changed over time. What makes the evidence reliable?

7.5.3 Connecting Modern Organisms to Ancient Organisms

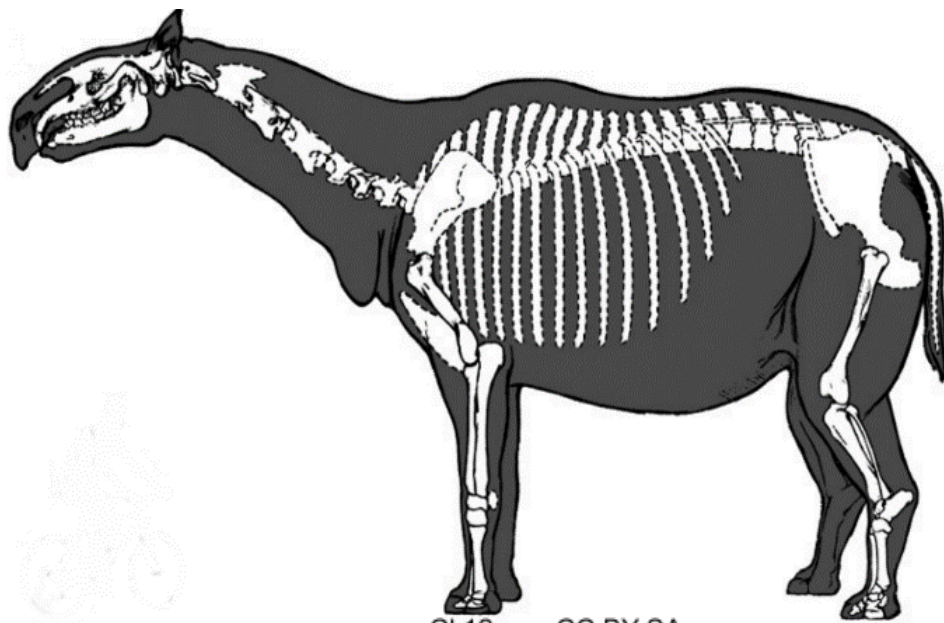
Phenomenon



https://c2.staticflickr.com/6/5232/5820747273_a423abc0a7_b.jpg
CC BY-NC



Skeleton of white rhinoceros by Joel Abroad, <https://flic.kr/p/fphFgt>
CC BY-SA-NC



Ck12.org, CC BY-SA

This animal is a Paraceratherium that became extinct over 23 million years ago. It stood over 16 feet tall and was over 4 feet long. Its skeleton looks very similar to a modern day white rhinoceros (image on the left).

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.5.3 Connecting Modern Organisms to Ancient Organisms

Construct explanations that describe the patterns of body structure similarities and differences between modern organisms, and between ancient and modern organisms, to infer possible evolutionary relationships. (LS4.A)



In this section, focus on understanding how scientists compare and contrast patterns to help identify relationships between fossils and modern organisms.

Evidence of Common Descent

When different species evolve from a common ancestor, we call it common descent. Paleontologists have found evidence of common descent in the fossil record. This evidence has helped scientists develop the theory of evolution.

Fossils are important for estimating when and how species change over time. We can use fossils to compare the anatomy of different groups of animals to determine how they are related, when they lived, and when they became extinct.

Similar Structures

Scientists use fossils to group animals into families. They can use the skeletal structure, size and shape of the skull and the type of teeth to determine how the animals are related. Take a look at these two skulls; the first is a skull of a modern crocodile and the second is an ancient skull of a megalania, which is one of the crocodile's ancestors. What evidence do you see that could indicate that they are related?



Alligator Crâne et Mandibule by Didier Descouens, CC BY-SA
Modern Crocodile Skull

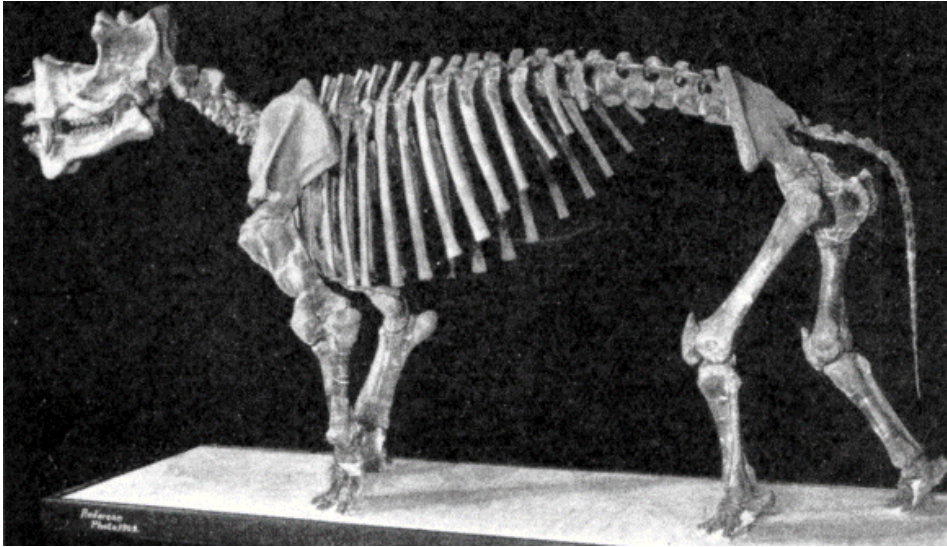


Megalania (*Varanus priscus*) skull. Photo by Steven G. Johnson.
Ancient Megalania Skull

Are They Related?

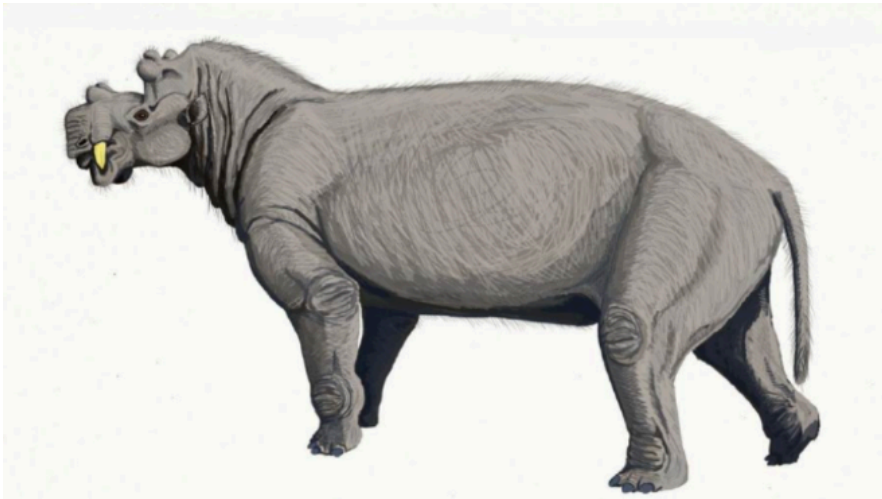
Have you ever heard that whales are related to elephants? What evidence do scientists use to determine family relations? Let's take a look at two very different animals that share a common ancestor.

Both the modern whale and the modern elephant are related to the Uintatherium that lived over 50,000 years ago. First let's compare the Uintatherium to its modern descendent, the elephant. What do you notice about their toes?



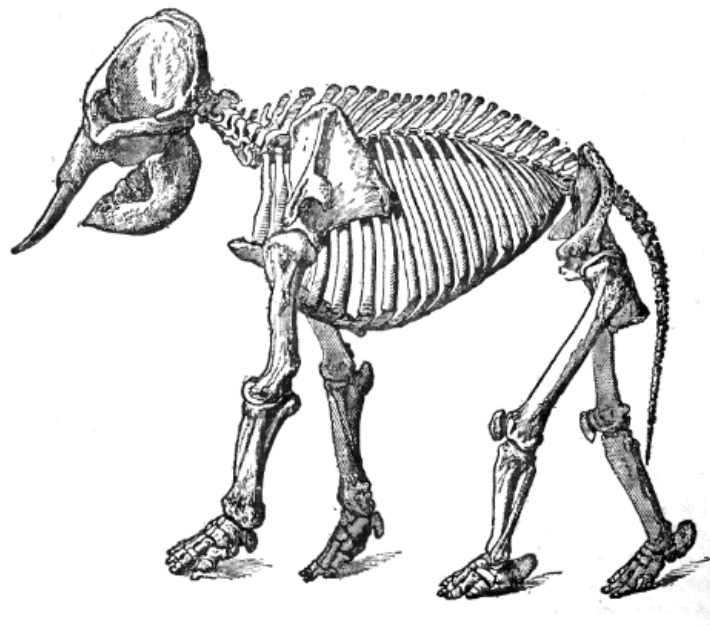
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Skeleton of a Uintatherium



Uintatherium by Dmitry Bogdanov, _DB.jpg, CC BY-SA

Illustration of a Uintatherium



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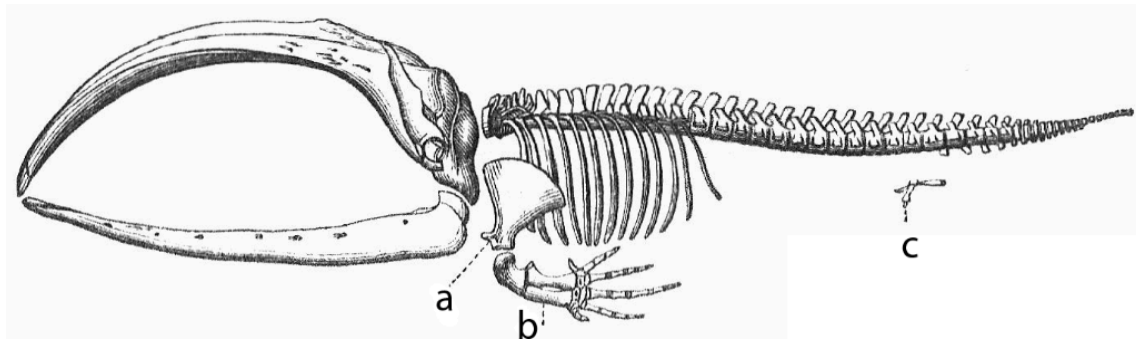
Skeleton of Modern Asian Elephant



Asian Elephant Frida at Quilpue Zoo by PBRO,
https://commons.wikimedia.org/wiki/File:Asian_Elephant_Frida_at_Quilpue_Zoo.jpg CC-BY-SA

Modern Asian Elephant

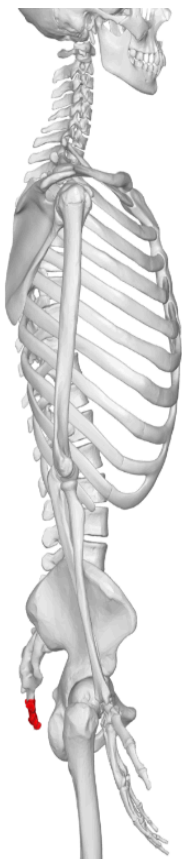
Now let's compare the Uintatherium to another one of its modern descendants, the modern whale. What evidence can you find that the modern whales are descendants of the Uintatherium?



Skeleton of a Modern Whale

Now that we have examined evidence that both the modern elephant and the modern whale have a common ancestor, the Uintatherium, what does this tell us about the relationship of elephants and whales today?

Other Evidence from Body Structures



Coccyx - lateral view05 by
BodyParts3D is made by
DBCLS, CC BY-SA

If you look closely at a skeleton, you might notice a triangular bone at the end of the spinal column. This is your tailbone. Why would you have a tailbone when you don't have a tail? You have a tailbone because your ancient ancestors *did* have a tail. These sorts of "left-over" structures are called vestigial structures and support the theory of evolution. We can use them to see how a species has changed over time.

Another example of vestigial structures are ostrich wings. Most birds need their wings to fly, but the wings of an ostrich are too small for flight. They provide evidence for evolution because they show that over generations the ostrich's wing size changed.

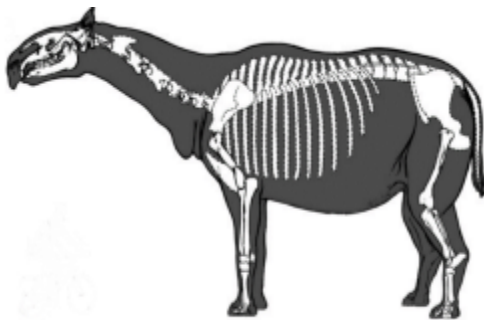


7.5.3 Connecting Modern Organisms to Ancient Organisms

Putting It Together



https://c2.staticflickr.com/6/5232/5820747273_a423abc0a7_b.jpg
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Ck12.org, CC BY-SA



Skeleton of white rhinoceros by Joel Abroad, <https://iis.knyftrfaj>
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Scientists have said that the Paraceratherium is related to the White Rhino. They have looked at bone structures, similarities in teeth and features of how muscles attach. Evidence like this from anatomy helps support the Theory of Evolution

Focus Questions:

1. Construct an explanation to infer possible evolutionary relationships using patterns found in the fossil and skeletons of the white rhinoceros and paraceratherium.
2. What are some examples of how anatomical structures provide evidence for evolution?
3. How do similarities and differences between modern organisms and ancient fossils provide evidence for evolution?

Final Task:

Research and Report on the fossil record of a modern organism. Pick a modern organism ie: elephants, aspen, bison, or horses, Pinyon Pine trees or whales. It may be easier to find information about certain organisms over others. Construct an explanation that describes the evidence that shows how that organism changed over time. Describe things like how many types there were in the past compared to today, where they lived, and how the rock layers the fossils were found in gave clues about how these organisms lived and died.

7.5.4 Comparative Embryology

Phenomenon



Chicken Embryo by DBCLS 統合TV, CC BY

Many different types of animals look like the above image at the embryo stage. Embryos have many similarities as they go through developmental stages.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

7.5.4 Comparative Embryology

Analyze data to compare patterns in the embryological development across multiple species to identify similarities and differences not evident in the fully formed anatomy. (LS4.A)



In this section, analyze pictorial data to compare patterns of embryological development across multiple species.

Embryo Growth and Development



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We all start as a single cell and soon grow into an embryo. Notice the remarkable details beginning to form. The eyes, backbone, and limb buds are obvious. Think about the amazing complexity that must be going on inside the embryo, and the tremendous amount of growth and development still to come.

After fertilization in animals occurs, the fertilized egg is called an embryo. In humans the embryonic stage lasts through the eighth week following fertilization. During this time, the embryo grows in

size and becomes more complex. It develops specialized cells and tissues and starts to form most organs.

A few of the developments that occur in the embryo during weeks 4 through 8 are listed in the figure below. By the eighth week of development, the human embryo is about 30 millimeters (just over 1 inch) in length. It has also begun to move.

Embryonic Development (Weeks 4-8)

Week 4

- Heart begins to beat
- Arm buds appear
- Liver, pancreas, and gall bladder start to form
- Spleen appears



Embryo at 4 weeks

Week 5

- Eyes start to form
- Leg buds appear
- Hands appear as paddles
- Blood begins to circulate
- Facial features start to develop

Week 6

- Lungs start to form
- Fingers and toes form

Week 7

- Hair follicles start to form
- Elbows and toes are visible

Week 8

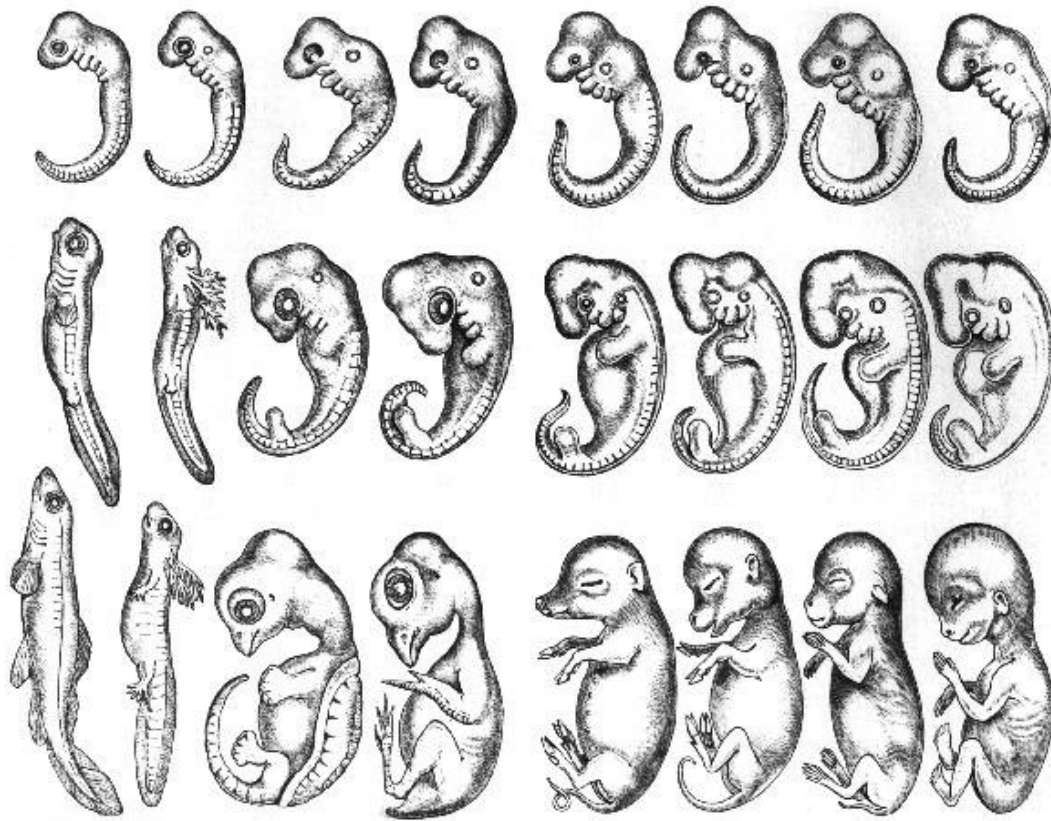
- Face begins to look human
- External ears start to form



Embryo at 8 weeks

(Note: the drawings of the embryos are not to scale.)

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This picture above was created by early scientists who were looking for similarities and differences among different species. Though the pictures above were simplified to show similarities and there has been some recent controversy regarding the pictures, it opened the door for other scientists to investigate how embryological development can be one way of showing evolutionary relationships.

Public Domain

Comparative embryology is the study of similar patterns among embryos. Some of these similarities are only present in the embryo form and not in their adult form. For example, all animals that have a backbone have gill slits and tails at some point in their embryonic development. As the animal grows, these characteristics disappear in animals that live on land, but are still present in the animals that live in or around water. Organisms that share traits are more closely related. These similarities in embryonic development show how some animals may share a common ancestor.

To analyze your own data regarding embryos, you can visit websites or find videos about embryological development.

7.5.4 Comparative Embryology

Putting It Together



Chicken Embryo by DBCLS 統合TV,, CC-BY

Embryos have many similarities as they go through developmental stages. These similarities are evidence of common ancestry and similarities in evolution. Scientists use information from embryological development to identify how closely related two different organisms are.

Focus Questions:

1. Construct an explanation as to why it is sometimes difficult to identify the species when just looking at the embryos.
2. How do scientists use embryos to show how closely related animals are?

Final Task:

Find a website that shows photos or pictures of the differences and similarities between types of embryos. Create your own list of observations about how they are similar. Develop questions you have about the embryos.

