7th Grade Science

for Utah SEEd Standards

Utah State Board of Education

2019-2020

7th Grade

for Utah SEEd Standards

Utah State Board of Education OER
2019-2020

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Table of Contents

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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?

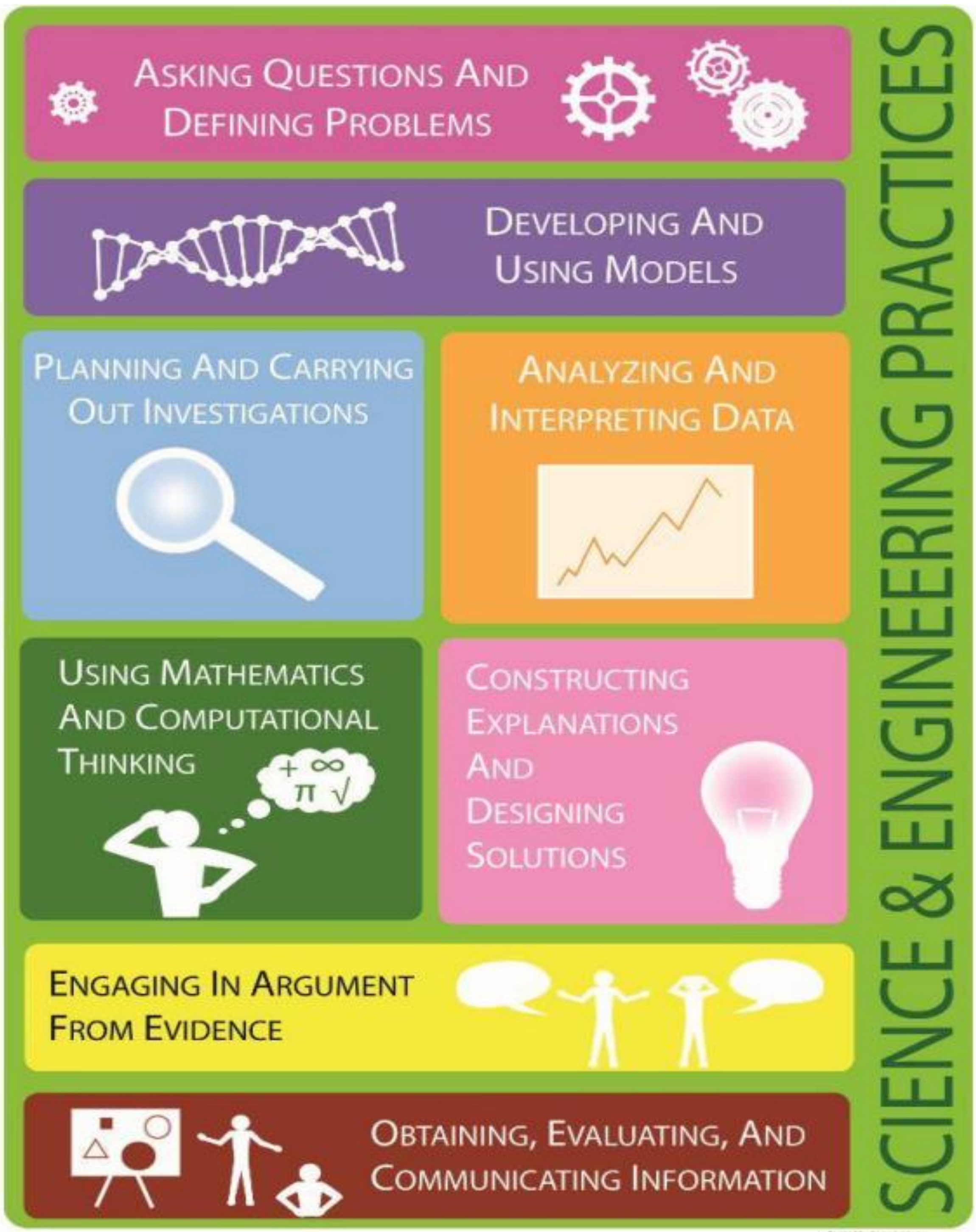
Look. There's a puddle. How often is there a puddle in the desert? The sand is wet and fine; and it makes swirling, layered patterns on the solid stone. There are pits and pockets in the rock, like the one that these two scientists are sitting in, and the gritty sand and the cold water accumulate there. 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

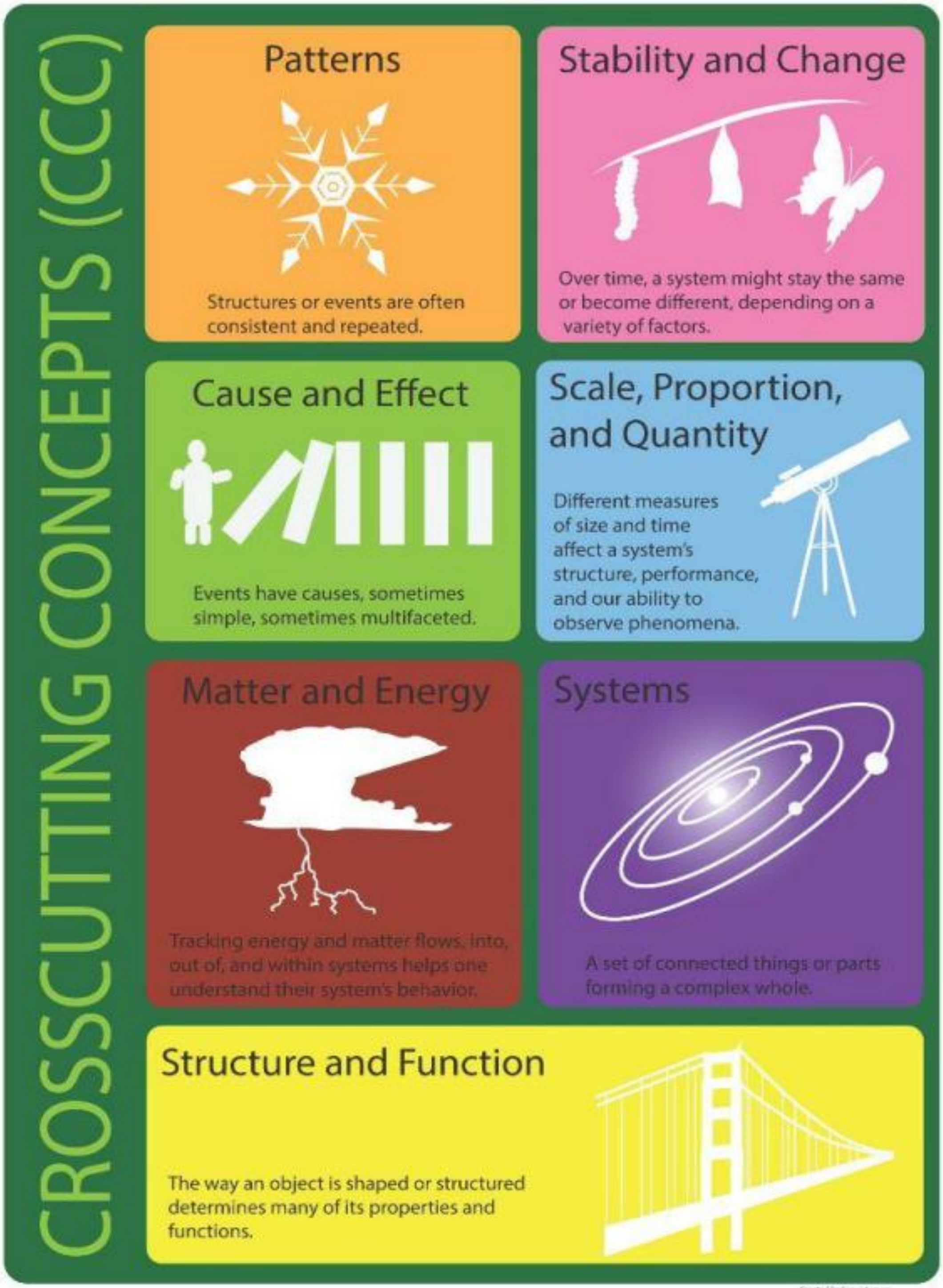
Science and Engineering Practices

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



Cross Cutting Concepts

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



A Note to Teachers

This Open Educational Resource (OER) textbook has been written specifically for students as a reputable source for them to obtain information aligned to the 7th Grade Science Standards. The hope is that as teachers use this resource with their students, they keep a record of their suggestions on how to improve the book. Every year, the book will be revised using teacher feedback and with new objectives to improve the book.

If there is feedback you would like to provide to support future writing teams please use the following online survey: http://go.uen.org/b62

CHAPTER 1

Strand 1: Forces Interact with Matter

Chapter Outline

Forces are push or pull interactions between two objects. Forces on matter aid all changes in motion, balance and stability, and transfer of energy. 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.

1.1 Forces and Motion (7.1.1)

Explore this Phenomenon

Hogle Zoo's Rolling Ball Fountain by Shauna Chapa, CC BY

1. This image shows a rolling ball fountain as seen Hogle Zoo or Lagoon. When you approach the ball it is not moving. How could you get the ball to move?

2. If you push the ball, it will begin moving. When you let go of the ball it will continue moving. Why does the ball continue to move?

3. What would happen if you pushed the ball in a different direction?

4. If you are not touching the ball and it begins to slow down or stop, what causes the ball to slow and stop?

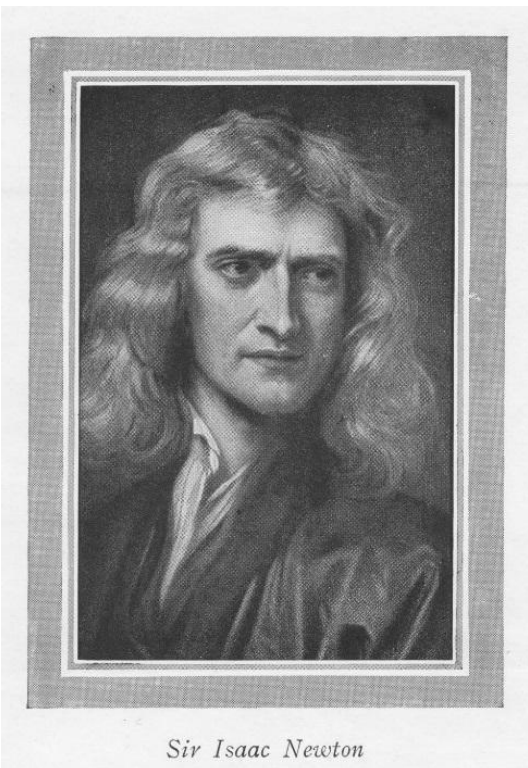
5. What other questions do you have about the movement of the ball?

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 focus on one dimension; the use of vectors will be introduced in high school.

It is important as you read this chapter to understand that the stability or change of an object is directly related to the mass of the object and what forces are acting on it. Unbalanced forces cause a change in motion, while balanced forces create stability.

Force and Motion



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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 observations he was able to explain the relationship between forces and motion.

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 (motion or 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

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 motion of an object is determined by the sum of the forces acting on it. 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, it means that the forces acting on that object are balanced. If an object is in motion, it means that the forces acting on that object are unbalanced. 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?

Putting It Together

Hogle Zoo's Rolling Ball Fountain by Shauna Chapa, CC BY

1. Now that you understand forces, why was the ball at rest when you first approached it?

2. Use what you know about mass, force and motion to explain what is happening when you push the ball?

3. Explain what is happening when the ball continues to roll, when you stop touching it.

4. When the ball is moving, are the forces balanced or unbalanced?

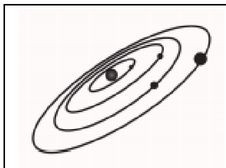
1.2 Action and Reaction (7.1.2)

Explore this Phenomenon

Sometimes when people go rifle shooting and use a scope on their gun, they end up with the type of injury shown in the picture above. First, they put the rifle butt to their shoulder, aim through the scope and shoot. Then….OUCH! As you read the following section, think of what may have caused this injury.

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

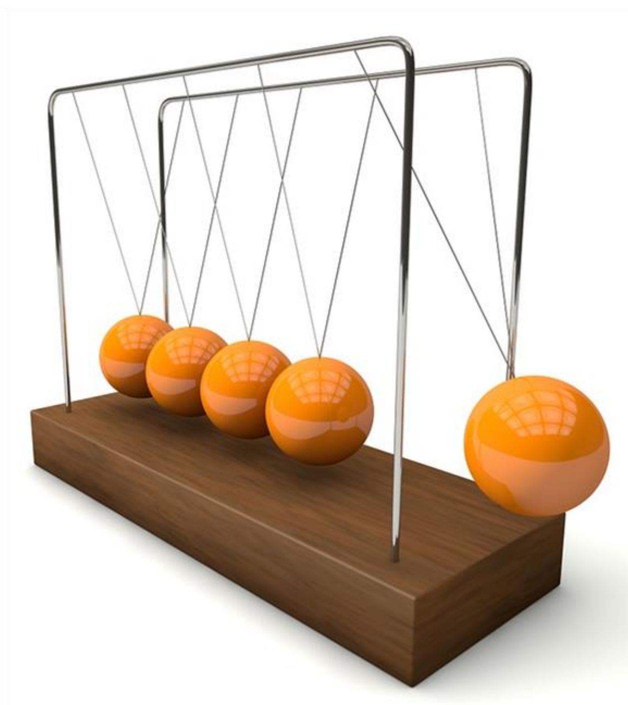


As you read, try to imagine two colliding objects as a system. Think about what forces or energy are going into the system and out of the system. What impact do those forces have on the system as a whole? Scientists and engineers are always looking for ways to reduce the damage that might be caused when two objects collide.

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.

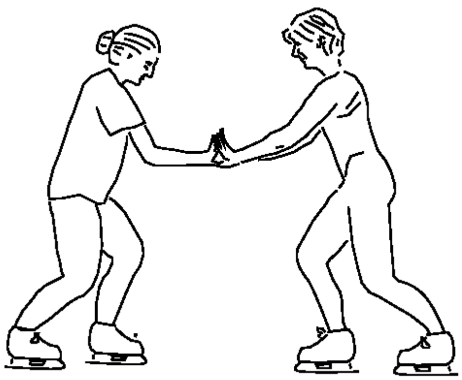
Think of a Newton's cradle as seen in the image. When a sphere on one end is lifted and released, it will collide with the other spheres. The collision transfers energy to the other spheres. The sphere on the far end will swing out from the transferred energy. The last sphere then impacts the row of spheres again and the energy is transferred back through the sphere and causes the original sphere to swing out again. The spheres will continue this motion until the forces become balanced again.



Pixabay.com, CC0

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?

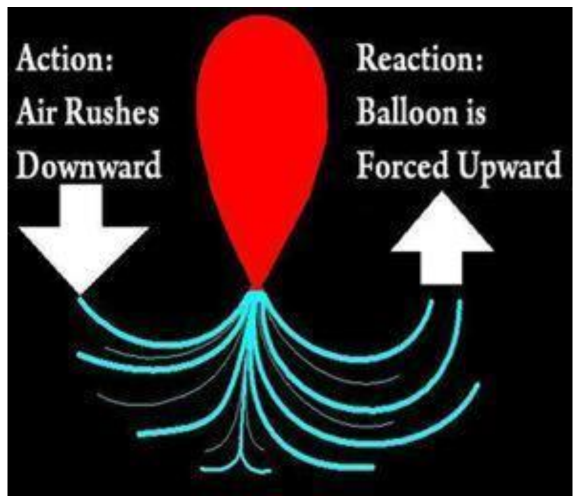
You have a lot more mass than the soccer ball. Remember that the more mass an object has, the more force is needed to move it. The force acting on the soccer ball is big enough to make the ball move. The opposite force acting on you is not big enough to make you move because you have more mass.



Beniamin Crowell

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 is when you release the air out of a balloon. If you let go of a balloon without tying it closed, the air rushes out of the balloon and the balloon goes flying in the other direction.



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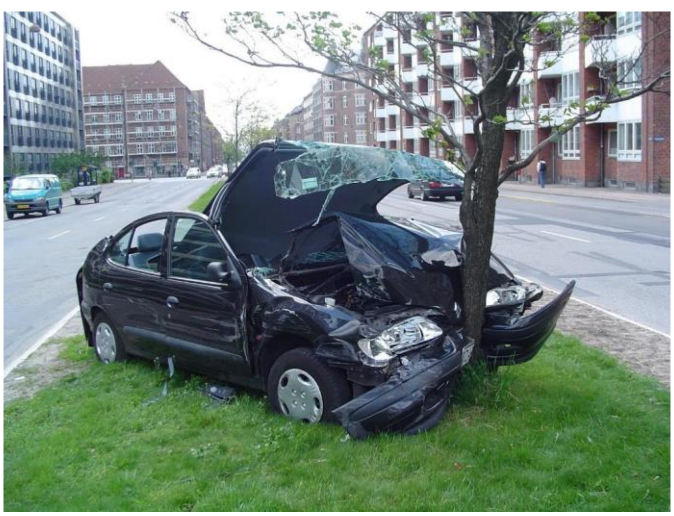


Wikimedia Commons

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?

Putting It Together

Let us revisit this phenomenon:

1. Create a model that shows the forces involved when a person shoots a gun.

2. Now, design a solution that shooters might use to help protect them from injury.

1.3 Electric and Magnetic Forces (7.1.3)

Explore this Phenomenon #1

Electric Slide by Ken Bosma,
https://flic.kr/p/5keFrC, CC BY

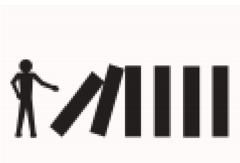
At the park, you see a child coming down the slide with hair sticking straight up.

1. What is causing this to happen?

As you read the following section, think of possible models you could build to show what causes the child's hair to stand up.

7.1.3 Electric and Magnetic Forces

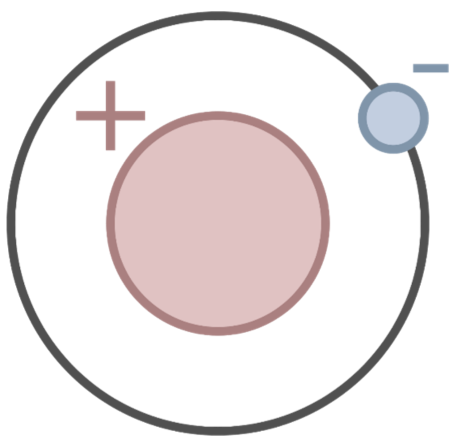
Construct a model using observational evidence that describes the nature of fields exist between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects)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



In this chapter, see if you can identify the causes and effects of electric and magnetic forces. As you observe forces try to identify the cause of each force. We can use cause and effect to help us predict what might happen in similar situations.

Introducing Electric Charge

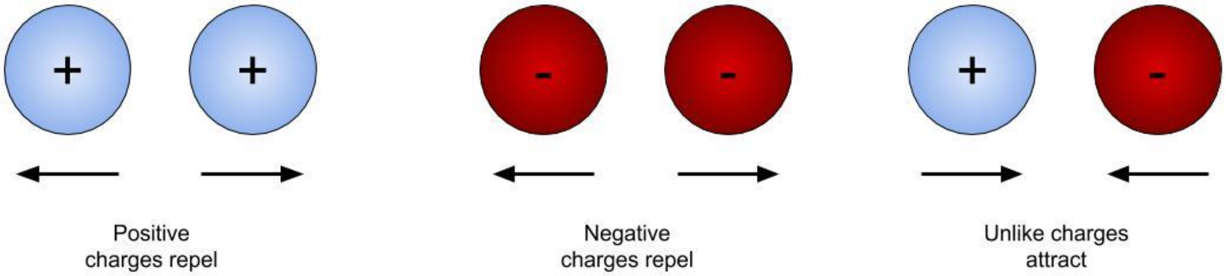
Electric charge is a physical property. It occurs between particles or objects. It causes them to attract or repel each other. They do not even have to touch. This is unlike the typical push or pull you may be familiar with (as discussed in section 7.1.1 in Forces in Motion). All electric charge is based 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, like charges, 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?



CC0

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. Electrons from your hair are transferred to the balloon and the balloon becomes negatively charged. Your hair gives up electrons and becomes positively charged.

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

Pictured below is another example of static electricity.

Wikipedia CC BY 2.0

Putting It Together

Electric Slide by Ken Bosma,
https://flic.kr/p/5keFrC, CC BY

Let us revisit this phenomenon:

1. Using your knowledge of electric forces, explain what causes your hair to stand up from static electricity.

2. Create, draw or find a model to help illustrate your explanation

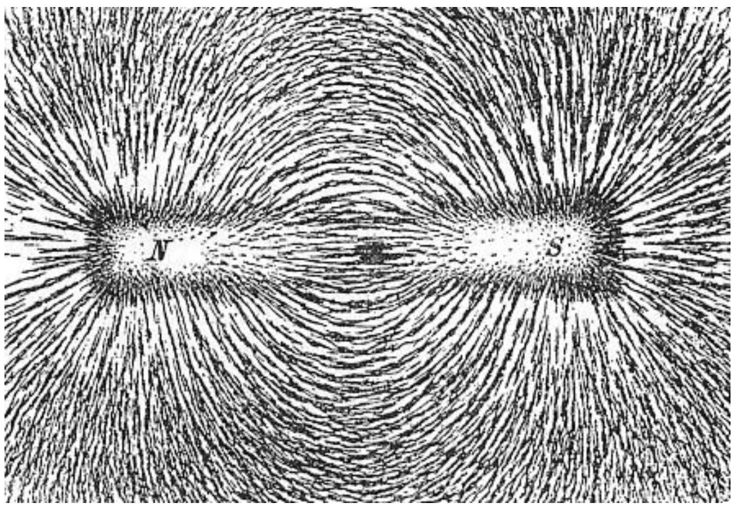
Explore this Phenomenon #2

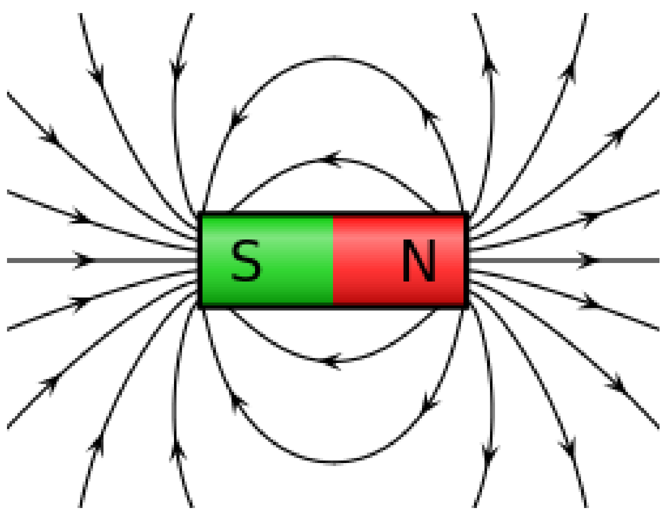
This roller coaster at Lagoon Amusement Park is not powered the way that most roller coasters are. Most roller coasters have a chain that pulls the car out of the station and up the first hill.

This coaster depends on magnets to travel out of the station and up the first hill. As you read the following section, think of possible models you could build to explain how magnets push the train forward and cause it to move so fast.

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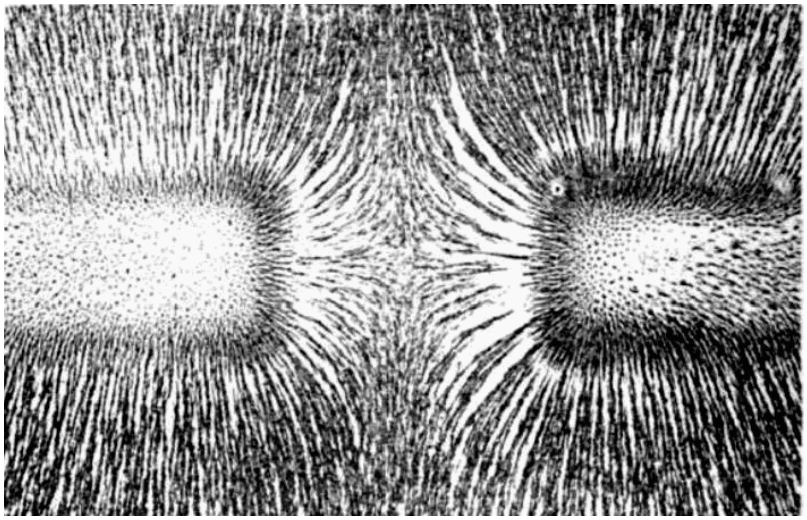
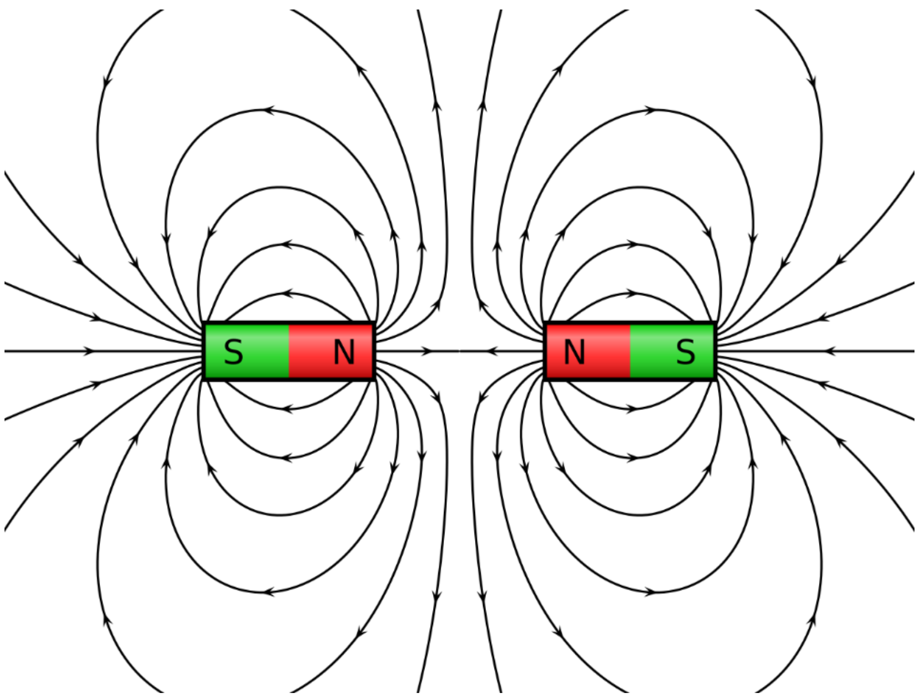
Magnetics can either attract matter or repel matter. If you put two magnets close with the same poles facing each other, they will repel each other. The following two pictures show magnets repelling each other, as evidence by the iron fillings.





Putting It Together

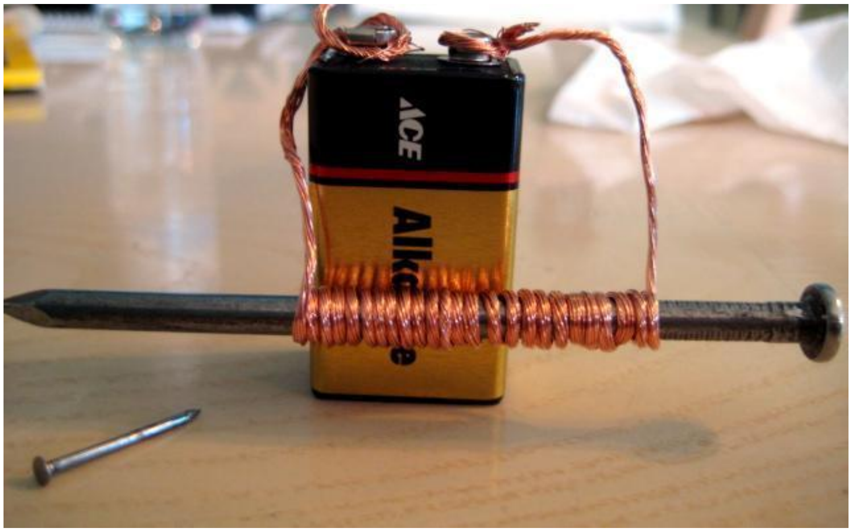
Let us revisit this phenomenon:

Magnets are used on the track and on the cars to make the roller coaster move.

1. Create a model or diagram showing how magnets would start the train moving forward.

1.4 Strength of Electric and Magnetic Forces (7.1.4)

Explore this Phenomenon

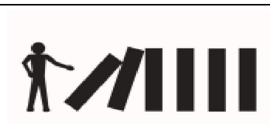


Electromagnet by Gina

You can turn a nail into a magnet by wrapping a wire around it and connecting the wire to a battery. As you read the following section, think of how you could collect and analyze data as to what factors may affect the strength of this magnet.

7.1.4 Factors that Affect the Strength of Electric and Magnetic Forces

Collect and analyze data to determine the factors that <u>affect</u> 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.



Magnets and electrical forces can exert different amounts of strength. In this section, pay special attention to how making changes to the magnets and electrical forces can cause a change in the strength or effect of these 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.

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

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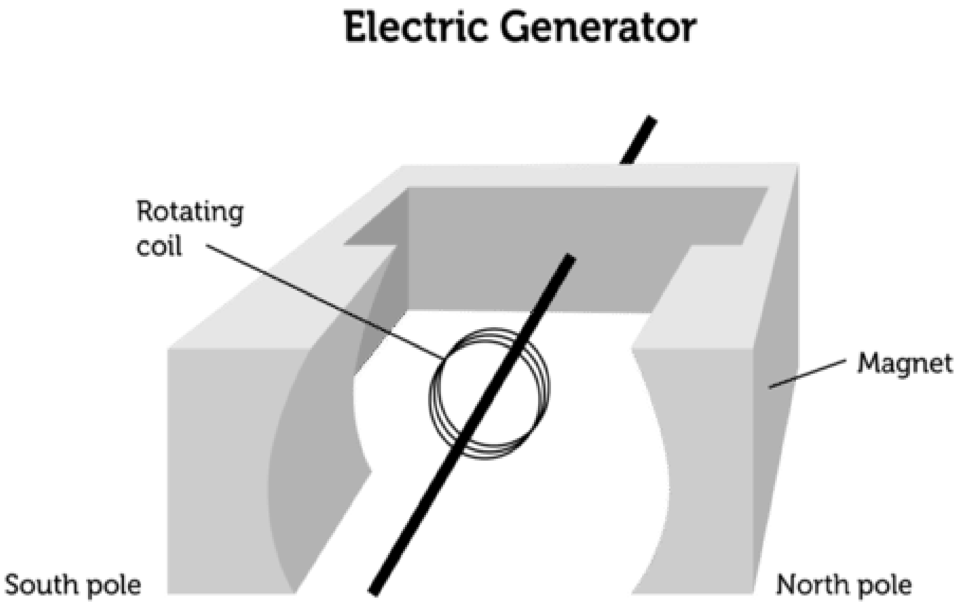
electromagnetic brakes and clutches. Electromagnets are commonly used as switches in electrical machines. A recent use for industrial electromagnets is to create magnetic levitation systems for bullet trains.

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.



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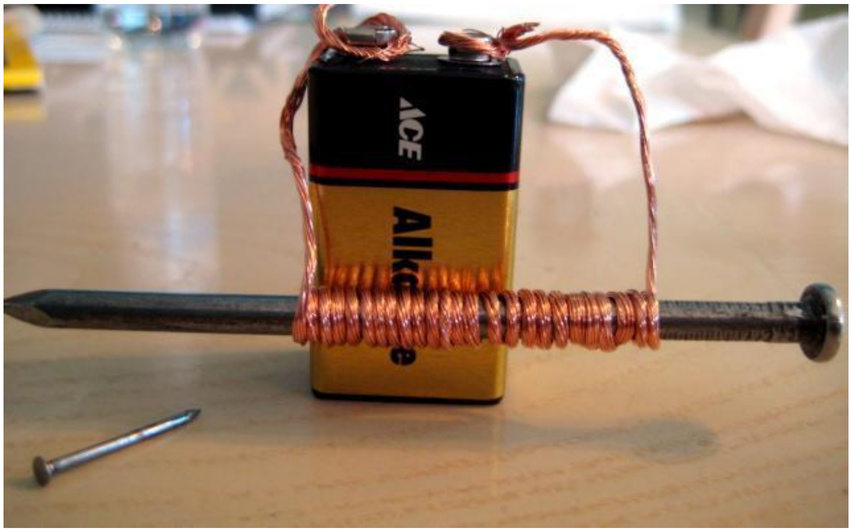
Putting It Together



Electromagnet by Gina Clifford, https://flic.kr/p/4rqaeL, CC BY-SA

Let us revisit this phenomenon:

1. You can build a simple electromagnet using a battery, wire, and nail. Which factor(s) affect how strong the electromagnet is?

   B. The diameter of the wire.
   C. The voltage of the battery.
   D. The size of the nail.
   E. The number of times you wrap the wire around the nail.

1.5 Gravity (7.1.5)

Explore this Phenomenon

NASA. Public Domain

According to NASA, it takes 1,607,185 pounds of fuel to launch a space shuttle from Earth. As you read the following section, engage in argument using evidence to answer the claim that it will take the same amount of fuel to launch a space shuttle from the Moon.

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 simulations or digital tools.

Systems can be big or small. A system model can be used to show the energy that goes in and out of a system. A system consists of all the parts (matter) that are in the system and everything that is affecting the system.

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.

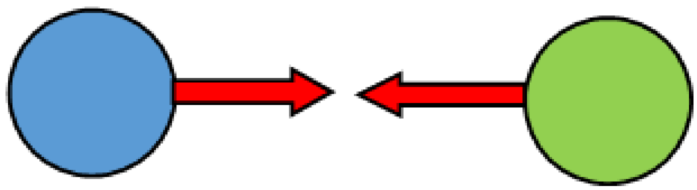
Mass Influences the Strength of Gravity

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 between you and all the objects around you. When you drop a paperclip, why doesn't it fall toward you instead of toward Earth?

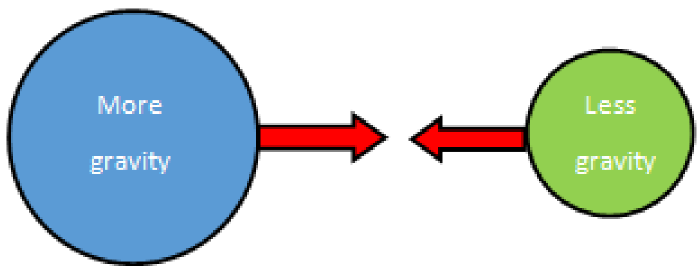
If we look at our solar system, the Sun's mass is about 98% of the total mass of the solar system. Our eight planets are exerting a force on the Sun and the Sun exerts an equal force on the planets. This attraction and the sideways motion of the planets keep them rotating around the Sun.

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.



Objects with more mass exert more gravity.

If distance increases, the force of gravity decreases.

Putting It Together

NASA. Public Domain

Let us revisit this phenomenon:

1. Create a model to show what amount of fuel would be needed to launch a space shuttle from the Moon versus what it would take to launch a space shuttle from Earth.

2. Could you launch a space shuttle from Jupiter, the largest planet in our solar system, with the same amount of fuel that is needed to launch a space shuttle from Earth? Explain your answer.

3. Space Travel Research is used to develop materials for space shuttles. The goal of the research is to have the smallest mass possible. Make an argument with evidence for why this research is important?

CHAPTER 2

Strand 2: Earth's Processes

Chapter Outline

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.

2.1 The Rock Cycle (7.2.1)

Explore this Phenomenon

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

You are in a museum and come across this rock display. The first observations you make are the visible patterns in the rock.

1. How do you think these patterns got there?
2. What are some other observations you have about this rock?

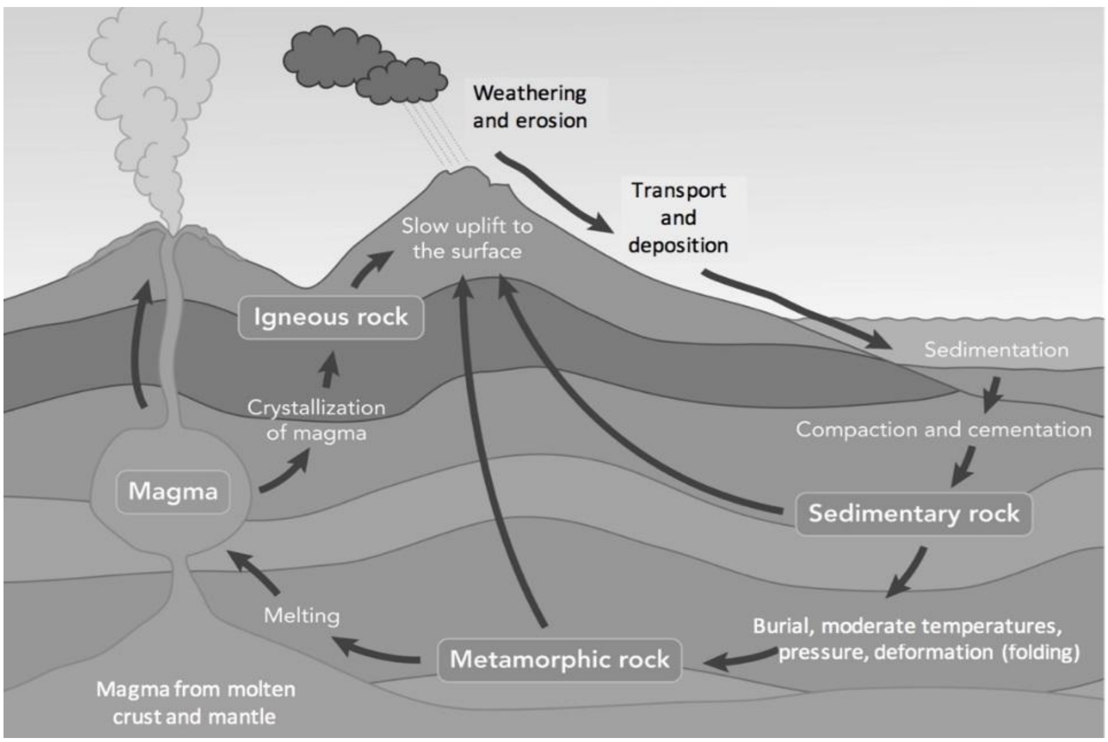
As you read the following section, think of possible ways you could model how this rock was made.

7.2.1 The Rock Cycle

Develop and use 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.

As you read about the rock cycle, try to imagine the amount and type of energy that is needed in order to get matter (rock) to change.

The Rock Cycle



Rock Cycle by Siyavula Education, https://flic.kr/p/mGaVoZ CC-BY

The rock cycle pictured above 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. 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

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. In addition, 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.

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.

Arches National Park Delicate Arch by Anna Irene, https://flic.kr/p/VDio7G CC BY-SA

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, https://flic.kr/p/jet71, CC BY-SA

Daughter Rock: Schist

Auriferous garnet schist (Dahlonega District, Dahlonega Gold Belt, Georgia, USA) by James St. John, https://flic.kr/p/rDcijH, CC BY

Putting It Together

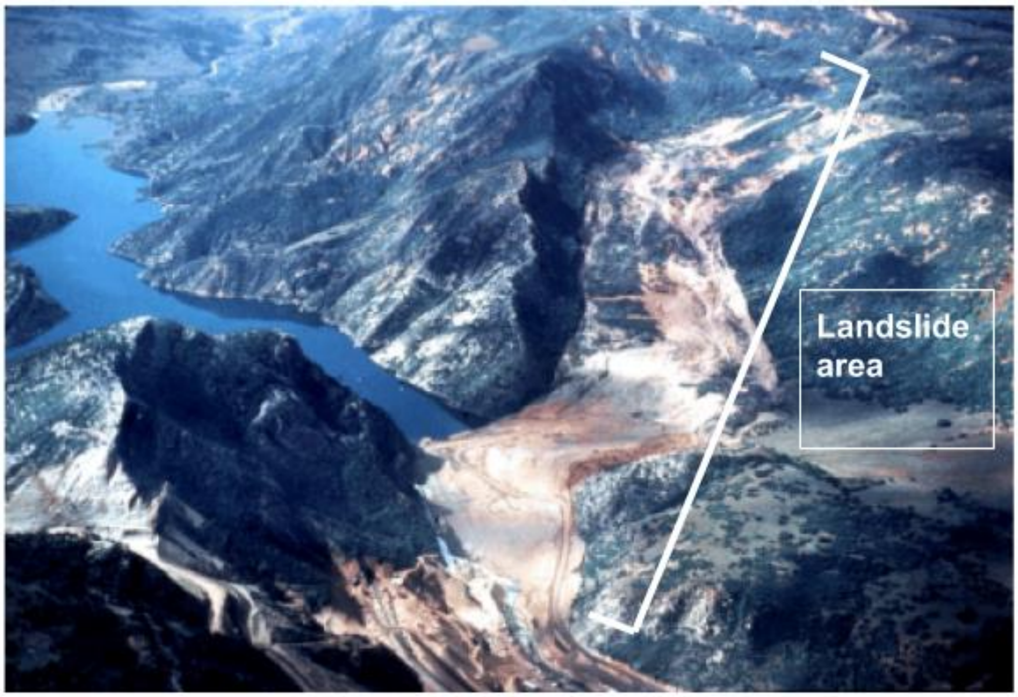
Ductility by Mike Beauregard
https://flic.kr/p/Q31jBL, CC BY

Let us revisit this phenomenon:

1. Create a rock cycle model that shows how this particular type of rock was formed.

2.2 Earth's Surface Changes over Time (7.2.2)

Explore This Phenomenon



Public Domain

In 1983, a giant landslide occurred near the town of Thistle, UT. The landslide plugged the Spanish Fork River creating a lake within a matter of days. It also destroyed roadways and railroad tracks.

1. What can this landslide tell us about the changes to the Earth's landscape over time?

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.

As you look at and read about the structure of the earth, keep in mind that most features took a very long time to form. Some features happen very quickly. It is important to remember that no matter how fast or slow, big or small, different processes contribute to how earth looks today and how it will change in the future. Studying these changes within a small system can help us make predictions about Earth as a whole.

Kaboom!

Public Domain

Amazing but true: 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.

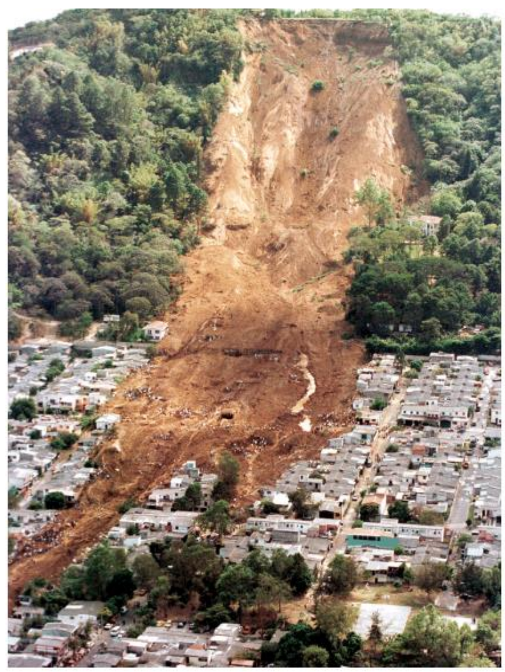
A volcano is a vent from which the material from a magma chamber deep in the Earth escapes. Volcanic eruptions can come from volcanic cones, fractured domes, a vent in the ground, or many other types of structures.

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.

Ck12.org, CC BY-SA

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 below. A landslide can be very destructive. It can bury or carry away entire villages in a matter of seconds or minutes.



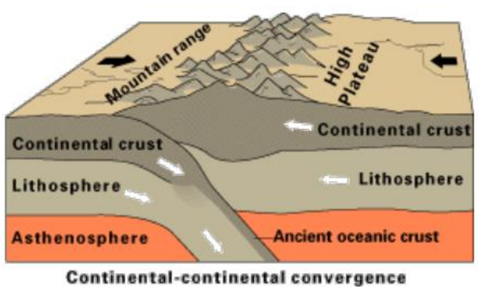
This 2001 landslide in El Salvador (Central America) was started by an earthquake. Soil and rocks flowed down a hillside and swallowed up houses in the city below. Public Domain

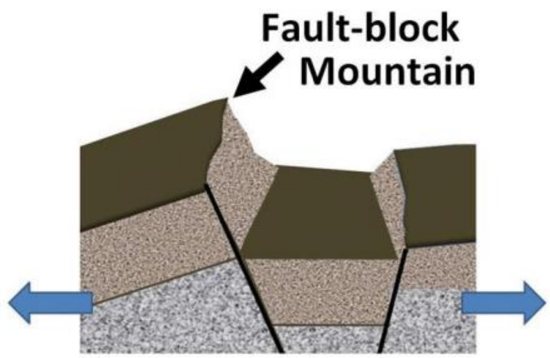
Erosion by Streams

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 below is the San Juan River in Southeastern Utah. The twist 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, https://flic.kr/p/27iZira, CC BY

Mountain Building

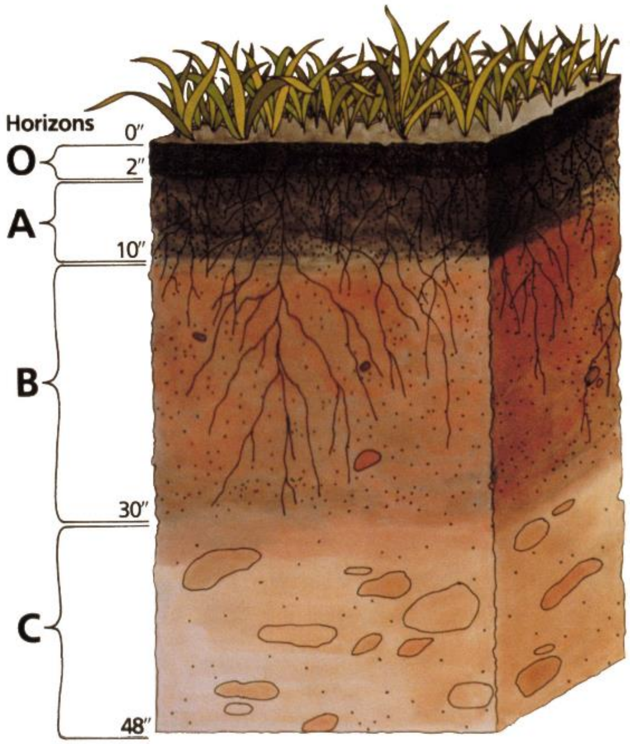




Fault-block Mountain by Brews ohare,

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 right. The Sierra Nevada mountain range was formed this way.

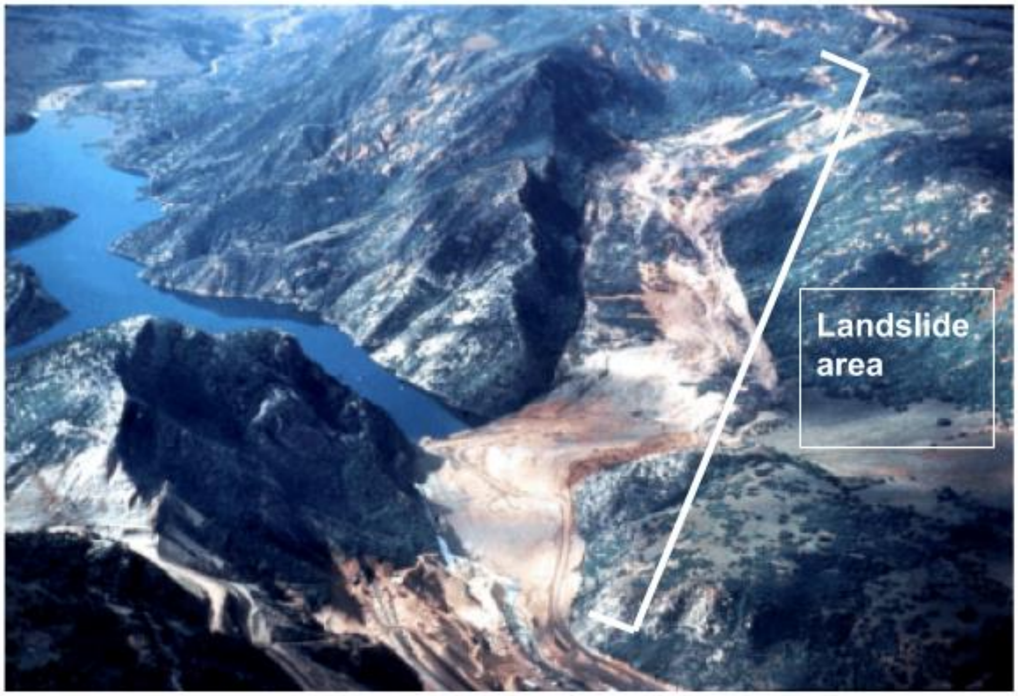
Deposition of Sediments



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 below 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 is 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.

Putting It Together



Public Domain

Let us revisit this phenomenon:

1. Using the evidence and information you gathered from the reading above, construct an explanation for how processes, such as this landslide, have changed the Earth's surface at varying time and spatial scales.

2.3 Engineering and Geologic Hazards (7.2.3)

Explore This Problem

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

The Hayward Earthquake Fault 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.

As you read the following section, think about the constraints and design solutions that people need to be aware of to be safe in the event of an earthquake. Also, think about the following questions:

- In Utah, where should we be aware of geologic hazards?
- What geologic hazards might affect the people who live in Utah?
- How do we know what buildings are at risk for damage in the event of a geologic hazard?
- What kinds of precautions can engineers take to protect out buildings from these geologic hazards?

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.

Sometimes unexpected things might happen that affect the stability of manmade structures. As you read, think like an engineer and see if you can identify the hazards we should watch out for as we build structures. You can predict and then evaluate the best design solution.

Geologic Hazards Affect Humans

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 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. Floodwaters from a river are shown in the image below.

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 these 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.

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

J.K. Nakata, U.S. Geological Survey

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

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.

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

Cost Considerations

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

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

https://www.flickr.com/photos/benjyfeen/9657774911

Putting It Together

Ck12.org, CC BY-SA

Let us revisit this problem:

1. In Utah what are some criteria we should be aware of when building in areas prone to geologic hazards?

2. What are some constraints that we should be aware of when building in areas prone to geologic hazards?

3. What kinds of precautions can engineers take to protect buildings from these geologic hazards?

4. If you were an engineer here in Utah, what questions would you ask to make sure your structural designs are the best fit for the geologic hazards?

2.4 Earth’s Interior (7.2.4)

Explore This Phenomenon

Arsty Density Column by Kelvinsong, CC BY

This cylinder contains different liquids. Notice how they are separated into different layers.

1. What do you think is happening to cause these layers in this cylinder?

As you read, think of how we might use this model to show how the layers of Earth are separated.

7.2.4 Earth's Interior

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

The earth formed billions of years ago. As you read, watch for the different causes that affected how the earth to formed layers.

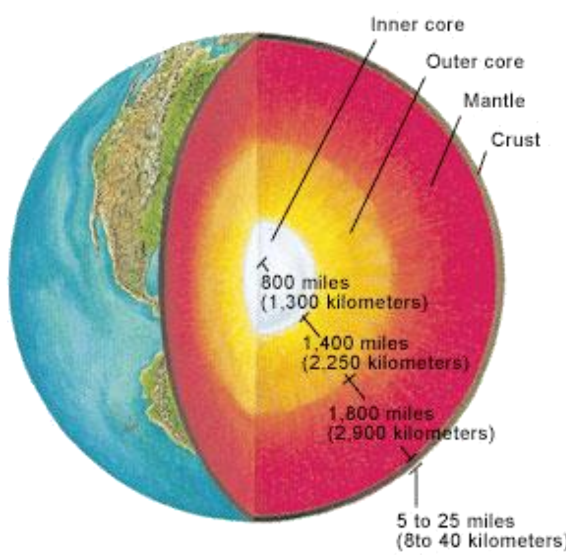
"You're My Density"

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

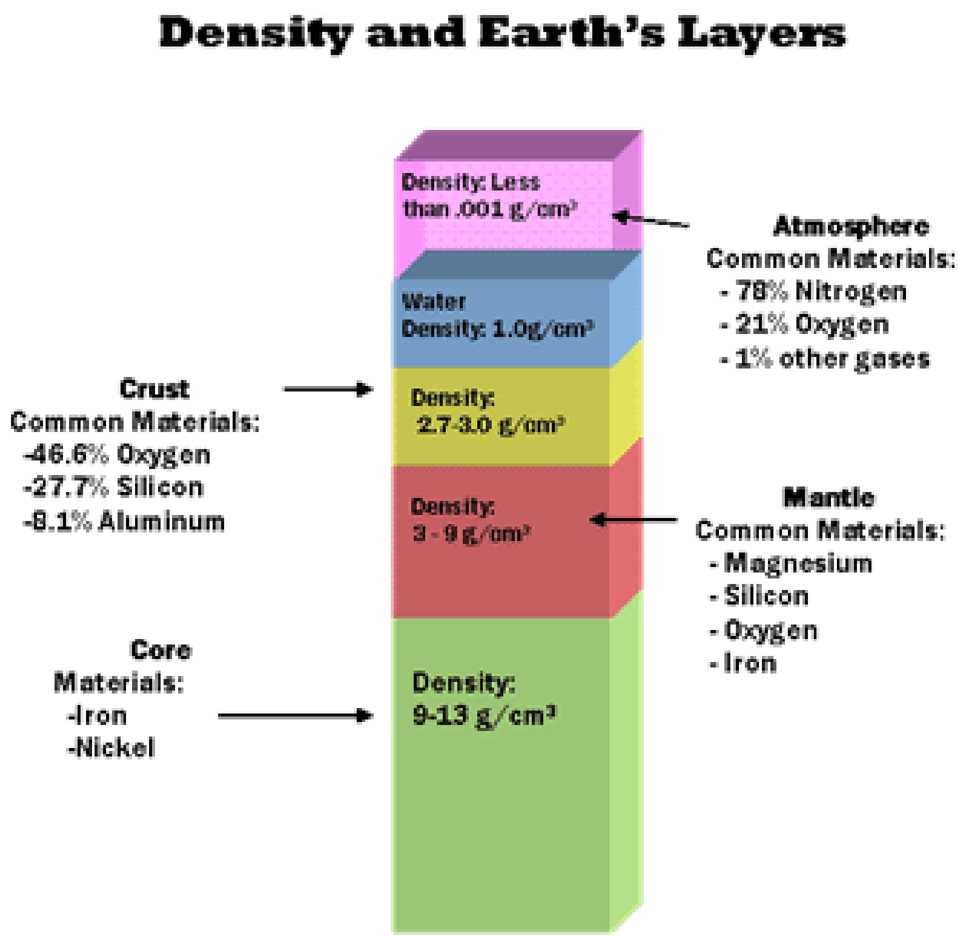
The very center part of the Earth is called the core. Earth's core is divided into the inner core and the outer core.



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 to expand so it must remain a 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/cm^3. 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 of the core 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



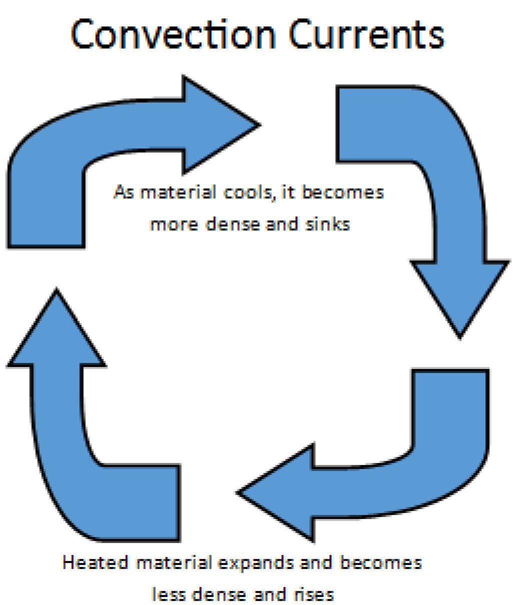
Ck12.org, CC BY-SA

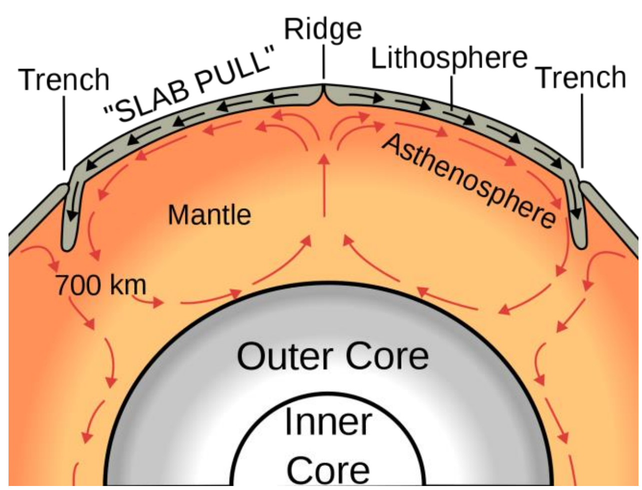
The Mantle

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 upper 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 lower mantle, they ride these currents. These currents 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.

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 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.

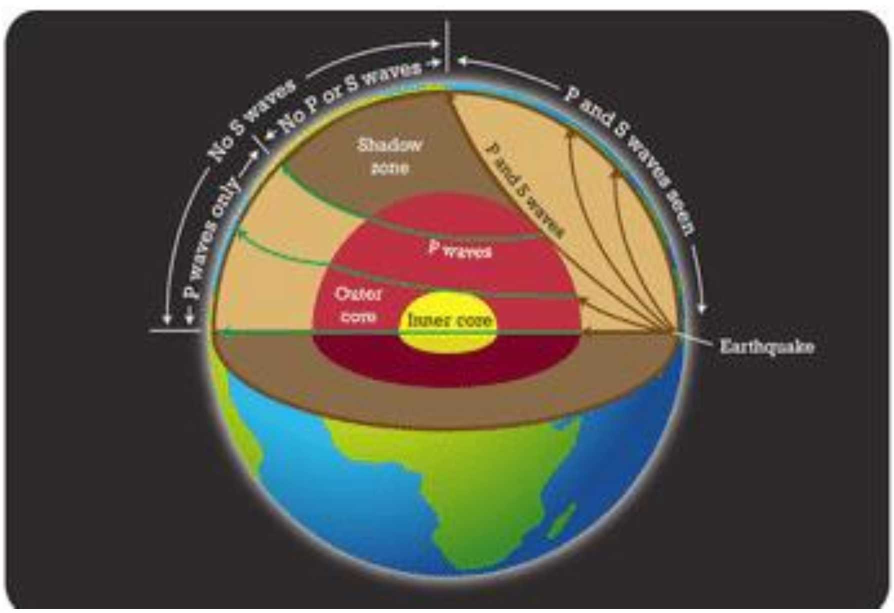
The density of Earth's crust is between 2.7 and 3.0 g/cm3. Since water has a density of 1.0g/cm3, it is less dense than the crust and it sits on top of the crust and fills in any seams, cracks, and empty areas that may be present.

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 and other gases in the air around us. It extends several miles above Earth's surface. The reason our atmosphere is above the Earth is that it is far less dense than each of the other layers is. 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?



The properties of seismic waves allow scientists to understand the composition of Earth's interior.

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 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 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 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.

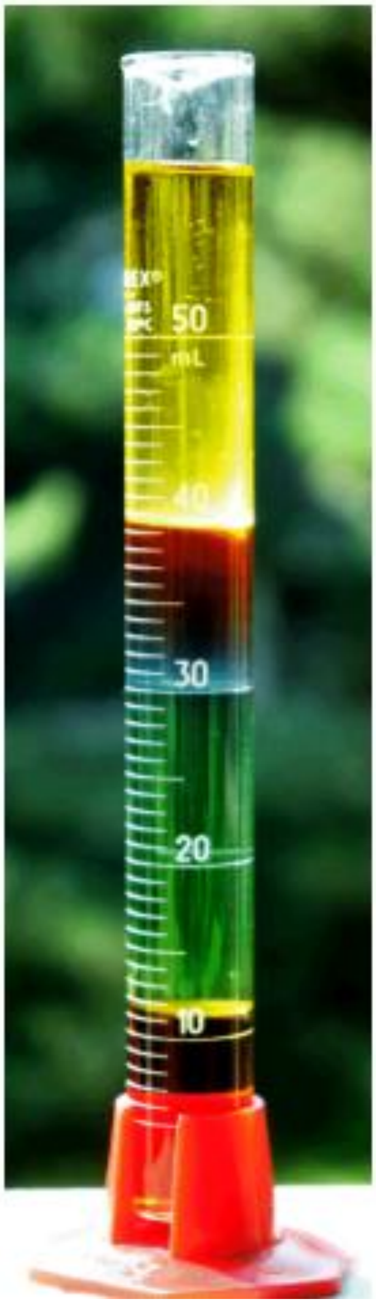
Meteorites

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.

Online Interactive Activity

- Plate Tectonics: http://go.uen.org/aYt

Putting It Together



Arsty Density Column by Kelvinsong, CC BY

Let us revisit this phenomenon:

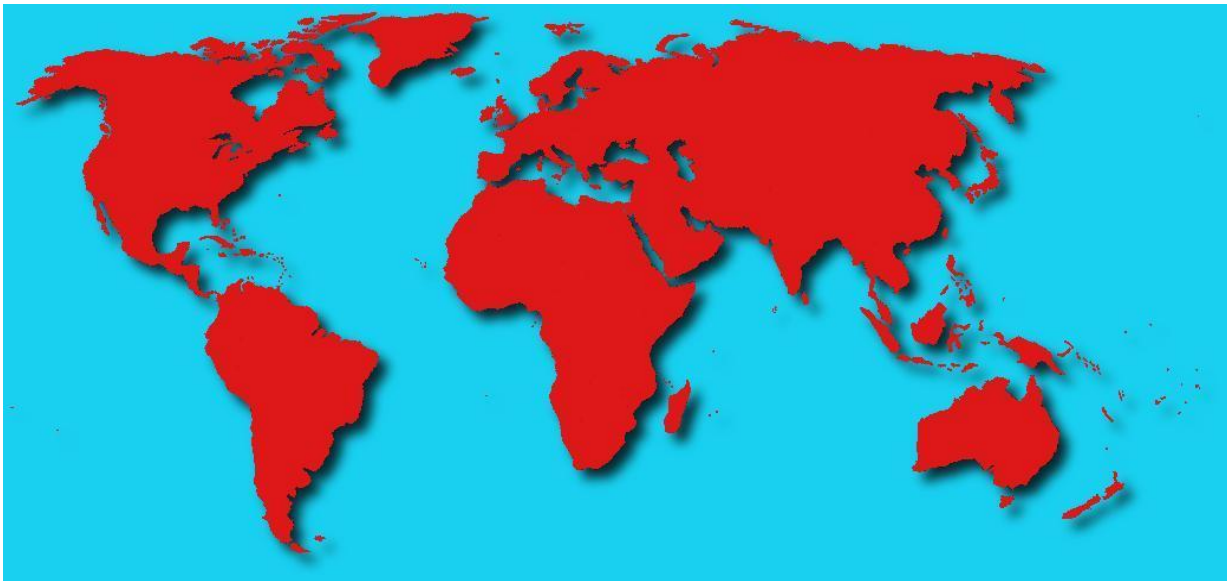
1. Using the knowledge you have gained, expand on or change your explanation of what caused these liquids to separate into different layers?

2. How does this relate to the layers of the Earth?

3. Explain the factors that caused Earth's interior to separate into the crust, mantle, and core?

2.5 Patterns in Plate Tectonics (7.2.5)

Explore this Phenomenon



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

Check out the image above. In the early 1900's, Alfred Wegener proposed that all of the land on Earth used to be connected in one large land mass.

1. What evidence do you see that might lead to support that claim?

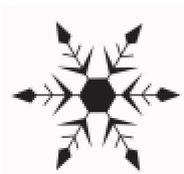
2. Draw a picture of what you think the large land mass might have looked like.

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.



Patterns exist everywhere in the natural world. In this section you can see how analyzing the patterns that we see on Earth today can help us explain what has happened in the past and make prediction 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. Plates can interact three ways 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. In 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 the plate interactions.t. 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 that the oceanic crust is denser than the continental crust.

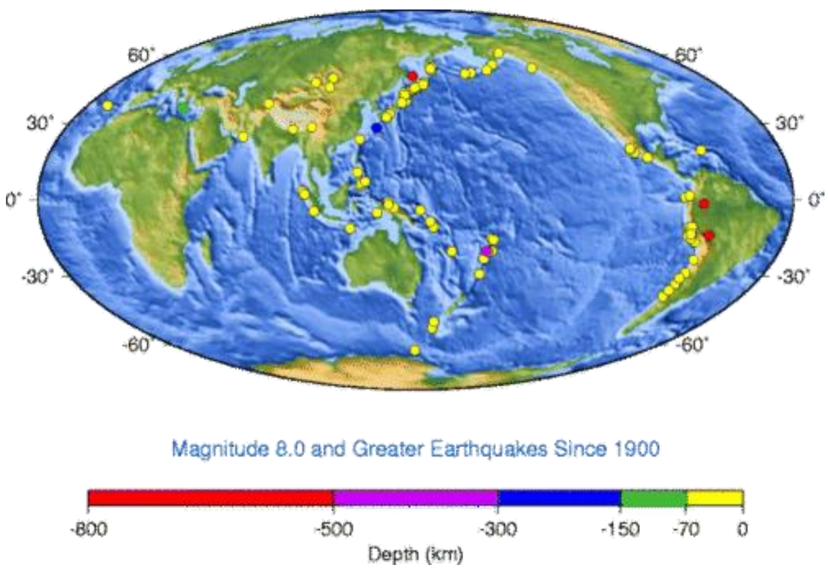
The Cascades have been active for 27 million years, although the current peaks are no more than 2 million years old. The volcanoes are far enough north and are in a region where storms are common, so many are covered by glaciers.

Earthquake Zones

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 see 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.

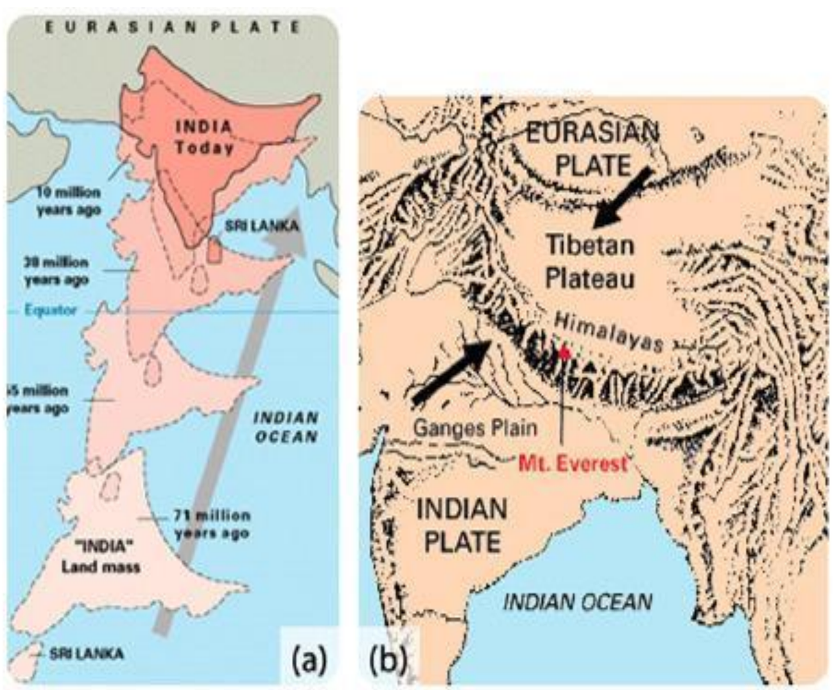
In the image above you can see the Cascade Mountain Range which was formed by volcanoes created from the oceanic crust moving beneath the North American continental crust. (Public Domain)



Earthquake epicenters for magnitude 8.0 and greater events since 1900. The earthquake depth shows that most large quakes are shallow focus, but some subducted plates because deep focus quakes. (Public Domain)

Continental Plates Moving Toward Each Other

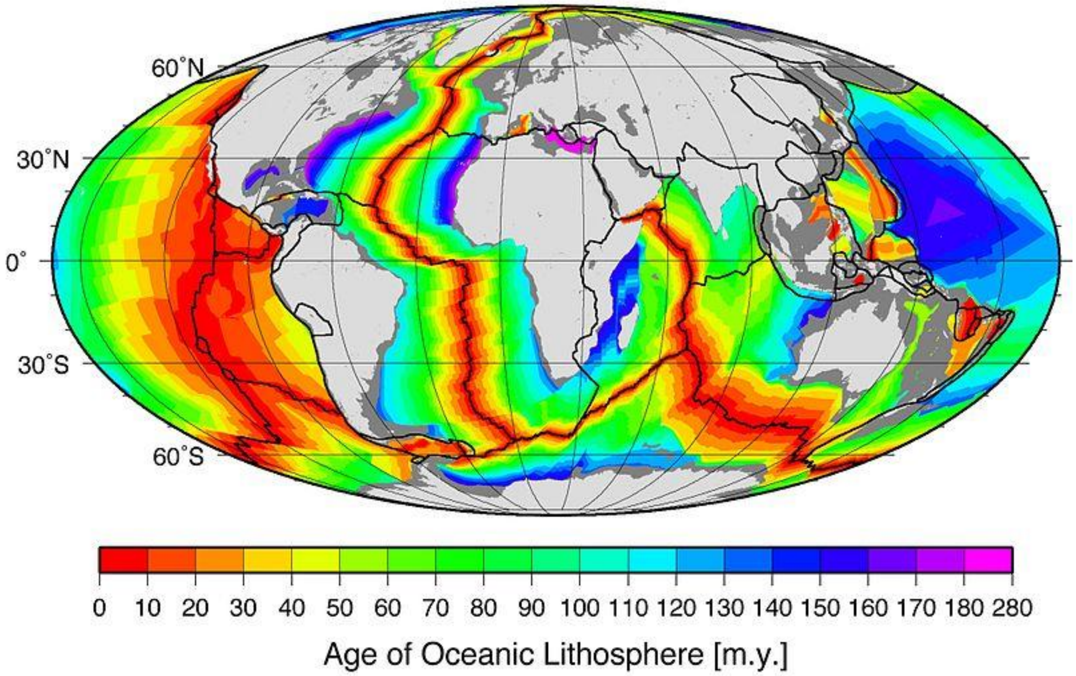
Two continental plates collide and smash upwards to create gigantic mountain ranges. There is currently no mountain range of this type in the western U.S., but we can find one where India is pushing into Eurasia.



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.

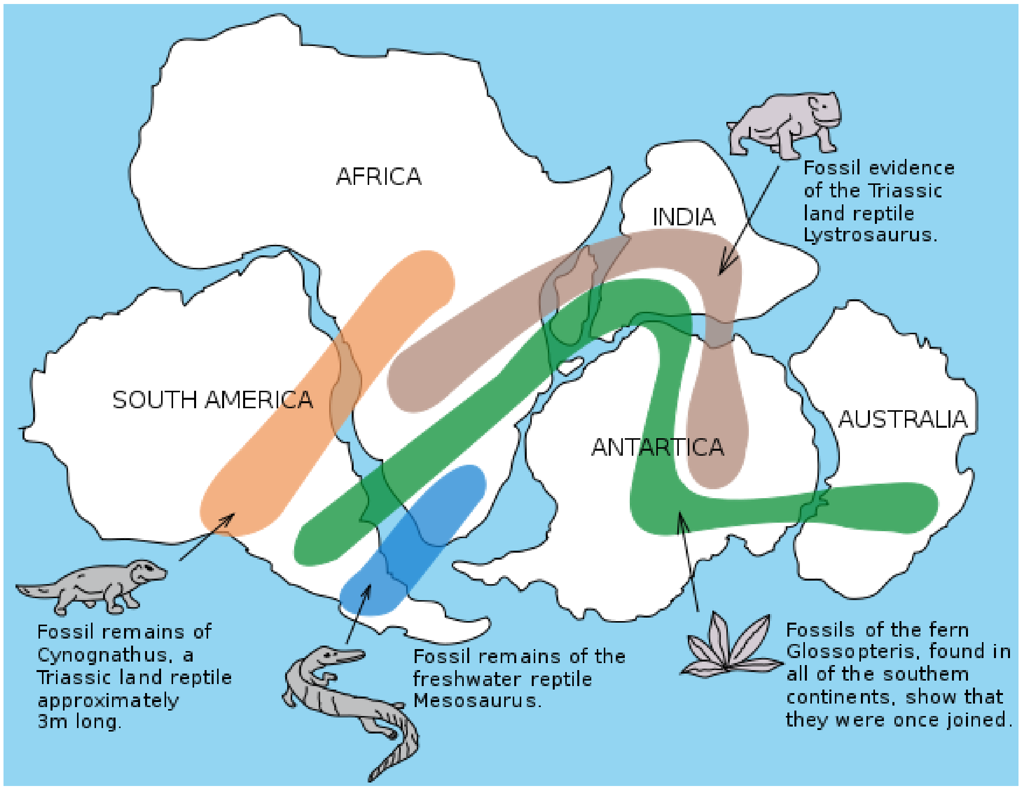


Age of Oceanic Lithosphere by Muller, R.D., M. Sdrolias, C. Gaina, and W.R. Roest, https://commons.wikimedia.org/wiki/File:Age_oceanic_lithosphere,_Muller_et_al.,_2008.jpg, CC BY-SA

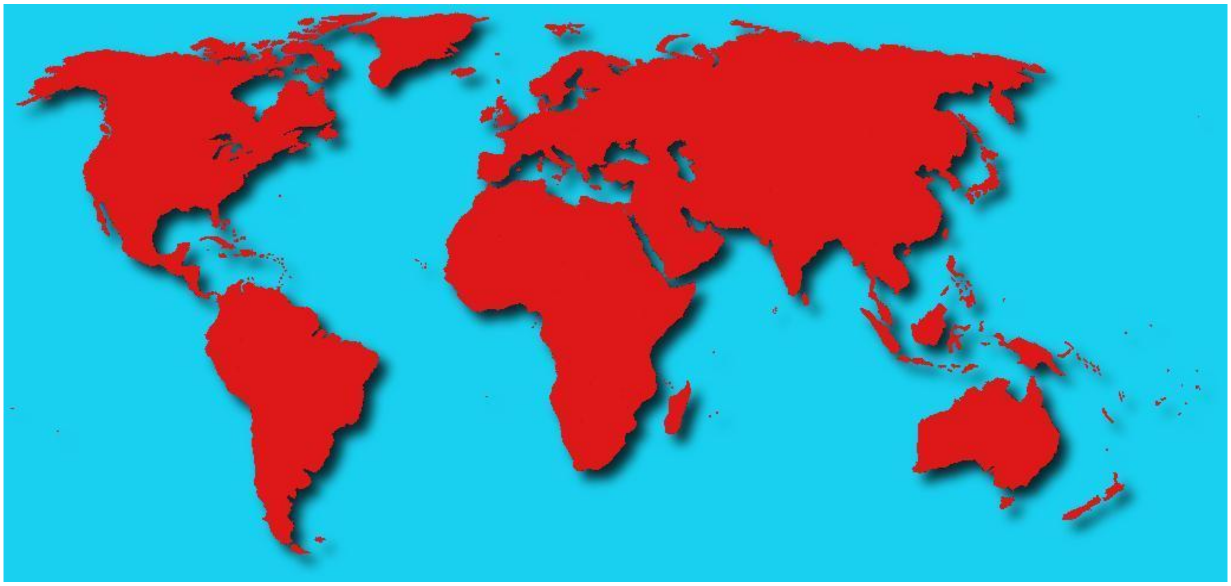
Fossil Evidence for Plate Movement

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 *Lystrosarus have* been found in South Africa, India, and Antarctica. Similarly, the freshwater reptile *Mesosaurus* has been found in only localized regions of the coasts of Brazil and West Africa. The only reason they could be on those continents are if the contents were once connected.

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. 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 are found on many separate continents which would have been together in the supercontinent of Pangaea.


AFRICA
INDIA
SOUTH AMERICA
ANTARTICA
AUSTRALIA
Fossil evidence of the Triassic land reptile Lystrosaurus.
Fossil remains of Cynognathus, a Triassic land reptile approximately 3m long.
Fossil remains of the freshwater reptile Mesosaurus.
Fossils of the fern Glossopteris, found in all of the southem continents, show that they were once joined.

Putting It Together



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

Let us revisit this phenomenon:

1- Using evidence found in this chapter, create an explanation as to why scientists think the coasts of South America and Africa were once connected.

2- What other patterns, besides the shape of the continents, could scientists use as evidence to prove that the continents are moving?

2.6 How Old is the Earth (7.2.6)

Explore this Phenomenon

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

Have you ever been on a hike or floating on a river in a large canyon? Did you notice the layers of different colors or materials in the canyon walls? How did those different layers get there? Are some layers older than other layers? As you read the following section, write an explanation gather evidence from the reading, as to why the canyon walls look like they do.

7.2.6 The Earth is How Old?

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.

Scientists use evidence to show the age and history of the Earth. As you read, think about the time scale and what evidence you could use 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. Scientist 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 of 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

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 below is an example of what marine organisms fossils may look like in rock that has been uplifted.

Fossils in a beach wall, by Brocken Inaglory, https://upload.wikimedia.org/wikipedia/commons/b/b3/Fossils_in_a_beach_wall.JPG, CC BY-SA

The photo below 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

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.

Sand dune in Coral Pink Sand Dunes State Park, Utah.
Ck12.org, CC BY-SA

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 on the 1700's.

Hutton’s Unconformity

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 were created at different times and by different forces. Often times, layers of rock were eroded away, so we are missing sections of history.

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.

Putting It Together

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

Let us revisit this phenomenon:

1. Create an argument from the evidence you gathered in the chapter, as to how we know the relative ages of the different layers of rock. Be sure to include at least three pieces of evidence

CHAPTER 3

Strand 3: Structure and Function of Life

Chapter Outline

(Pixabay.com. CC0)

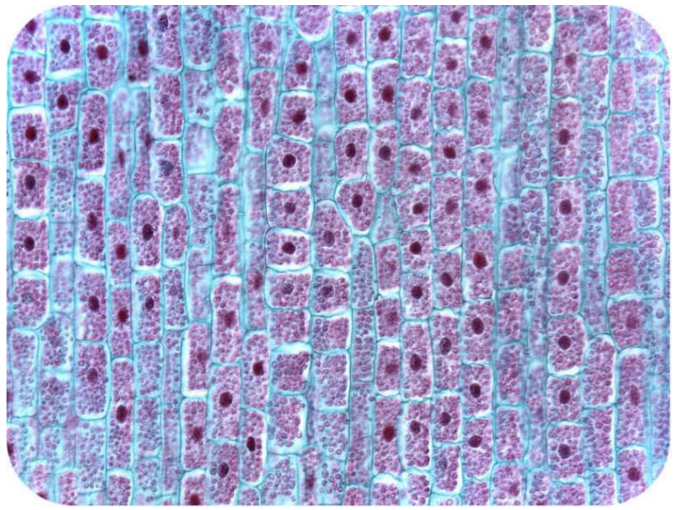
All living things (or things that were once living) are made of smaller structures called cells. The basic structural unit of all living things is the cell. Parts of a cell work together to function as a system. Cells work together and form tissues, organs, and organ systems. Organ systems interact to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

3.1 Cells are the Building Blocks of Life (7.3.1)

Explore this Phenomenon

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

This is what the pinecone looks like in a microscope.



This is what a coin looks like in a microscope.

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, repeating structures can often be seen.

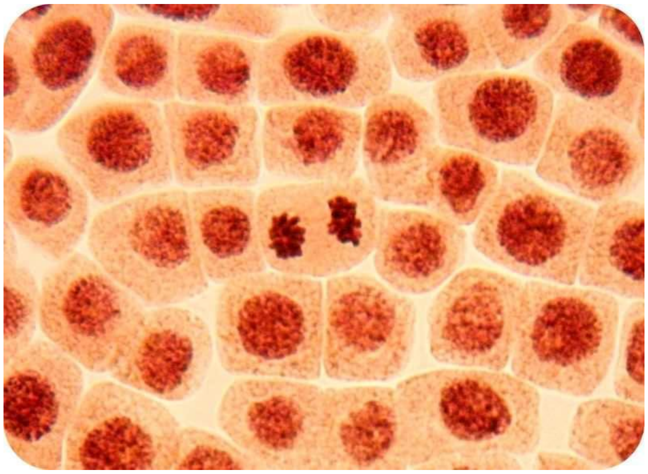
As you read the following section, think about what investigation you could plan and carry out to determine if something is or was once alive.

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.

Cells make up all living things. Different cells have different shapes and sizes that help them perform a specific job. In this section see if you can identify how the structure and function of the tiny cells contribute to the structure and function of the whole organism

Introduction to Cells



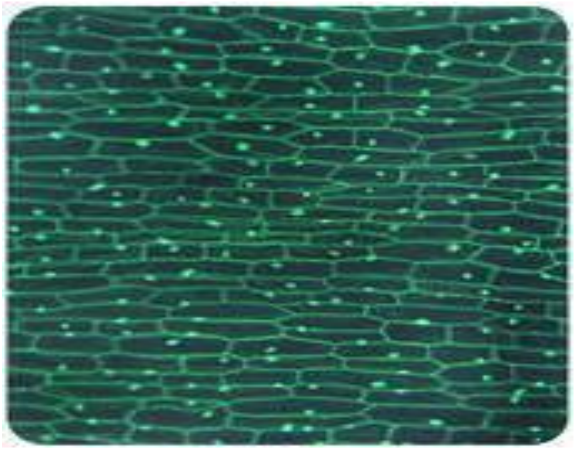
ck12.org

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. In addition, 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 in this image of onion cells.



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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:

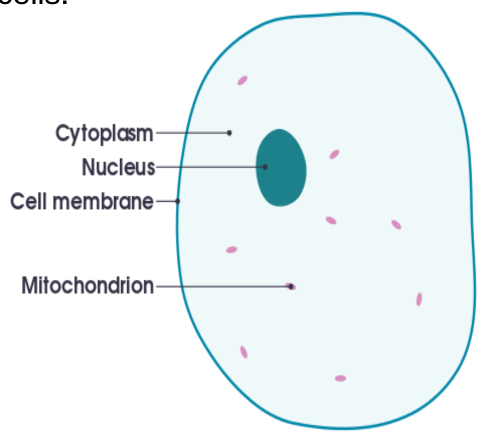
1. All organisms are composed of cells.
2. Cells are alive and the basic living units of organization in all organisms.
3. All cells come from other cells.

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.

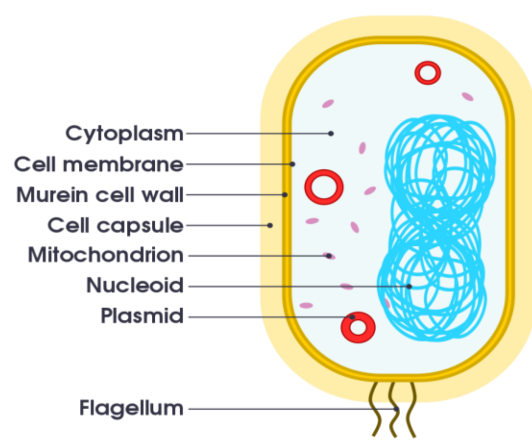
Single-celled vs Multicellular Organisms

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



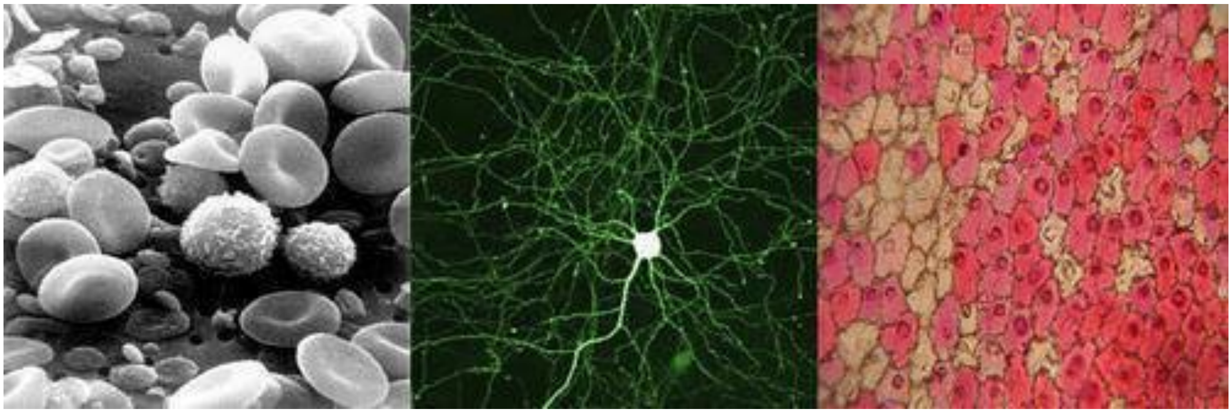
Simple diagram of bacterium by domdomegg, CC-BY

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 are 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 next images, cells are shaped in ways that help them do their jobs. Multicellular (many-celled) organisms have many types of specialized cells in their bodies.

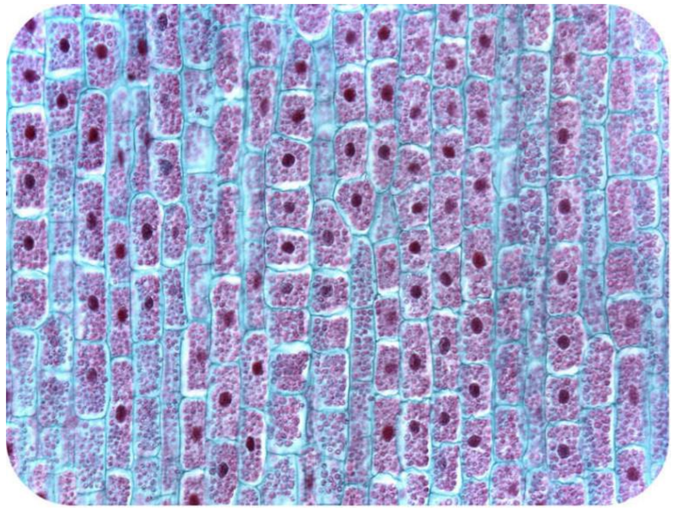


Red blood cells (*left*) are specialized to carry oxygen in the blood.

Putting It Together

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

This is what the pinecone looks like in a microscope.



This is what a coin looks like in a microscope.

Let us revisit this phenomenon:

1. What kind of investigation can you plan and carry out to provide evidence that the basic structure of all living things are made of cells?

2. What evidence can you gather that proves this pinecone came from a living thing?

3. How long do you think the cells in the pinecone will stay alive after it falls from the tree?

3.2 Function of Cell Parts (7.3.2)

Explore this Phenomenon

Sheep Around A Tree by Henry Burrows, https://flic.kr/p/2amNCJW, CC BY-SA

All living things must have energy to survive. The sheep in this picture are eating grass to get energy to live. If trees do not eat, construct an explanation as to how they get the energy they need for survival.

7.3.2 Functions of Cell Parts

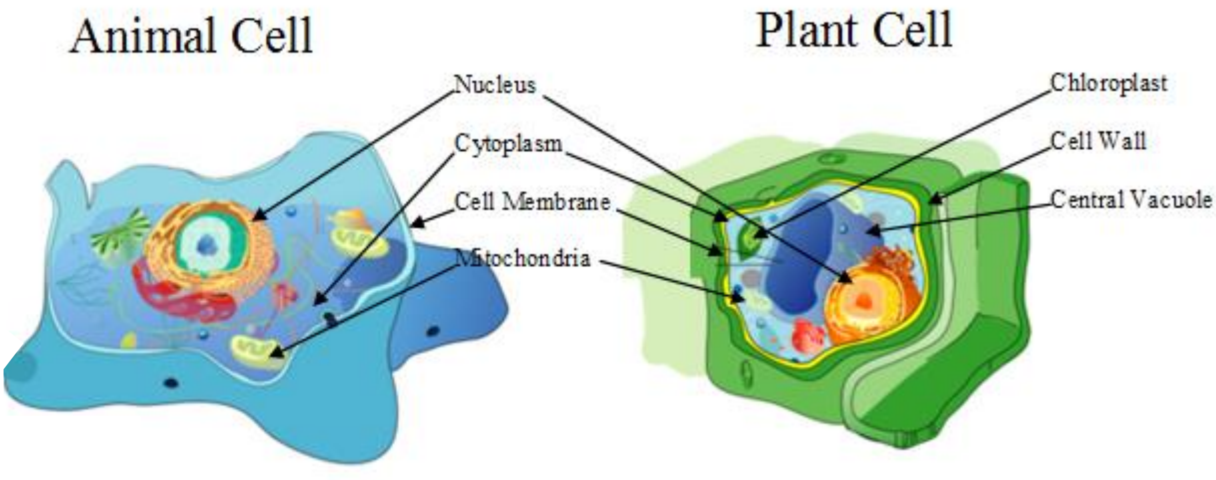
Develop and use a model to describe the function of a cell in living systems and the way parts of cells contribute to cell function. Emphasize the cell as a system, including the interrelating roles of the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

In the last section, you were able to analyze how the structure and number of different cells contribute to an organism. In this section, you will see how different cell parts contribute to the function of the cell. Pay attention to how the shape and size of the cell parts might contribute to their function in the cell.

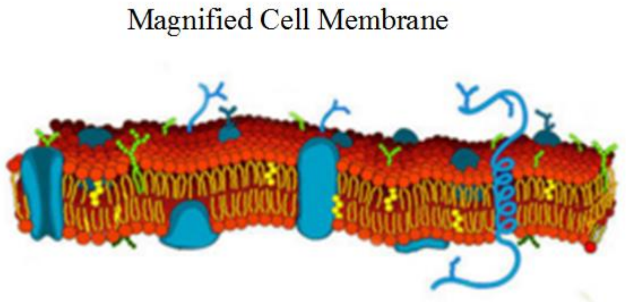
Organelles

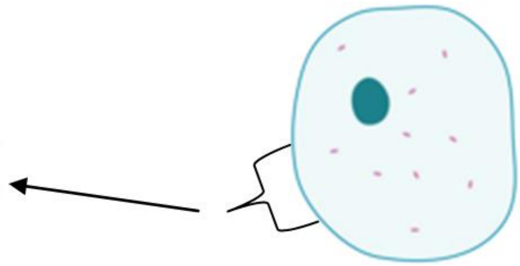
Cells are defined as the basic unit of all living things. This means that the cell is the smallest unit that can still be considered living. Cells are a working system of parts just as a bicycle is a working system of parts. You can break a bicycle down into smaller parts, but it will no longer function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



Cell Membrane

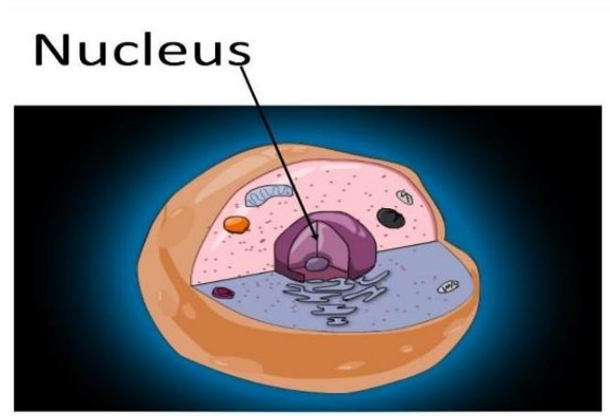




The cell membrane is the layer surrounding the cell. The function or job of the cell membrane is to hold all of the cell's contents together and to control what goes in and out of the cell. The cell membrane is semipermeable, which means that some things can freely cross it and some things cannot. This 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.

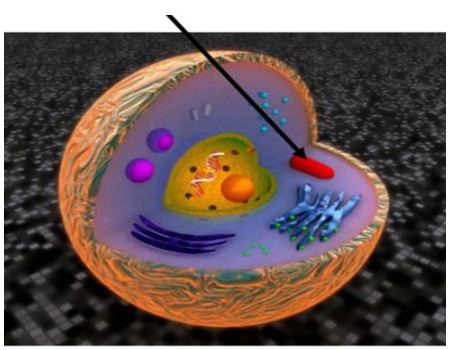
Nucleus

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



Ck12.org, CC BY-SA

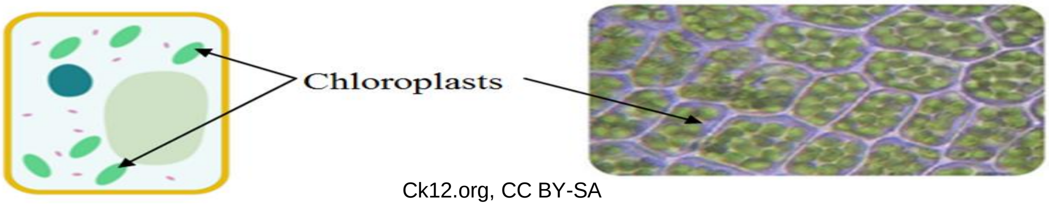
Mitochondria



Ck12.org, CC BY-SA

All cells need energy to survive. In the mitochondria, small molecules of food are broken apart using oxygen. 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.

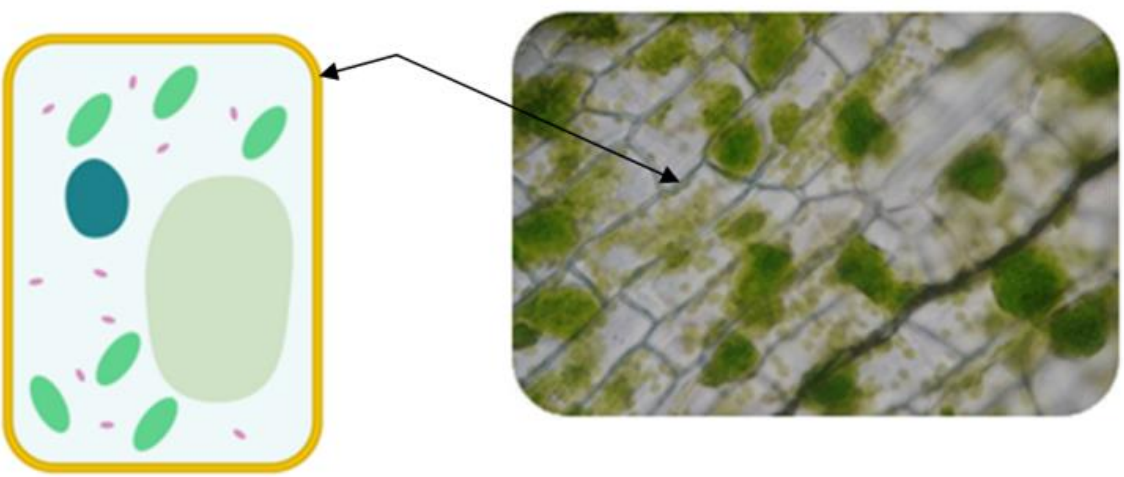
Chloroplast



Plants do not consume food like animals do. They have to make their own food in order to release energy in the mitochondria needed for survival. The chloroplasts are organelles in plant cells that make food through a process called photosynthesis. Chloroplasts are only found in plant cells, 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.

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.



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

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 a tree that makes them strong enough to grow as tall as they are. Animals do not need cell walls because their bones and muscles support them. Animal cells only have a cell membrane.

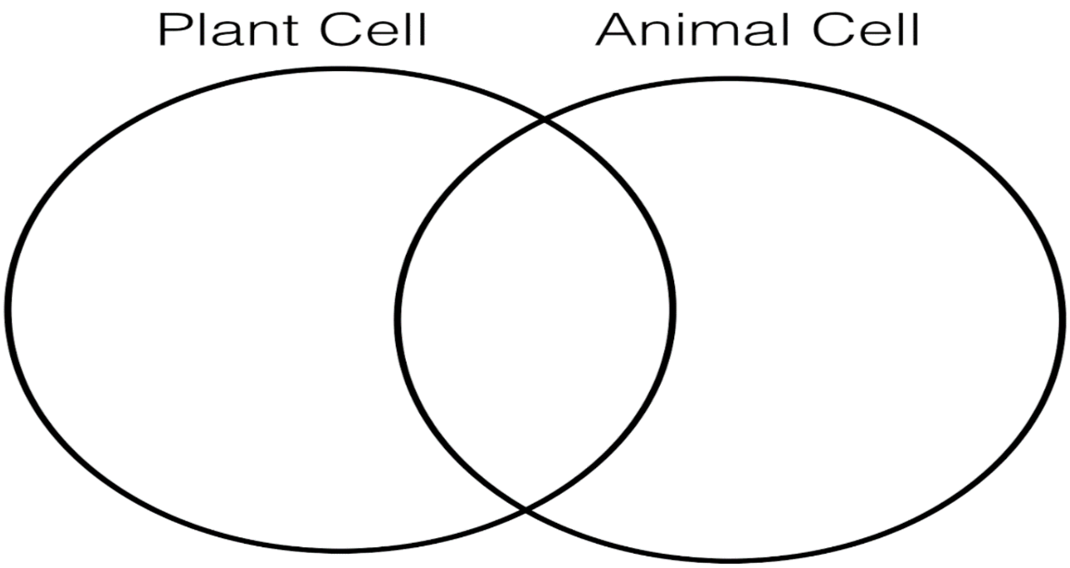
Second, plant cells have chloroplasts that capture the sun's energy to convert carbon dioxide and water to sugar. They make their own food. Since animals have to get food to eat from other sources, they do not need chloroplasts.

Think like a Scientist

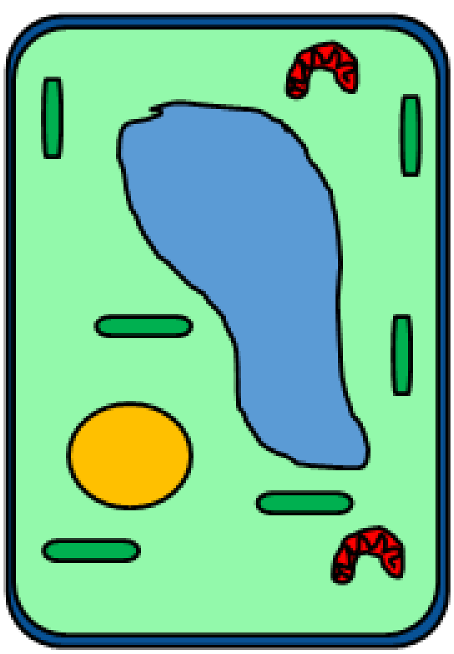
Fill in the table below. Put a checkmark for each organelle/structure that is found in each cell type.

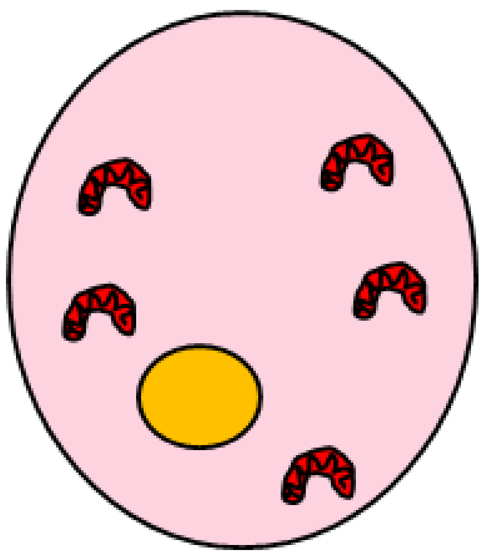
Organelle/Structure	Plant Cell	Animal Cell
Cell Wall		
Cell Membrane		
Nucleus		
Mitochondria		
Chloroplast		

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



Label the following cell with the correct animal cell parts.





Putting It Together

Sheep Around A Tree by Henry Burrows, https://flic.kr/p/2amNCJW, CC BY-SA

Let us revisit this phenomenon:

Trees do not eat like the sheep in the image above. Construct an explanation as to how they get the energy they need for survival. Be sure to include the organelles in the cells that contribute to these different functions.

3.3 Organization of the Human Body (7.3.3)

Explore This Phenomenon

CC0

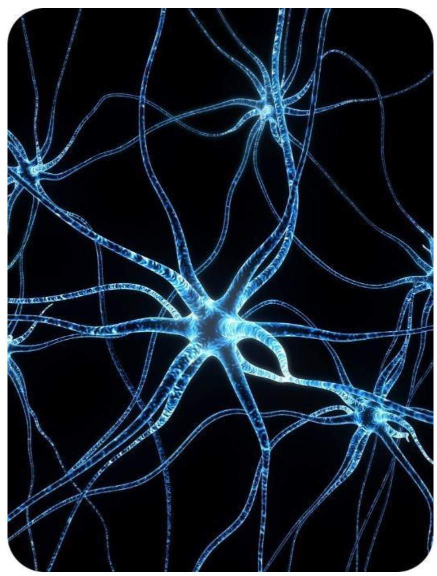
Often after exercising, a person will sweat. As you read the following, think of possible ways to explain what is happening inside this boy's body to make him sweat.

7.3.3 Organization of the Human 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.

Cells make up the tissues that make up organs and organ systems. Each of these systems contributes to the function of the organism as a whole. In this section analyze how systems that have specific functions work together to perform all the functions of life. Ponder what would happen to the organism is one of the systems stopped working.

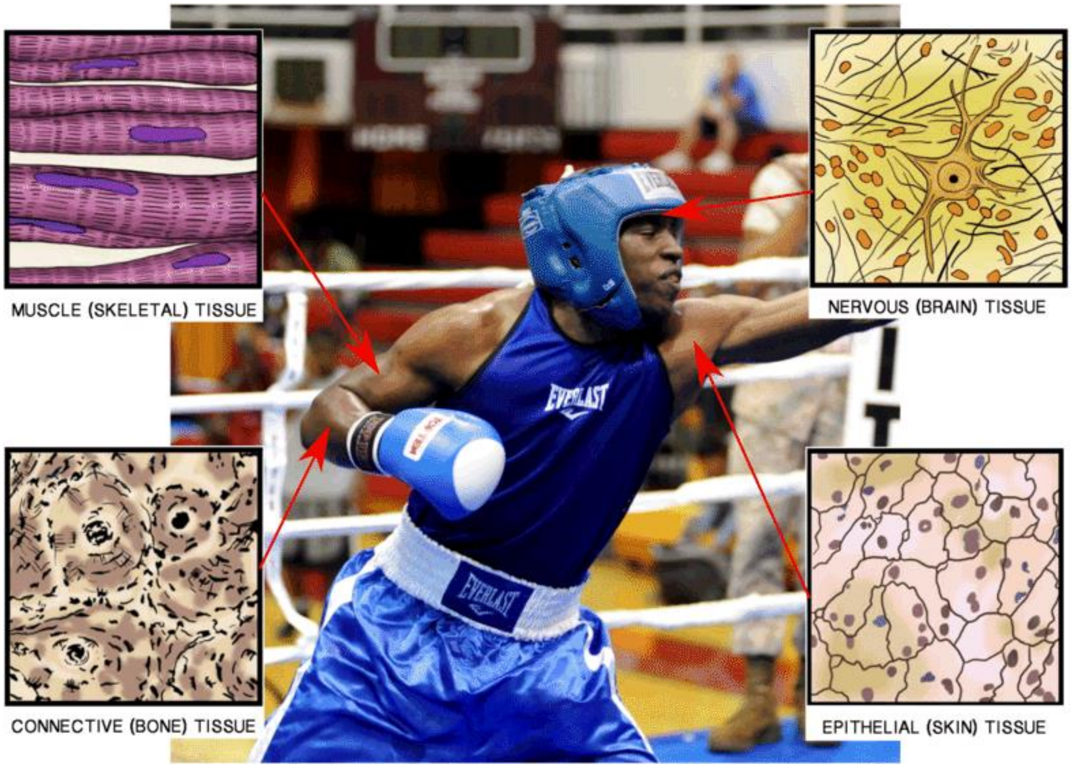
Organization of Your Body: Cells, Tissues, Organs



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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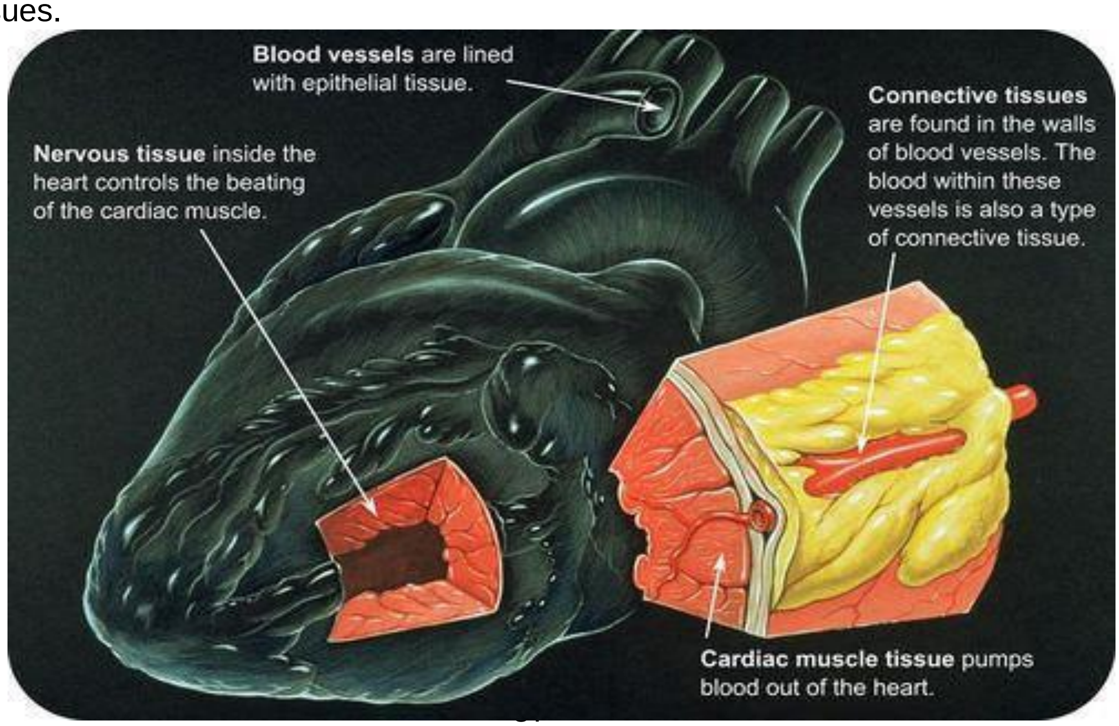
Groups of Tissues Form Organs

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 on the next page. 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.

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Organ System	Major Tissues and Organs	Function
Circulatory	Heart; blood vessels; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves wastes 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 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 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.

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Putting It Together

Let us revisit this phenomenon:

Often after exercising, a person will sweat. Look at the image above. Beginning at the cellular level construct an explanation as how the different body systems work together to keep this boy cool.

CHAPTER 4

Strand 4: Reproduction and Inheritance

Chapter Outline

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.

4.1 Types of Reproduction (7.4.1)

Explore this Phenomenon

https://flic.kr/p/d8ndiL - Brent Myers CC-BY

Above is a picture of a desert grassland whiptail. All members of this species are females!

1-Predict how is it possible that new offspring can be born when there are no males in the population.

2-Do they have similar traits as their mother?

3-Don’t organisms always have to have two parents? Write to explain your thinking.

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.

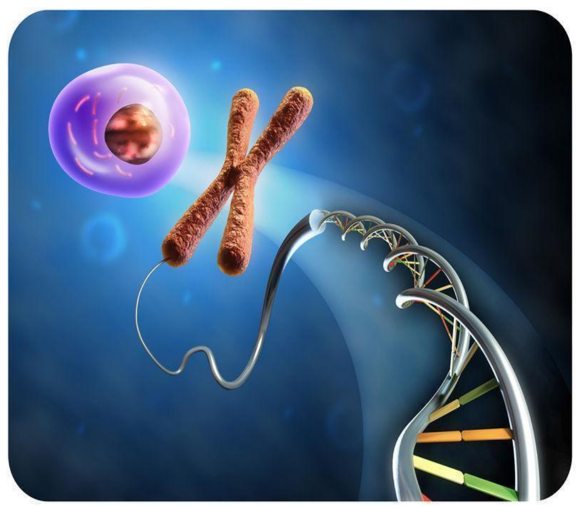
Our genes that we inherit from our parents determine our traits. In this section, analyze how the number of parents an organism has can affect its genetic variation.

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 so 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

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 all 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

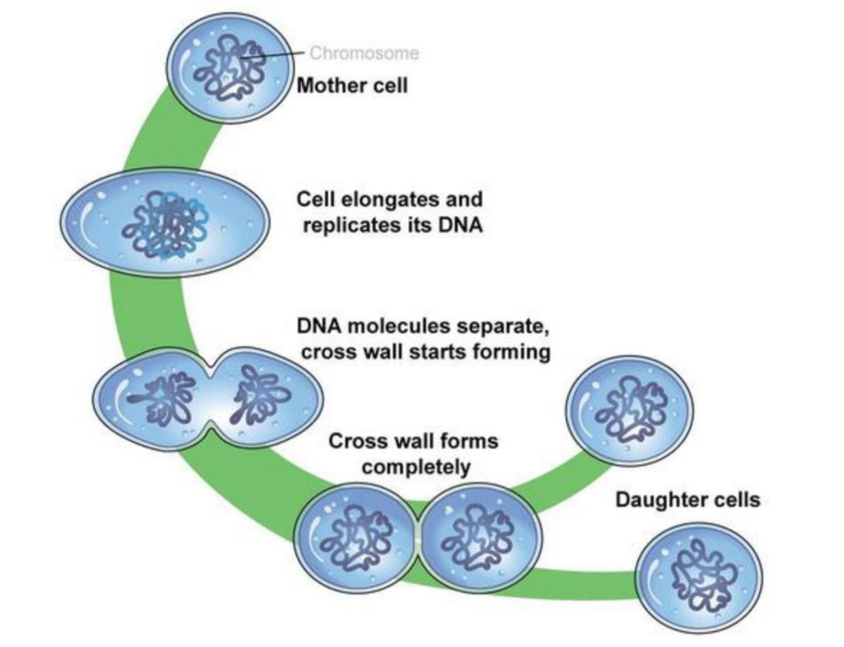
Asexual reproduction is reproduction where the offspring arises from a single organism. There is only one parent. Bacteria are examples of living things that reproduce asexually. Other simple unicellular organisms such as protists, like an ameoba also reproduce asexually. Having just one parent is possible in multicellular 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. Some organisms can reproduce both ways!

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 above 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.

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.

When sperm and egg combine, a new organism is created. (ck12.org, CC BY-SA)

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.

Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.
(ck12.org, CC BY-SA)

Check This Out

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?

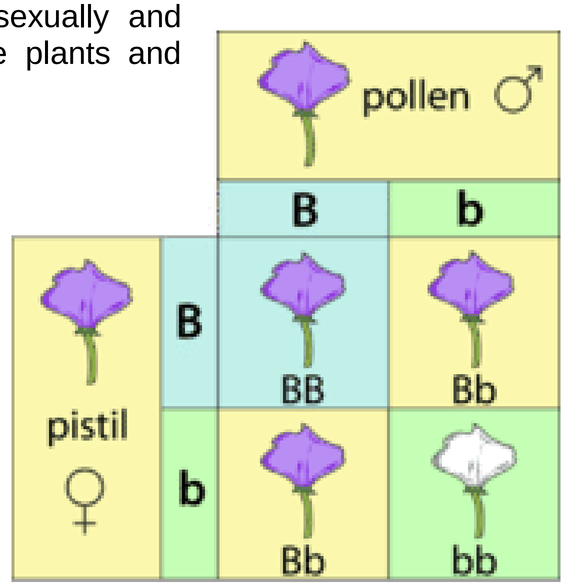
Some other organisms that reproduce both asexually and sexually are starfish, hydra, sponge, and some plants and fungi.

Punnet Squares

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.

This example of a Punnett square 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*).



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.

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 requires two parents, Punnett squares are not used to model asexual reproduction.

Putting It Together

https://flic.kr/p/d8ndiL - Brent Myers CC-BY

Let us revisit this. Above is a picture of a desert grassland whiptail. All members of this species are females!

1. Using your knowledge of inheritance, describe the traits of the offspring of these lizards.

2. How would having identical traits be an advantage?

3. How would having identical traits be a disadvantage?

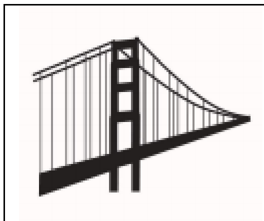
4.2 Adaptations for Reproduction (7.4.2)

Explore this Phenomenon

If you go to a flower store, you will see flowers in many different bright colors. As you read the following section think of possible ways you could construct an explanation for why the flowers are brightly colored.

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 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.



Plants and animals have many structures that help them survive. As you read this section, specifically examine the different structural adaptations that 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 the 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 have tiny "parachutes." Maple seeds have "wings" that act like little gliders. Burdock seeds are covered with tiny hooks that cling to animal fur.

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

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 special behaviors 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 killdeers 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?

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 view the following videos:

- Behavior on a Sage Grouse at http://go.uen.org/aYA
- Elk Fighting in River at http://go.uen.org/aYD

Pixabay

Putting It Together

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Let us revisit this phenomenon:

Now that you have obtained and evaluated information regarding reproductive adaptations, construct a new explanation as to why flowers have such bright colors. Compare your new explanation to your original idea. How has your thinking changed?

4.3 Mutations (7.4.3)

Explore this Phenomenon

CC0

This baby was born with two thumbs on one hand. Neither one of his parents have two thumbs. As you read the following section, think of how he have gotten this trait.

1. Do you think this trait is beneficial to this baby?

2. Why or why not?

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. Specific changes of genes at the molecular level, mechanisms for protein synthesis or specific types of mutations will be introduced at the high school level.

Your DNA controls your traits. Changes in the structure of your DNA, called mutations, could cause changes to your physical traits or affect how certain body parts function. As you read and see mutations in real life, see if you can determine 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?

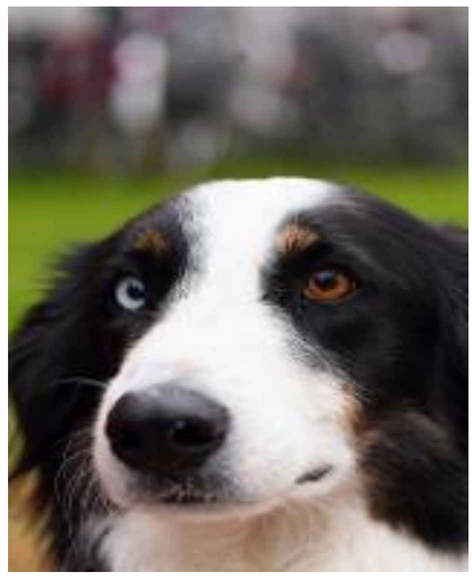
A mutation in the DNA may have no effect. However, sometimes a mutation can cause a protein to be made incorrectly. A defect in the protein can affect how well the protein works, or whether it works at all.

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.

Ck12.org, CC BY-SA

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 a neutral trait. 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.



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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.

Putting It Together

Let us revisit this phenomenon:

1. Describe different environments where this mutation would be beneficial, harmful, or neutral.

4.4 Genetic Changes Caused by Humans (7.4.4)

Explore this Phenomenon

Dogs come in many shapes and sizes. Each breed of dog has different personalities, demeanors and talents. Golden retrievers are often used as therapy dogs. German shepherds are often used by law enforcement to help in police work. All dogs are descendants of wolves. As you read the following section, make a claim to describe why their characteristics are so different from wolves and from each other.

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.

Organisms inherit traits from their parents. By selecting for desirable traits in breeding of plants and animals, humans can cause the inheritance of those traits. For example, humans domesticated dogs by selecting young wolves that were calm and obedient. Look for other examples of humans affecting the inheritance of traits and see how it affects your life today.

Artificial Selection

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 bred 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.

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

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.

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.

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.

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.

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.

Putting It Together

Let's revisit this. Dogs come in many shapes and sizes. Golden retrievers are often used as therapy dogs. German shepherds are often used by law enforcement to help in police work

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?

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

CHAPTER 5

Strand 5: Changes in Species over Time

Chapter Outline

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.

5.1 Developing Traits that Affect Survival (7.5.1)

Explore this Phenomenon

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.

1. Write a prediction as to why you think this might be happening.

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.

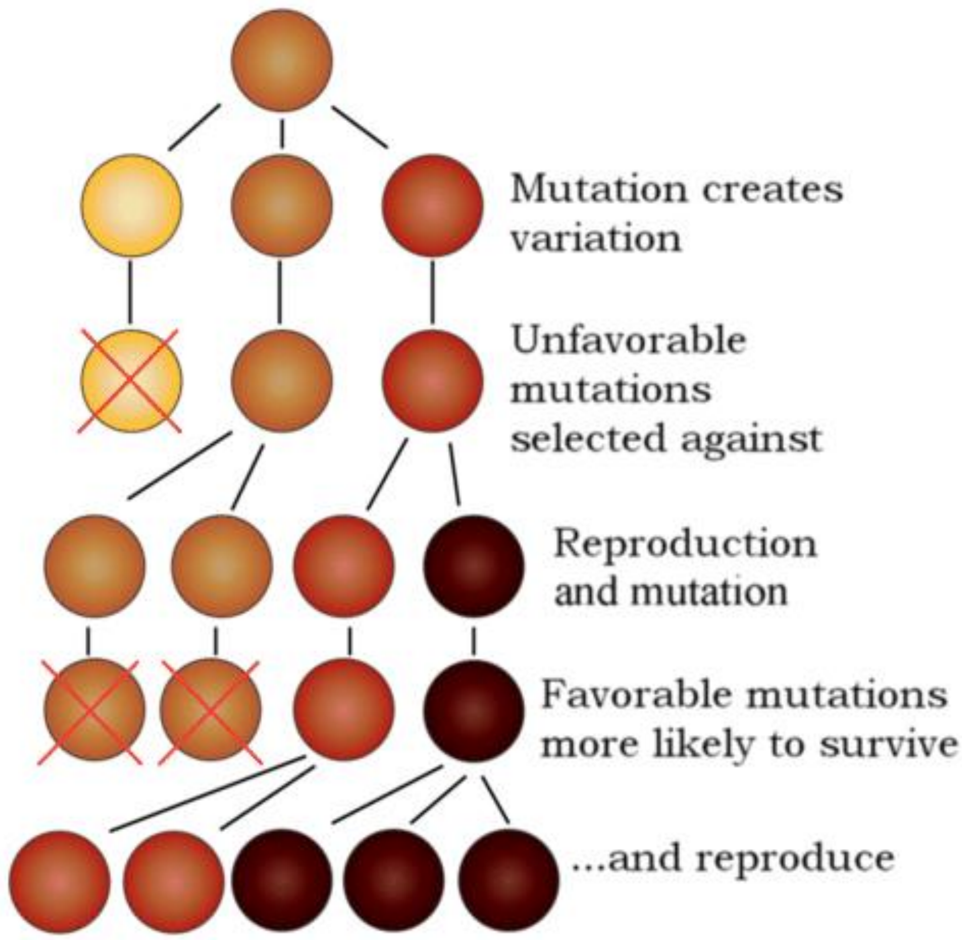
Living things inhabit many different environments all across the world. The environments helped to shape the traits of the organisms that live in them. For example, the harsh heat of the desert influenced the traits of the cactus while polar bears have adapted to living in the arctic. In this chapter see if you can identify 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.

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 many 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.



Genetic mutation is central to the creation of biological diversity.

Adaptations

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.

Public Domain, commons.wikimedia

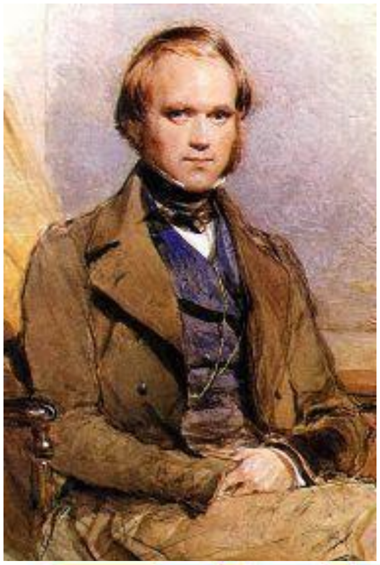
Cacti have thick, water-retaining bodies that help them conserve water.

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. However, a few oak trees have a mutation in their DNA that gave them the ability survive the fungus. Those oak trees are better adapted to the new environment than the others are, 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.

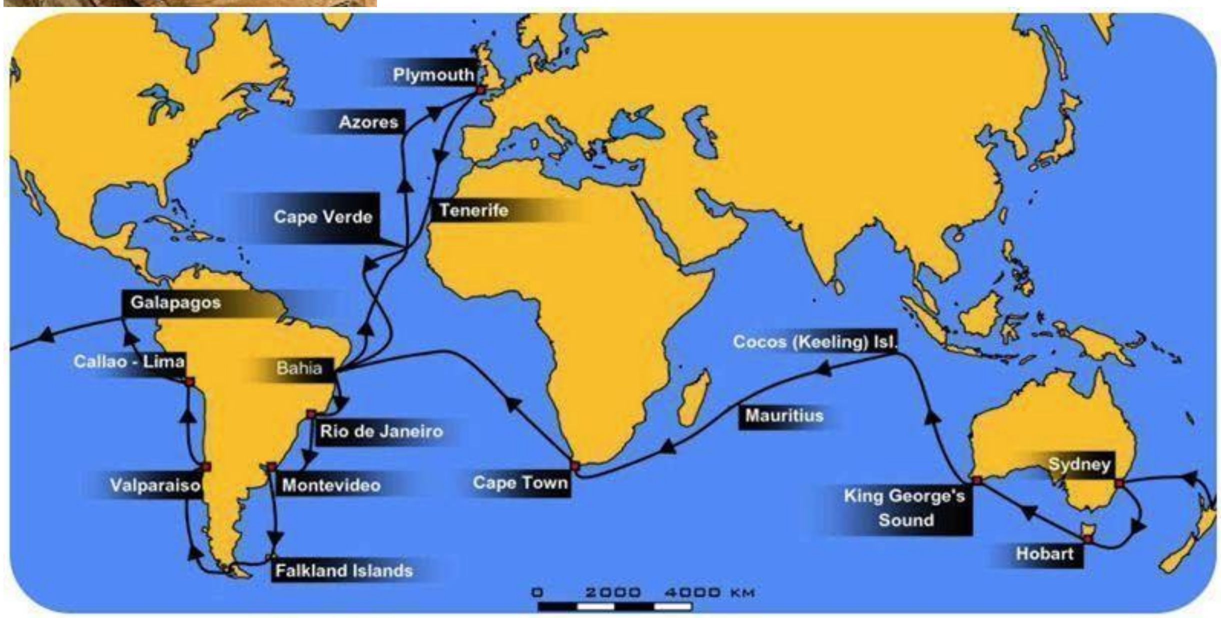
Charles Darwin



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.

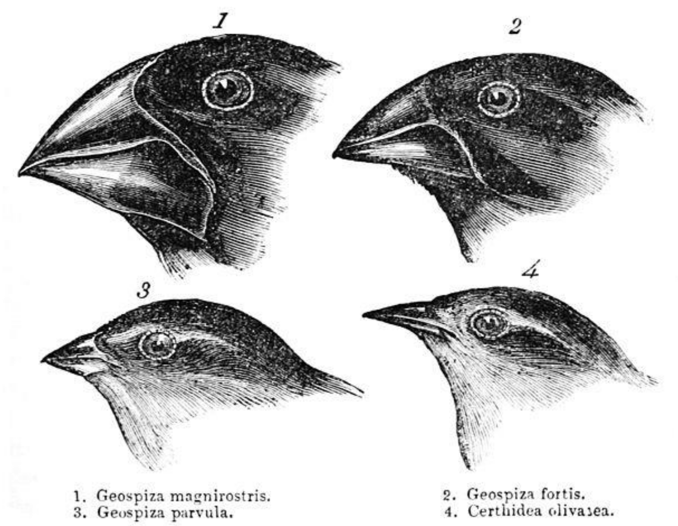


Aboard the Beagle, Darwin visited the Galápagos Islands, a group of 16 volcanic islands near the equator, about 600 miles from the west coast of South America. The islands are famous for many species of organisms that are found nowhere else in the world.

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?


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



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. 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 fox 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.

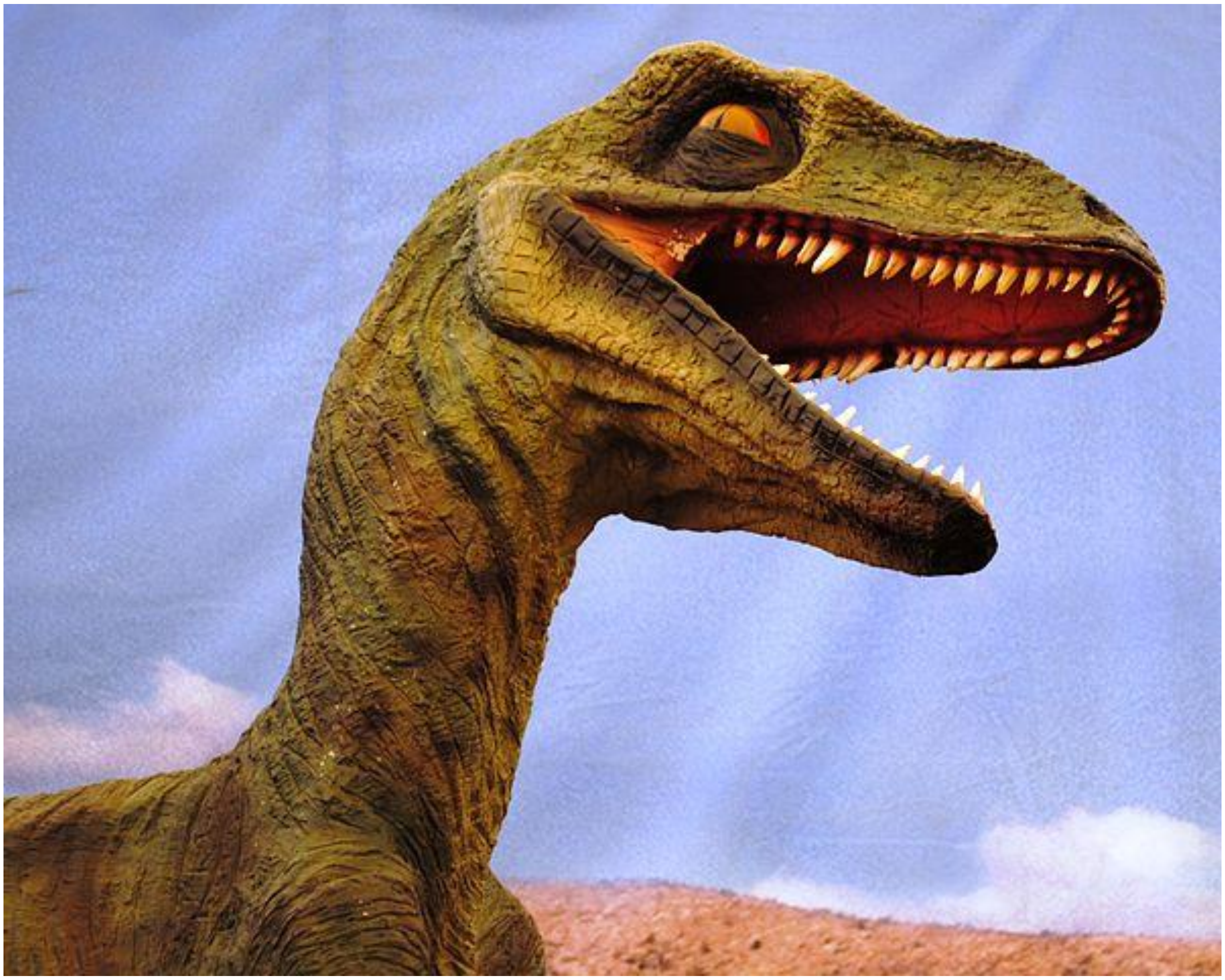
Putting It Together

Let us revisit this phenomenon:

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?

5.2 Changes to Life over Time (7.5.2)

Explore This Phenomenon



Dinosaurious Park, Utahraptor by HombreDHojalata,

The Utahraptor was discovered in 1991 near Moab, UT. Scientists claim that the Utahraptor is the largest raptor that ever lived in Utah. As you read the following section, construct an explanation as to what evidences scientists could use to support that it was the biggest raptor in Utah.

7.5.2 Changes to Life over Time

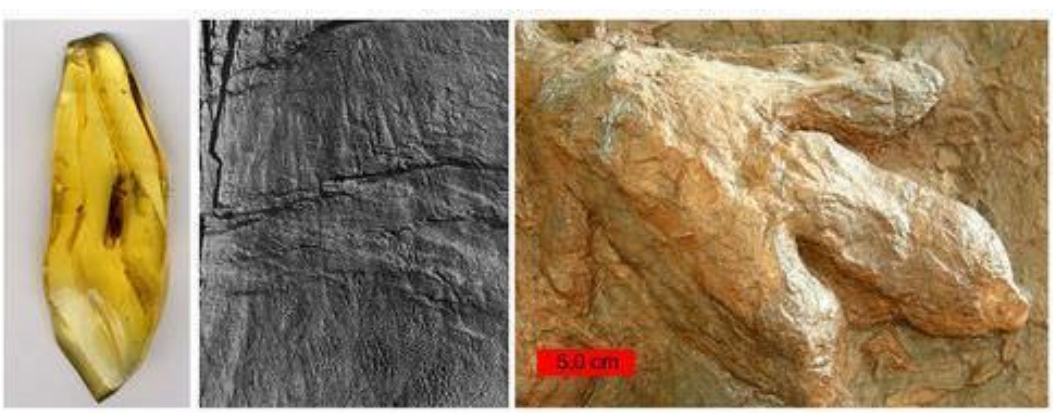
Analyze and interpret **data** for <u>patterns</u> in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

The patterns that we see in the natural world today can help us understand things that happened in the past. Try to identify what patterns found in the fossil record today have helped us tell the story of Earth's history.

The Fossil Record

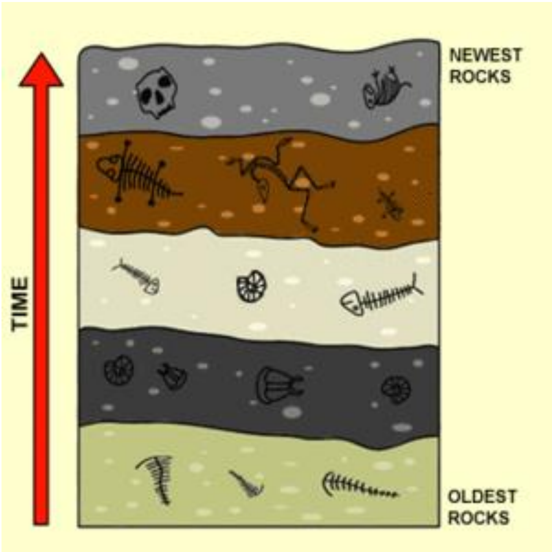
What is on this rock? This rock contains a portion of a fossilized tree fern. Scientists study fossils of plants, animals, and other organisms in order to better understand what life was like on Earth many years ago and how it has changed over time. Fossils are important evidence for the theory of evolution.

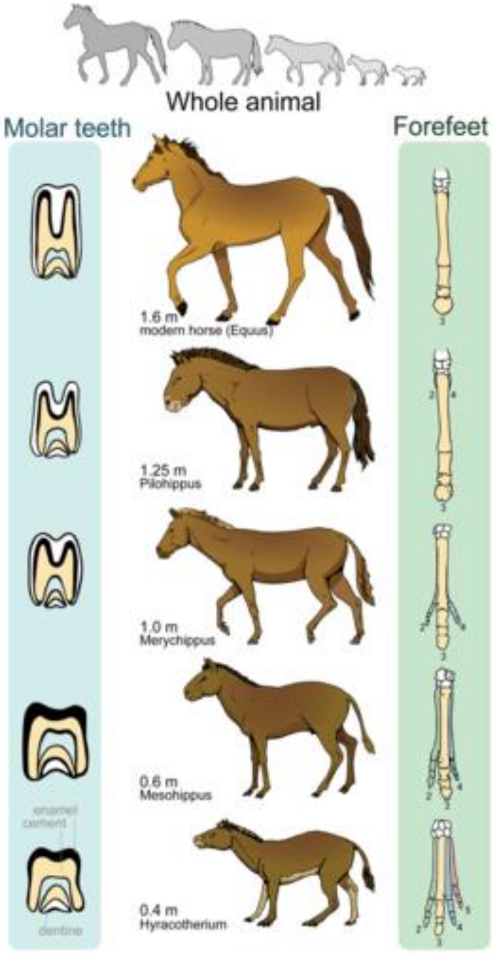
Fossils are the preserved remains of animals, plants, and other organisms from the distant past. Because most parts of organisms decompose rapidly following death, fossilization usually preserves only hard body parts like bones, teeth. Other fossils include footprints, burrows, droppings, eggs, nests,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



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.





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

Evidence of Animal Evolution

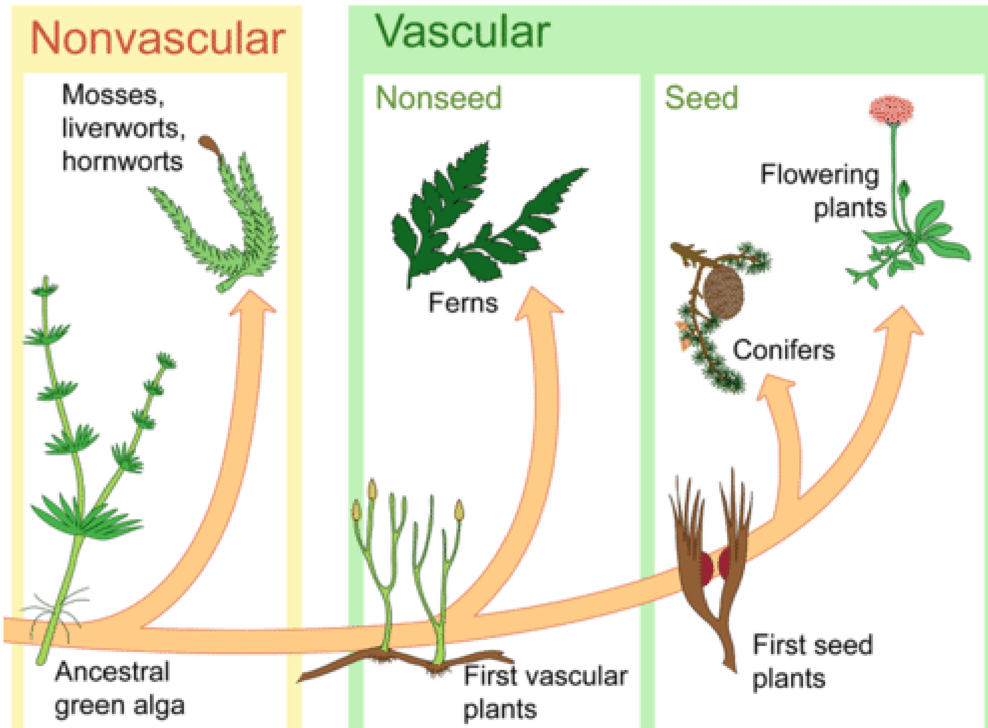
The oldest horse fossils show what the earliest horses were like. They were about the size of a fox, and they had four long toes. Additional evidence in the rock layers shows they lived in wooded marshlands, where they probably ate soft leaves. Through time, the climate became drier, and grasslands slowly 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. Check out this video to learn more: http://go.uen.org/aZM

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.



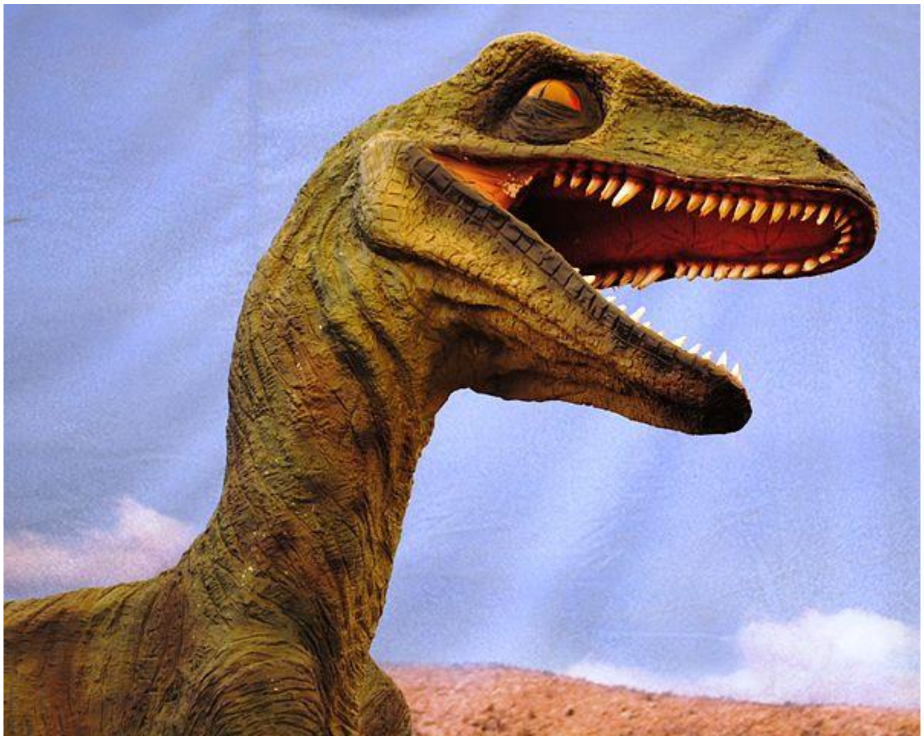
Ck12.org, CC BY-SA

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

To analyze additional data regarding fossils you can go to the following websites:

- James Hagadorn, Paleontologist: Traces of Early Animal Life: http://go.uen.org/b33
- Jenny Clack, Paleontologist: The First Vertebrate Walks on Land http://go.uen.org/b34

Putting It Together



Dinosaurious Park, Utahraptor by HombreDHojalata, CC BY-SA

Let us revisit this phenomenon:

The Utahraptor was discovered in 1991 near Moab, UT. Scientists claim that the Utahraptor is the largest raptor that ever lived in Utah.

1. What evidences could scientists use to make the claim that the Utahraptor was the largest raptor to be found in Utah?

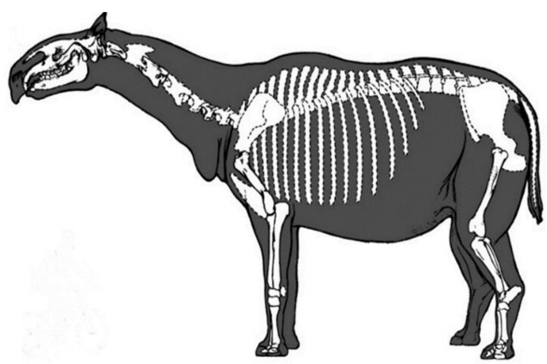
2. What other characteristics about the Utahraptor could be inferred based on the evidence collected?

5.3 Connecting Modern Organisms to Ancient Organisms (7.5.3)

Explore this Phenomenon

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

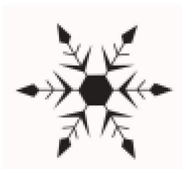
This animal is a Paraceratherium that became extinct over 23 million years ago. It stood over 16 feet tall and was over 4 feet long.



Its skeleton (image on the right) looks very similar to a modern day white rhinoceros (image on the left). As you read the following section, construct possible explanations about the similarities and differences seen in the skeletal structure of the two different animals.

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.



Scientists use the fossil record to construct ideas about organisms that have gone extinct. Fossil records show patterns in the traits of ancient organisms that are similar to organisms on Earth today. As you read, see if you can identify any patterns between ancient and modern species.

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 ancestor. What evidence do you see that could indicate that they are related?

Modern Crocodile Skull

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

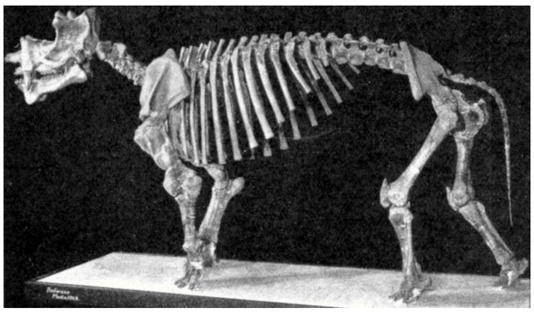
Ancient Megalania Skull

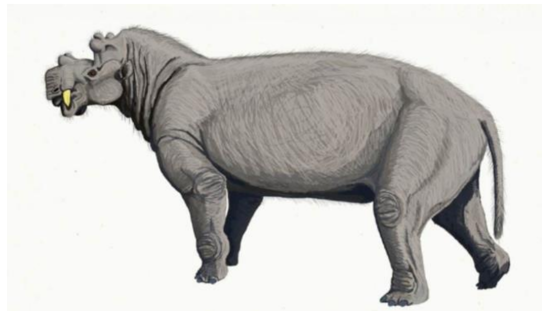
Megalania (Varanus priscus) skull. Photo by Steven G. Johnson.

Are They Related?

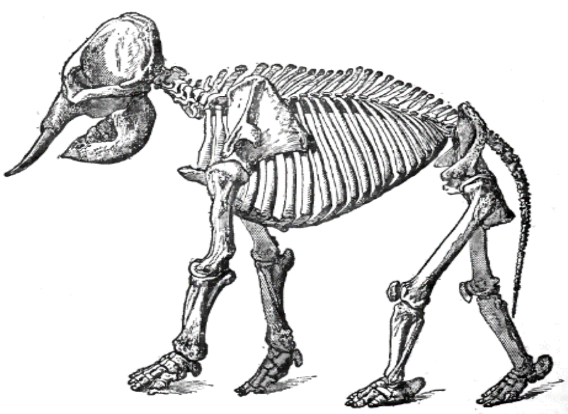
Have you ever heard that whales are related to elephants? What evidence do scientist use to determine family relations? Let us take a look at two very different animals that share a common ancestor.

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?



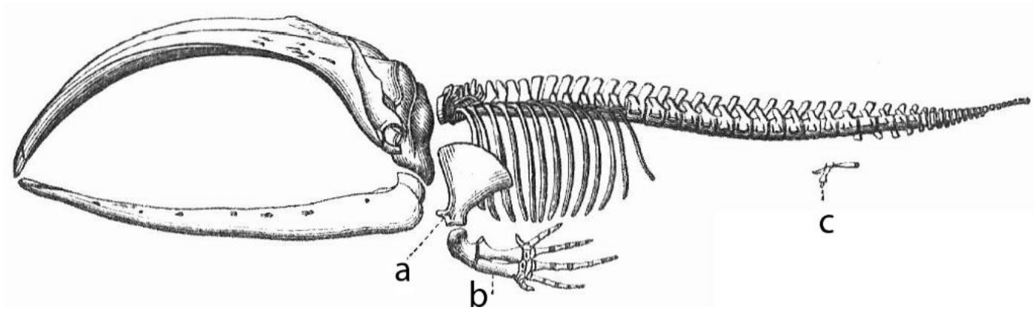


Uintatherium by Dmitry Bogdanov, https://en.wikipedia.org/wiki/



Asian Elephant Frida at Quilpue Zoo by PBRO,

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

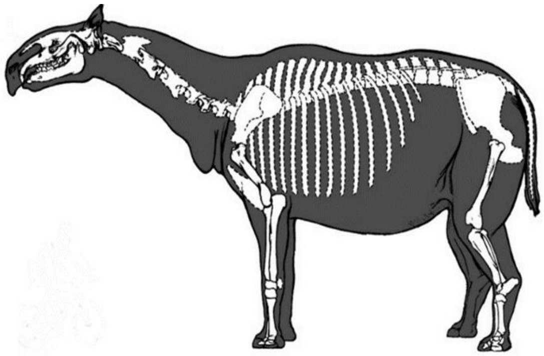
If you look closely at a skeleton, you might notice a triangular bone at the end of the spinal column. This is your tailbone. Why would you have a tailbone when you do not have a tail? You have a tailbone because your ancient ancestors *did* have a tail. These sorts of "left-over" structures are called 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.

Putting It Together

https://c2.staticflickr.com/6/5232/5820747273_a423a

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



Let us revisit this phenomenon:
Scientist have said that the Paraceratherium is related to the White Rhino. Construct an explanation to infer possible evolutionary relationships using patterns found in the fossil and skeleton above.

5.4 Comparative Embryology (7.5.4)

Explore this Phenomenon

Chicken Embryo by DBCLS 統合 TV,
https://commons.wikimedia.org/wiki/Category:Chicken_embryos#/media/File:201307_chicken

Many different types of animals look like the above image at the embryo stage. As you read the following section, analyze pictorial data to compare patterns of embryological development across multiple species.

7.5.4 Comparative Embryology

Analyze displays of pictorial **data** to compare patterns in the embryological development across multiple species to identify similarities and differences not evident in the fully formed anatomy.

In this section, you will analyze embryological development of different species. Scientists look at patterns found between embryos to show how close organisms are related. Look for the similarities and differences between embryos to see if you can predict what embryos are more closely related.

Embryo Growth and Development

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 occur, the fertilized egg is called an embryo. 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, a 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

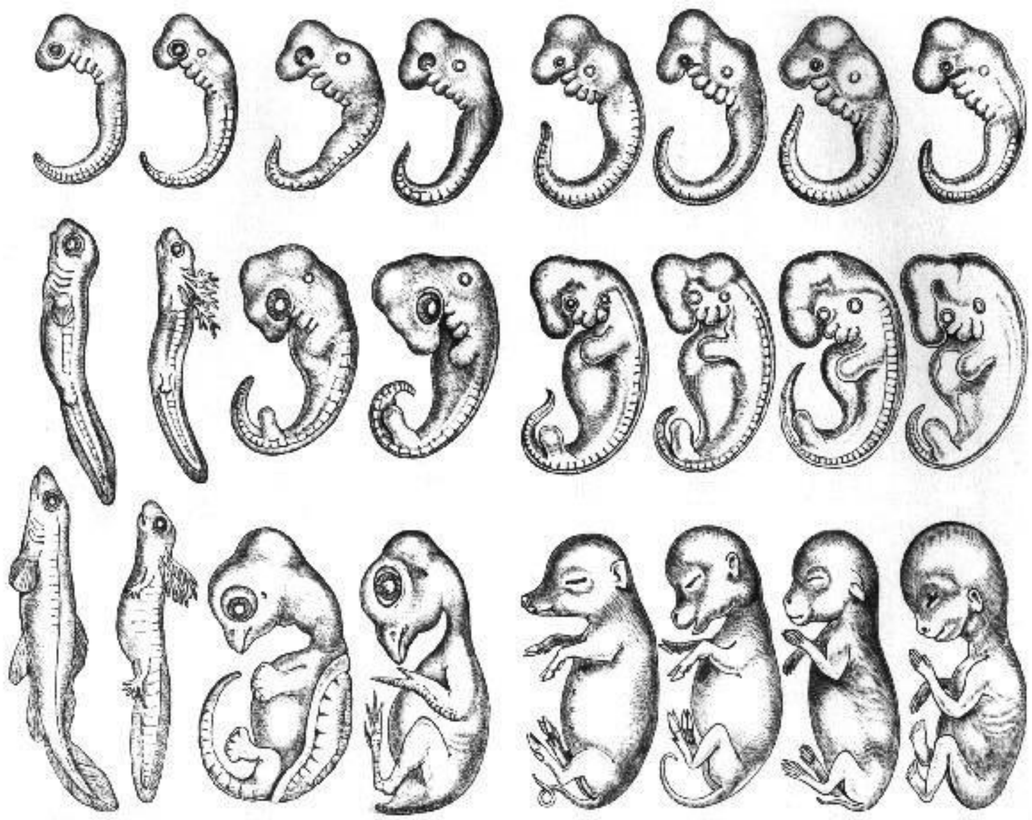
- Hair follicles start to form
- Elbows and toes are visible

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.)



(Public Domain)

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.

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 as 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 these websites:

- NOVA: Guess the Embryo http://go.uen.org/b35
- NOVA: The Zoo of You http://go.uen.org/b36

Putting It Together

Chicken Embryo by DBCLS 統合 TV, https://commons.wikimedia.org/wiki/Category:Chicken_embryos#/media/File:201307_chicken_embryo.png,

Let us revisit this phenomenon:

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?