Earth Science 8

May 18 – May 22

Time Allotment:30 minutes per day

Student Name: ________________________________

Teacher Name: ________________________________

Packet Overview

Date	Objective(s)	Page Number
Monday, May 18	1. Students will review fundamentals of meteorology	1
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Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

Student signature:

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I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

Parent signature:

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Earth Science 8: Review
May 18 – May 22

Lesson 1: Monday, May 18

Meteorology Review

Earth's atmosphere is a thin blanket of gases and tiny particles—together called air. Without air, the Earth would just be another lifeless rock orbiting the Sun. Although we are rarely aware of it, air surrounds us. We are most aware of air when it moves, creating wind. Like all gases, air takes up space. These gases that make up our air are packed closer together near the Earth's surface than at higher elevations.

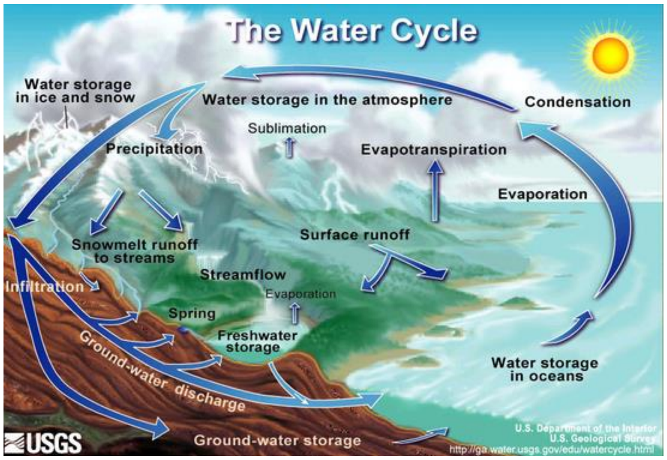
All living things need some of the gases in air for life support. In particular, all organisms rely on oxygen for respiration—even plants require oxygen to stay alive at night or when the Sun is obscured. Plants also require carbon dioxide in the air for photosynthesis. All weather happens in the atmosphere. The atmosphere has many other important roles as well. These include moderating Earth's temperatures and protecting living things from the Sun's most harmful rays.

Significance of the Atmosphere

Without the atmosphere, planet Earth would be much more like the Moon than like the planet we live on today. The Earth's atmosphere, along with the abundant liquid water on the Earth's surface, are keys to our planet's unique place in the solar system. Much of what makes Earth exceptional depends on the atmosphere. Let's consider some of the many reasons we are lucky to have an atmosphere.

Without the atmosphere, Earth would be lifeless. Carbon dioxide (CO_2) and oxygen (O_2) are the most important gases for living organisms. CO2 is vital for use by plants in **photosynthesis**, in which plants use CO2 and water to convert the Sun's energy into food energy. This food energy is in the form of the sugar glucose ($C_6H_{12}O_6$). Plants also produce O_2. Photosynthesis is responsible for nearly all of the oxygen currently found in the atmosphere.

Water moves from the atmosphere onto the land, into soil, through organisms, to the oceans and back into the atmosphere in any order. This movement of water is called the water cycle or **hydrologic cycle**.



Water changes from a liquid to a gas by **evaporation**. **Water vapor** is the name for water when it is a gas. When the Sun's energy evaporates water from the ocean surface or from lakes, streams, or puddles on land, it becomes water vapor. The water vapor remains in the atmosphere until it **condenses** to become tiny droplets of liquid. The tiny droplets may come together to create **precipitation**, like rain and snow. Snow may become part of the ice in a glacier, where it may remain for hundreds or thousands of years. Eventually, the snow or ice will melt to form liquid water. A water droplet that falls as rain, could become part of a stream or a lake, or it could sink into the ground and become part of **groundwater**.

All **weather** takes place in the atmosphere, virtually all of it in the lower atmosphere. Weather describes what the atmosphere is like at a specific time and place, and may include temperature, wind and precipitation. It is the changes we experience from day to day. **Climate** is the long-term average of weather in a particular spot. Although the weather for a particular winter day in El Paso may include snow, the climate of El Paso is generally warm and dry.

The physical and chemical changes that happen on Earth's surface due to precipitation, wind and reactions with the gases in our atmosphere are called **weathering**. Weathering alters rocks and minerals and shapes landforms at the Earth's surface. Without weathering, Earth's surface would not change much at all. For example, the Moon has no atmosphere, water or winds, so it does not have weathering. The footprints that astronauts made on the Moon decades ago will remain there until someone (human or alien) smooths them out!

Ozone in the Upper Atmosphere Makes Life on Earth Possible

Ozone is a molecule composed of three oxygen atoms, (O_3). Ozone in the upper atmosphere absorbs high energy **ultraviolet radiation** (UV) coming from the Sun. This protects living things on Earth's surface from the Sun's most harmful rays. Without ozone for protection, only the simplest life forms would be able to live on Earth.

The Atmosphere Keeps Earth's Temperature Moderate

Our atmosphere keeps Earth's temperatures within an acceptable range; the difference between the very coldest places on Earth and the very hottest is about 150°C (270°F). Without our atmosphere, Earth's temperatures would be frigid at night and scorching during the day. Our daily temperatures would resemble those seen on the Moon, where the temperature range is 310°C (560°F) because there is no atmosphere. **Greenhouse gases** trap heat in the atmosphere. Important greenhouse gases include carbon dioxide, methane, water vapor and ozone.

Composition of Air

Gas	Symbol	Concentration (%)
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Argon	Ar	0.93
Neon	Ne	0.0018

Air is made almost entirely of two gases. The most common gas is nitrogen, and the second most common gas is oxygen (O_2). Nitrogen and oxygen together make up 99% of the planet's atmosphere. All other gases together make up the remaining 1%. Although each of these trace gases are only found in tiny quantities, many such as ozone, serve important roles for the planet and its life. One very important minor gas is carbon dioxide, CO_2, which is essential for photosynthesis and is also a very important greenhouse gas.

In nature, air is never completely dry. Up to 4% of the volume of air can be water vapor. **Humidity** is the amount of water vapor in air. The humidity of the air varies from place to place and season to season. This fact is obvious if you compare a summer day in Houston where humidity is very high, with a winter day in El Paso where humidity is very low. When the air is very humid, it feels heavy or sticky.

Pressure and Density

The atmosphere has different properties at different elevations above sea level, or **altitudes**. The **density** of the atmosphere (the number of molecules in a given volume) decreases the higher you go. This is why explorers who climb tall mountains, like Mt. Everest, have to set up camp at different elevations to let their bodies get used to the changes. What the atmosphere is made of, or the composition of the first 100 kilometers of the atmosphere stays the same with altitude, with one exception: the ozone layer at about 20-40 kilometers above the Earth. In the ozone layer, there is a greater concentration of ozone than in other portions of the atmosphere.

The molecules in gases are able to move freely. If no force acted on a gas at all, it would just escape or spread out forever. Gravity pulls gas molecules in towards the Earth's surface, pulling stronger closer to sea level. This means that atmospheric gases are denser at sea level, where the gravitational pull is greater. Gases at sea level are also compressed by the weight of the atmosphere above them. The weight of the atmosphere on a person's shoulders is equal to more than one ton. The force of the air weighing down over a unit of area is known as its atmospheric pressure, or **air pressure**. People and animals are not crushed because molecules inside our bodies are pushing outward to compensate. Air pressure is felt from all directions, not just from above.

The atmosphere has lower atmospheric pressure and is less dense at higher altitudes. There is less pull from gravity and there is less gas to push down from above. Without as much weight above them, the gases expand, so the air is lighter. For each 6 km (3.7 mile) increase in altitude, the air pressure decreases by half. At 5,500 meters (18,000 feet) above sea level, the air pressure is just less than half of what it is at sea level. This means that the weight of the air on a person’s shoulders at that altitude is only one-half ton. At a high enough altitude, there is no gas left. The density of the atmosphere at 30 km (19 miles) above sea level is only 1% that of sea level. By 700 km (435 miles) from the planet's surface, the air pressure is almost the same as that in the vacuum of deep space.

If your ears have ever 'popped', you have experienced a change in air pressure. This occurs when you go up or down in altitude quickly, such as flying in an airplane or riding in a car as it goes up or down a mountain. Gas molecules are found inside and outside your ears. When you change altitude quickly, your inner ear keeps the density of molecules at the original altitude. The popping occurs when the air molecules inside your ear suddenly move through a small tube in your ear equalizing the pressure. This sudden rush of air is felt as a popping sensation.

Colder, drier places on Earth usually have higher air pressure, while warmer, more humid places usually have lower air pressure. This happens because large areas of air move up or down by convection. Air pressure also often changes over time, as low and high pressure systems change locations. These phenomena will be discussed when we learn about weather.

Review Questions (1-2 sentences)

1. What will happen if the humidity of the atmosphere increases?

2. Is weathering more effective in a humid or a dry climate?

<u>Lesson 2: Tuesday, May 19</u>

Meteorology Review (continued)

Think back to what we have learned about convection currents this year. Warm air rises, creating an upward-flowing limb of a convection cell. Upward flowing air lowers the air pressure of the area, forming a **low pressure zone**. The rising air sucks in air from the surrounding area, creating wind.

At the top of the troposphere, the air travels horizontally from a low pressure zone to a high pressure zone. Since it is at the top of the troposphere, the air cools as it moves. This cold, dense air creates the downward flowing limb of the convection cell. Where the sinking air strikes the ground, air pressure is relatively high. This creates a **high pressure zone**. The sinking air is relatively cool, since it has traveled across the tropopause.

Air that moves horizontally between high and low pressure cells makes wind. The winds will race from the high to low zones if the pressure difference between them is large. If the difference is smaller, the winds will be slower.

Convection in the atmosphere creates the planet's weather. It's important to know that warm air can hold more moisture than cold air. When warm air near the ground rises in a low pressure zone, it cools. If the air is humid, it may not be able to hold all the water it contains as vapor. Some water vapor may condense to form clouds or even precipitation. Where cooler air descends at a high pressure zone, it warms. Since it can then hold more moisture, the descending air will evaporate water on the ground.

Air moving between large high and low pressure systems creates the global wind belts that profoundly affect regional climate. Smaller pressure systems create localized winds that affect the weather and climate of a local area.

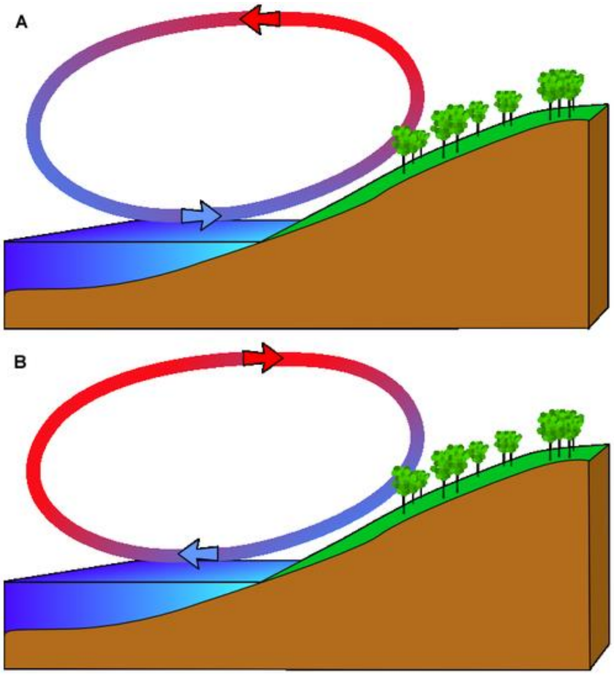
Local Winds

Local winds are created when air moves from small high pressure systems to small low pressure systems. High and low pressure cells are created by a variety of conditions. Some of these winds have very important effects on the weather and climate of certain regions.

Land and Sea Breezes

You learned that water has a very high specific heat: it maintains its temperature well. This means that water heats and cools more slowly than land. Sometimes there is a large temperature difference between the surface of the sea (or a large lake) and the land next to it. This temperature difference causes small high and low pressure regions to form, which creates local winds.

In the summer, and to a lesser degree in the day, a low pressure cell forms over the warm land and a high pressure cell forms over the cooler ocean. During warm summer afternoons, winds called **sea breezes** blow from the cooler ocean over the warmer land. Sea breezes often have a speed of about 10 to 20 km (6 to 12 miles) per hour and can lower air temperature much as 5 to 10°C (9 to 18°F). The effect of land and sea breezes is felt only about 50 to 100 km (30 to 60 miles) inland.



Sea and land breezes. (A) Sea breezes blow from the cooler sea to the warmer land. This cools the land near shore in summer and in the daytime and moderates coastal temperatures. (B) Land breezes blow *from the cooler land to the warmer sea. This warms the land near shore in winter and at night and moderates coastal temperatures.*

The opposite occurs in the winter, the land is colder than the nearby water due to its lower specific heat. The cold land cools the air above it. This causes the air to become dense and sink, which creates a high pressure cell. Meanwhile, the warmer ocean warms the air above it and creates a low pressure cell. This occurs to a smaller degree at night, since land cools off faster than the ocean. Winds called land breezes blow from the high to the low pressure cell. These local winds blow from the cooler land to the warmer ocean. Some warmer air from the ocean rises and then sinks on land, causing the temperature over the land to become warmer.

Land and sea breezes are very important because they moderate coastal climates. In the hot summer, sea breezes cool the coastal area. In the cold winter, land breezes blow cold air seaward. These breezes moderate coastal temperatures.

Atmospheric Circulation

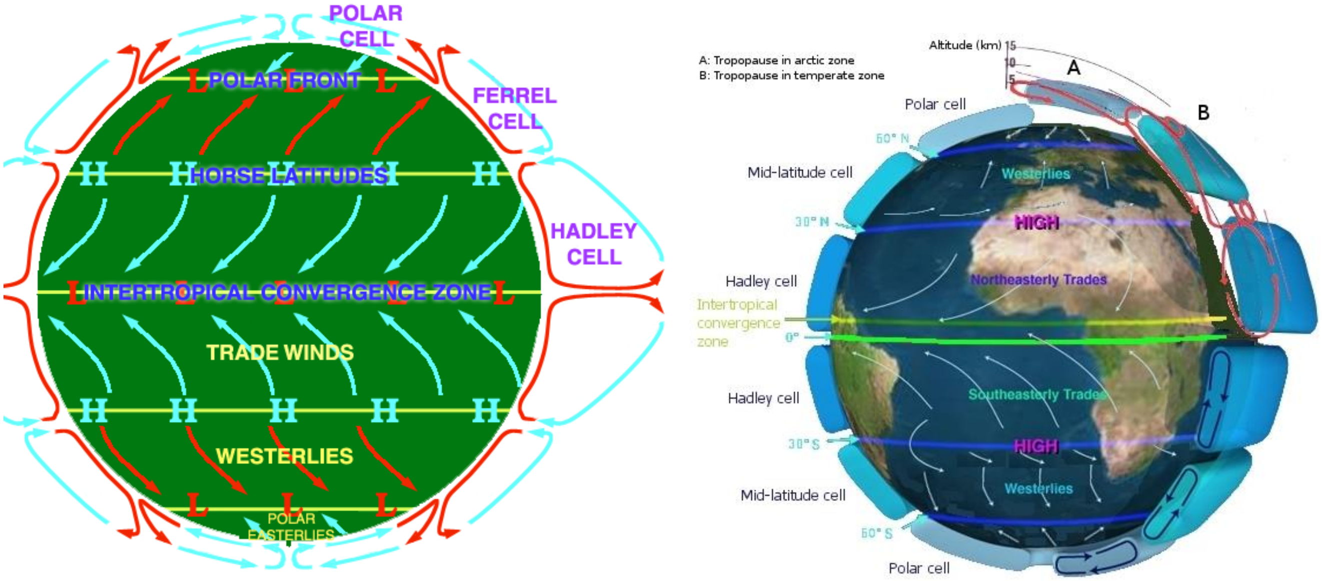
You have already learned that more solar energy hits the equator than the polar areas. The excess heat forms a low pressure cell at the equator. Warm air rises to the top of the troposphere where half of the warmed air moves toward the North Pole and half toward the South Pole. The air cools as it rises and moves along the top of the troposphere. When the cooled air reaches a high pressure zone, it sinks. Back on the ground, the air then travels toward the low pressure at the equator. The air rising at the low pressure zone at the equator and sinking at a high pressure in the direction of the North or South Pole creates a convection cell.

If the Earth was just a ball in space and did not rotate, there would be only one low pressure zone and it would be at the equator. There would also be one high pressure at each pole. This would create one convection cell in the northern hemisphere and one in the southern. But because the planet does rotate, the situation is more complicated. The planet's rotation means that the Coriolis Effect must be taken into account.

The **Coriolis Effect** causes freely moving objects to appear to move right in the Northern Hemisphere and to the left in the Southern Hemisphere. The objects themselves are actually moving straight, but the Earth is rotating beneath them, so they seem to bend or curve. An example might make the Coriolis Effect easier to visualize. If an airplane flies 500 miles due north, it will not arrive at the city that was due north of it when it began its journey. Over the time it takes for the airplane to fly 500 miles, that city moved, along with the Earth it sits on. The airplane will therefore arrive at a city to the west of the original city (in the Northern Hemisphere), unless the pilot has compensated for the change.

A common misconception of the Coriolis Effect is that water going down a drain rotates one way in the Northern Hemisphere and the other way in the Southern Hemisphere. This is not true because in a small container like a toilet bowl, other factors are more important. These factors include the shape of the bowl and the direction the water was moving when it first entered the bowl.

But on the scale of the atmosphere and oceans, the Coriolis Effect is very important. Let's look at atmospheric circulation in the Northern Hemisphere as a result of the Coriolis Effect. Air rises at the equator as described above. But as the air moves toward the pole at the top of the troposphere, it deflects to the right. (Remember that it just appears to deflect to the right because the ground beneath it moves.) At about 30°N latitude, the air from the equator meets relatively cool air flowing toward the equator from the higher latitudes. This air is cool because it has come from higher latitudes. Both batches of air descend, creating a high pressure cell. Once on the ground, the air returns to the equator. This convection cell is called the Hadley Cell and is found between 0° and 30°N.



***Left:** The atmospheric circulation cells, showing direction of winds at Earth's surface. **Right:** The major wind belts and the directions they blow.*

There are two more convection cells in the Northern Hemisphere. The Ferrell cell is between 30°N and 50° to 60°N. This cell shares its southern, descending side with the Hadley cell to its south. Its northern rising limb is shared with the Polar cell located between 50°N to 60°N and the North Pole, where cold air descends.

There are three mirror image circulation cells in the Southern Hemisphere. In that hemisphere, the Coriolis effect makes objects appear to deflect to the left.

Global Wind Belts

Global winds blow in belts encircling the planet. The global wind belts are enormous and the winds are relatively steady. We will be able to figure out how the wind in these belts blows using the information you just learned about atmospheric circulation.

In between each convection cell, where air moves vertically, there is little wind. But where air moves horizontally along the ground between the high and low pressure zones, steady winds form. The air movement of each large circulation cell creates the major wind belts. The wind belts are named for the directions from which the winds come. The westerly winds, for example, blow from west to east. Some names remain from the days when sailing ships depended on wind for their power.

Let's look at the global wind belts at the Earth's surface in the Northern Hemisphere. In the Hadley cell, air moves north to south, but is deflected to the right by the Coriolis Effect. These winds therefore blow from the northeast to the southwest. They are called the *trade winds* because at the time of sailing ships they were good for trade. Winds in the Ferrel cell blow from the southwest and are called the westerly winds or *westerlies*. The westerlies are the reason a flight across the United States from San Francisco to New York City takes less time than the reverse trip. On the outbound flight, the airplane is being pushed along by the westerlies, but on the reverse trip the airplane must fight against the air currents. In the Polar cell, the winds travel from the northeast and are called the *polar easterlies*. These names hold for the winds in the wind belts of the Southern Hemisphere as well.

The usual pattern of atmospheric circulation cells and the global wind belts determine normal global climate, but many other factors come into play locally. The high and low pressure areas created by the six atmospheric circulation cells generally determine the amount of precipitation a region receives. In low pressure regions, where air is rising, rain is common. In high pressure cells, the sinking air causes evaporation and the region is usually dry. More specific climate affects will be described in the chapter about climate.

The junction between the Ferrell and Polar cells is a low pressure zone. At this location, relatively warm, moist air that has circulated from the equator meets relatively cold, dry air that has come from the pole. The result is a place of extremely variable weather, known as the **polar front**. This weather is typical of much of North America and Europe.

The polar jet stream is found high up in the atmosphere where the two cells come together. A **jet stream** is a fast-flowing river of air at the boundary between the troposphere and the stratosphere. A jet stream can flow faster than 185 km/hr (115 mi/hr) and be thousands of kilometers long and a few hundred kilometers in width, but only a few kilometers thick. Jet streams form where there is a large temperature difference between two air masses. This explains why the polar jet stream is the world’s most powerful.

Jet streams move seasonally as the angle of the Sun in the sky moves north and south. The polar jet stream moves south in the winter and north in the summer between about 30°N and 50° to 75°N. The location of the jet stream determines the weather a location on the ground will experience. Cities to the south of the polar jet stream will be under warmer, moister air than cities to its north. Directly beneath the jet stream, the weather is often stormy and there may be thunderstorms and tornadoes.

Review Questions (1-2 sentences)

1. Why does the Coriolis Effect cause air (or water) to appear to move clockwise in the Northern Hemisphere? When would the Coriolis Effect cause air to appear to move counterclockwise?

2. Sailors once referred to a portion of the ocean as the 'doldrums'. This is a region where there is frequently no wind, so ships would become becalmed for days or even weeks. Given what you know about atmospheric circulation, where do you think the doldrums might be in terms of latitude?

Lesson 3: Wednesday, May 20

Astronomy Review

Many scientists can interact directly with what they are studying. Biologists can collect cells, seeds, or sea urchins and put them in a controlled laboratory environment. Physicists can subject metals to stress or smash atoms into each other. Geologists can chip away at rocks to see what is inside. But astronomers, scientists who study the universe beyond Earth, rarely have a chance for direct contact with their subject. Instead, astronomers have to observe their subjects at a distance, an astronomical distance.

Electromagnetic Radiation

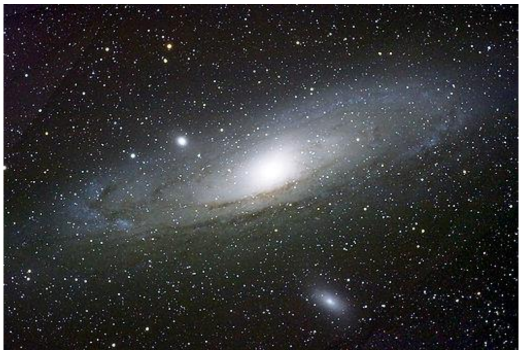
Earth is separated from the rest of the universe by very large expanses of space. Occasionally, matter from the outside reaches Earth, such as when a meteorite makes it through the atmosphere. But for the most part, astronomers have one main source for their data—light. Light can travel across empty space, and as it does so, it carries both energy and information. Light is one type of **electromagnetic (EM) radiation**, or energy transmitted through space as a wave.

The Speed of Light

Light travels faster than anything else in the universe. In the almost completely empty vacuum of space, light travels at a speed of approximately 300,000,000 meters per second (670,000,000 miles per hour). To give you an idea of how fast that is, a beam of light could travel from New York to Los Angeles and back again nearly 40 times in just one second. Even though light travels extremely fast, objects in space are so far away that it takes a significant amount of time for light from those objects to reach us. For example, light from the Sun takes about 8 minutes to reach Earth.

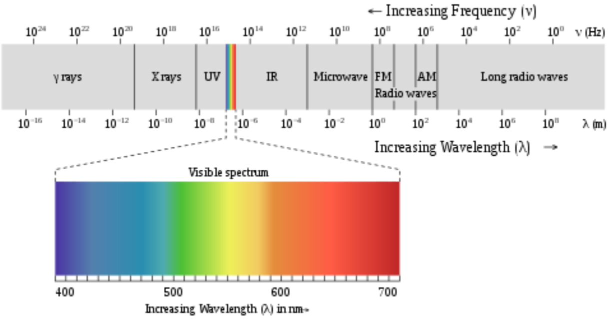
Looking Back in Time

When we look at astronomical objects such as stars and galaxies, we are not just seeing over great distances—we are also seeing back in time. Because light takes time to travel, the image we see of a distant galaxy is an image of how the galaxy used to look. For example, the Andromeda Galaxy, shown below, is about 2.5 million light years from Earth. If you look at the Andromeda Galaxy in a telescope, you will see the galaxy as it was 2.5 million years ago. If you want to see the galaxy as it is now, you will have to wait and look again 2.5 million years into the future!



The Electromagnetic Spectrum

Visible light—the light that human eyes can see—comes in a variety of colors. The color of visible light is determined by its wavelength. Visible light ranges from wavelengths of 400 nm to 700 nm, corresponding to the colors violet through red. But what about EM radiation with wavelengths shorter than 400 nm or longer than 700 nm? Such radiation exists all around you—you just can't see it! Visible light is part of a larger **electromagnetic spectrum**.



What does the electromagnetic spectrum have to do with astronomy? Every star, including our Sun, emits light at a wide range of wavelengths, all across the visible spectrum, and even outside the visible spectrum. Astronomers can learn a lot from studying the details of the spectrum of light from a star.

Some very hot stars emit light primarily at **ultraviolet** wavelengths, while some very cool stars emit mostly in the **infrared**. There are extremely hot objects that emit **X-rays** and even **gamma rays**. Light from some of the faintest, most distant objects is in the form of **radio waves**. In fact, a lot of the objects most interesting to astronomers today can't even be seen with the naked eye. Astronomers use telescopes to detect the faint light from distant objects and to see objects at wavelengths all across the electromagnetic spectrum.

Types of Telescopes

Optical Telescopes

Humans have been making and using lenses for magnification for thousands and thousands of years. However, the first true telescopes were made in Europe in the late 16th century. These telescopes used a combination of two lenses to make distant objects appear both nearer and larger. The term *telescope* was coined by the Italian scientist and mathematician Galileo Galilei (1564–1642). Galileo built his first telescope in 1608 and subsequently made many improvements to telescope design.

Telescopes that rely on the refraction, or bending, of light by lenses are called **refracting telescopes**, or simply *refractors*. The earliest telescopes, including Galileo's, were all refractors. Many of the small telescopes used by amateur astronomers today are refractors with a design similar to Galileo's. Refractors are particularly good for viewing details within our solar system, such as the surface of Earth's moon or the rings around Saturn.

Around 1670, another famous scientist and mathematician—Sir Isaac Newton (1643–1727)—built a different kind of telescope.

Left: *Reflecting telescopes used by amateur astronomers today are similar to the one designed by Isaac Newton in the 17th century.* ***Right:*** *A modern variation of the reflecting telescope, known as a 'Schmidt–Cassegrain' telescope.*

Newton's telescope used curved mirrors instead of lenses to focus light. Telescopes that use mirrors are called **reflecting telescopes**, or *reflectors*. The mirrors in a reflecting telescope are much lighter than the heavy glass lenses in a refractor. This is significant, because thick glass lenses in a telescope mean that the whole telescope must be much stronger to support the heavy glass. In addition, it's much easier to precisely make mirrors than to precisely make glass lenses. For that reason, reflectors can be made larger than refractors. Larger telescopes can collect more light, which means they can study dimmer or more distant objects. The largest optical telescopes in the world today are reflectors.

Radio Telescopes

Notice it says above that the largest *optical* telescopes in the world are reflectors. Optical telescopes are designed to collect visible light. There are even larger telescopes that collect light at longer wavelengths—radio waves. These telescopes are called—can you guess?—**radio telescopes**. Radio telescopes look a lot like satellite dishes. In fact, both are designed to do the same thing—to collect and focus radio waves or **microwaves** from space.

The largest single telescope in the world is at the Arecibo Observatory in Puerto Rico. This telescope is located in a naturally-occurring sinkhole that formed when water flowing underground dissolved the limestone rock. If this telescope were not supported by the ground, it would collapse under its own weight. The downside of this design is that the telescope cannot be aimed to different parts of the sky—it can only observe the part of the sky that happens to be overhead at a given time.

Left: *The radio telescope at the Arecibo Observatory in Puerto Rico has a diameter of 305 m.* ***Right:*** *The Very Large Array in New Mexico has 27 radio dishes, each 25 meters in diameter. When all the dishes are spread out and pointed at the same object, they act like a single telescope with a diameter of 22.3 mi.*

A group of radio telescopes, such as the Very Large Array, can be linked together with a computer so that they are all observing the same object. The computer can combine the data from each telescope, making the group function like one single telescope.

Review Questions (1-2 sentences)

1. What are the two main types of optical telescopes- describe their differences.

2. Identify four regions of the electromagnetic spectrum that astronomers use when observing objects in space.

<u>Lesson 4: Thursday, May 21</u>

Astronomy Review, continued

The constellation Orion is a familiar pattern of stars in the sky.

For centuries, people have seen the same stars you can see in the night sky. People of many different cultures have identified **constellations**, which are apparent patterns of stars in the sky.

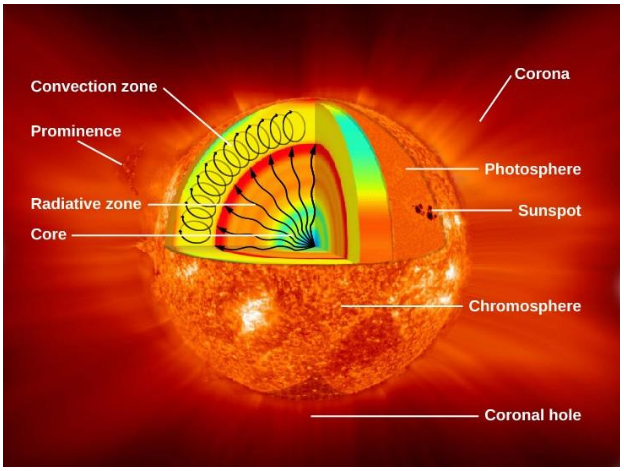
The patterns in constellations and in groups or clusters of stars, called **asterisms**, stay the same night after night. However, in a single night, the stars move across the sky, keeping the same patterns. This apparent nightly motion of the stars is actually due to the rotation of Earth on its axis. It isn't the stars that are moving; it is actually Earth spinning that makes the stars seem to move. The patterns shift slightly with the seasons, too, as Earth revolves around the Sun. As a result, you can see different constellations in the winter than in the summer. For example, Orion is a prominent constellation in the winter sky, but not in the summer sky.

Nuclear Fusion

Stars are made mostly of hydrogen and helium. These are both very lightweight gases. However, there is so much hydrogen and helium in a star that the weight of these gases is enormous. In the center of a star, the pressure is great enough to heat the gases and cause **nuclear fusion reactions**. In a nuclear fusion reaction, the nuclei, or centers of two atoms join together and create a new atom from two original atoms. In the core of a star, the most common reaction turns two hydrogen atoms into a helium atom. Nuclear fusion reactions require a lot of energy to get started, but once they are started, they produce even more energy.

The energy from nuclear reactions in the core pushes outward, balancing the inward pull of gravity on all the gas in the star. This energy slowly moves outward through the layers of the star until it finally reaches the outer surface of the star. The outer layer of the star glows brightly, sending the energy out into space as electromagnetic radiation, including visible light, heat, ultraviolet light, and radio waves.

Solar Anatomy



The Sun, a fairly typical main sequence star, is a sphere, but unlike the Earth and the Moon, is not solid. Most atoms in the Sun exist as **plasma**, or a fourth state of matter made up of superheated gas with an electrical charge. Our Sun consists almost entirely of the elements hydrogen and helium. Because the Sun is not solid, it does not have a defined outer boundary. It does, however, have a definite internal structure. There are several identifiable layers of the Sun:

The **core** is the innermost or central layer of the Sun. The core is plasma, but moves similarly to a gas. Its temperature is around 27 million degrees Celsius. In the core, nuclear reactions combine hydrogen atoms to form helium, releasing vast amounts of energy in the process. The energy released then begins to move outward, towards the outer layers of the Sun.

The **radiative zone** is just outside the core, which has a temperature of about 7 million degrees Celsius. The energy released in the core travels extremely slowly through the radiative zone. Particles of light called photons can only travel a few millimeters before they hit another particle in the Sun, are absorbed and then released again. It can take a photon as long as 50 million years to travel all the way through the radiative zone.

The **convection zone** surrounds the radiative zone. In the convection zone, hot material from near the Sun's center rises, cools at the surface, and then plunges back downward to receive more heat from the radiative zone. This movement helps to create solar flares and sunspots, which we'll learn more about in a bit. These first three layers make up what we would actually call "the Sun". The next three layers make up the Sun's atmosphere. Of course, there are no solid layers to any part of the Sun, so these boundaries are fuzzy and indistinct. This is an example of convection currents.

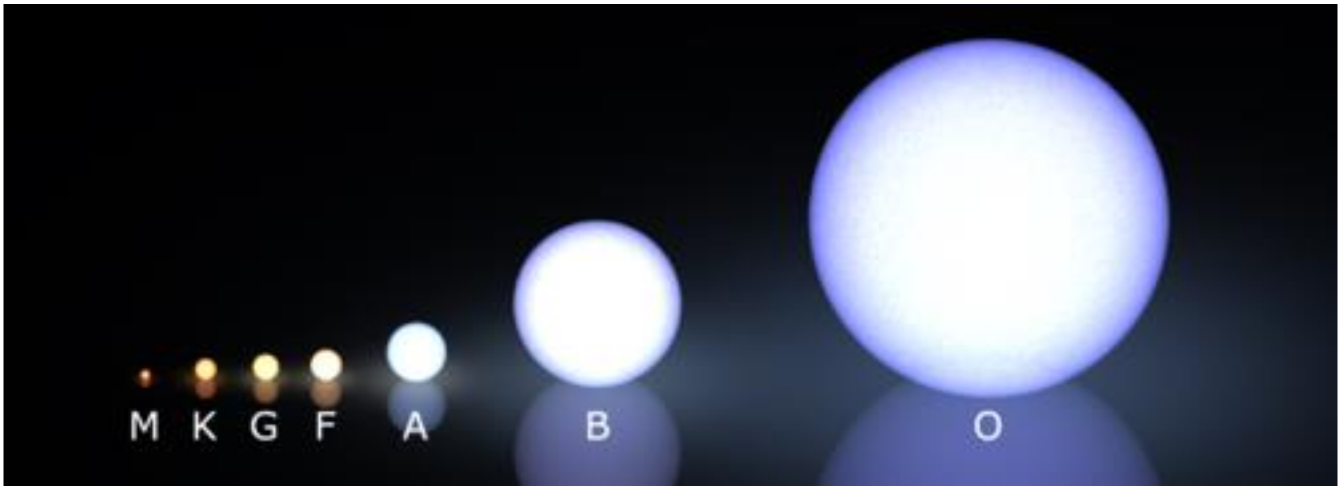
How Stars Are Classified

The most common way of classifying stars is by color. The table below shows how this classification system works. The class of a star is given by a letter. Each letter corresponds to a color, and also to a range of temperatures. Note that these letters don’t match the color names; they are left over from an older system that is no longer used.

Classification of Stars by Color and Temperature

Class	Color	Temperature Range	Sample Star
O	Blue	30,000 K or more	Zeta Ophiuchi
B	Blue-white	10,000-30,000 K	Rigel
A	White	7,500-10,000 K	Altair
F	Yellowish-white	6,000-7,500 K	Procyon A
G	Yellow	5,500-6,000 K	Sun
K	Orange	3,500-5,000 K	Epsilon Indi
M	Red	2,000-3,500 K	Betelgeuse, Proxima Centauri

For most stars, surface temperature is also related to size. Bigger stars produce more energy, so their surfaces are hotter. The table above shows a typical star of each class, with the colors about the same as you would see in the sky.



Typical stars by class, color, and size. For most stars, size is related to class and to color. This image shows a typical star of each class. The colors are approximately the same as you would see in the sky.

The Main Sequence

For most of a star's life, the nuclear fusion in the core combines hydrogen atoms to form helium atoms. A star in this stage is said to be a **main sequence star**, or to be on the main sequence. This term comes from the Hertzsprung-Russell diagram, that plots a star's surface temperature against its true brightness or magnitude. For stars on the main sequence, the hotter they are, the brighter they are. The length of time a star is on the main sequence depends on how long a star is able to balance the inward force of gravity with the outward force provided by the nuclear fusion going on in its core. More massive stars have higher pressure in the core, so they have to burn more of their hydrogen "fuel" to prevent gravitational collapse. Because of this, more massive stars have higher temperatures, and also run out of hydrogen sooner than smaller stars do.

Red Giants and White Dwarfs

As a star begins to use up its hydrogen, it then begins to fuse helium atoms together into heavier atoms like carbon. Eventually, stars contain fewer light elements to fuse. The star can no longer hold up against gravity and it starts to collapse inward. Meanwhile, the outer layers spread out and cool. The star becomes larger, but cooler on the surface and red in color. Stars in this stage are called **red giants**.

Eventually, a red giant burns up all of the helium in its core. What happens next depends on how massive the star is. A typical star like the Sun, stops fusion completely at this point. Gravitational collapse shrinks the star’s core to a white, glowing object about the size of Earth. A star at this point is called a white dwarf. Eventually, a white dwarf cools down and its light fades out.

Supergiants and Supernovas

A star that has much more mass than the Sun will end its life in a more dramatic way. When very massive stars leave the main sequence, they become red supergiants. The red star Betelgeuse in Orion is a red supergiant.

Unlike red giants, when all the helium in a red supergiant is gone, fusion does not stop. The star continues fusing atoms into heavier atoms, until eventually its nuclear fusion reactions produce iron atoms. Producing elements heavier than iron through fusion takes more energy than it produces. Therefore, stars will ordinarily not form any elements heavier than iron. When a star exhausts the elements that it is fusing together, the core succumbs to gravity and collapses violently, creating a violent explosion called a **supernova**. A supernova explosion contains so much energy that some of this energy can actually fuse heavy atoms together, producing heavier elements such as gold, silver, and uranium. A supernova can shine as brightly as an entire galaxy for a short time, as shown in Figure 26.4.

If the core remaining after a supernova is more than about 5 times the mass of the Sun, the core will collapse so far that it becomes a **black hole**. Black holes are so dense that not even light can escape their gravity. For that reason, black holes cannot be observed directly. But we can identify a black hole by the effect that it has on objects around it, and by radiation that leaks out around its edges.

Measuring Star Distances

The Sun is much closer to Earth than any other star. Light from the Sun takes about 8 minutes to reach Earth. Light from the next nearest star, Proxima Centauri, takes more than 4 years to reach Earth. Traveling to Proxima Centauri in spacecraft similar to those we have today would take tens of thousands of years.

Light-years

Because astronomical distances are so large, it helps to use units of distance that are large as well. A **light-year** is defined the distance that light travels in one year. One light-year is 9,500,000,000,000 (9.5 trillion) kilometers, or 5,900,000,000,000 (5.9 trillion) miles. Proxima Centauri is 4.22 light-years away, which means that its light takes 4.22 years to reach us.

One light-year is approximately equal to 60,000 AU and 4.22 light-years is almost 267,000 AU. Recalling that Neptune, the farthest planet from the Sun, orbits roughly 30 AU from the Sun, we can realize that the distance from the Earth to stars other than our own Sun is much greater than the distance from the Earth to other planets within our own solar system.

Review Questions (1-2 sentences)

1. What distinguishes a nebula and a star?

2. What is the definition of a light-year?

Lesson 5: Friday, May 22

Geology Review- Plate tectonics and the Earth's interior.

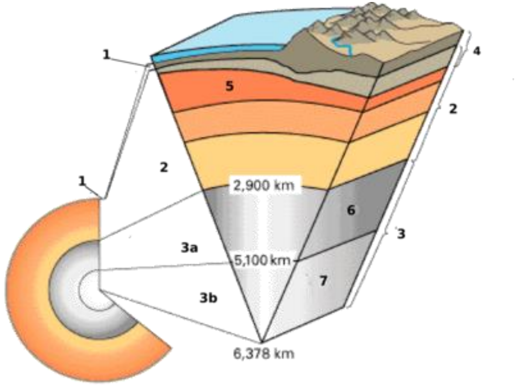
Plate tectonics is the unifying theory of geology. This important theory explains why Earth's geography has changed through time and continues to change today. It explains why some places are prone to earthquakes and some are not; why some regions have deadly volcanic eruptions, some have mild ones, and some have none at all; and why mountain ranges are located where they are. Plate tectonic motions affect Earth's rock cycle, climate, and the evolution of life. Plate tectonic theory is relatively recent, having been developed by scientists during the twentieth century.

Before you can learn about plate tectonics, you need to know something about the layers that are found inside Earth. From outside to inside, the planet is divided into crust, mantle, and core. Often geologists talk about the lithosphere, which is the crust and the uppermost mantle. The lithosphere is brittle–it is easily cracked or broken–whereas the mantle beneath it behaves plastically; it can bend. Geologists must use ingenious methods, such as tracking the properties of earthquake waves, to learn about the interior of our planet.

The Earth is composed of several layers. On the outside is the relatively cold, brittle crust. Below the crust is the hot, convecting mantle. At the center is the dense, metallic inner core.

Crust and Lithosphere

Earth's outer surface is its crust; a thin, brittle outer shell made of rock. Geologists call the outermost, brittle, mechanical layer the lithosphere. The difference between crust and lithosphere is that lithosphere includes the uppermost mantle, which is also brittle.

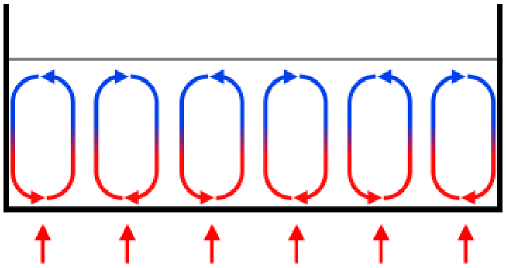


A cross section of Earth showing the following layers: (1) crust (2) mantle (3a) outer core (3b) inner core (4) lithosphere (5) asthenosphere (6) outer core (7) inner core. The lithosphere is made of the crust plus the uppermost part of the mantle. The asthenosphere is directly under the lithosphere and is part of the upper mantle.

Mantle

Beneath the crust lies the mantle. Like the crust, the **mantle is made of rock**. The mantle is differentiated from the crust by an increase in rock density as indicated by a sudden increase in seismic wave velocities. One very important feature of the mantle is that it is **extremely hot.** Although the higher temperatures far exceed the melting points of the mantle rocks at the surface the mantle is almost exclusively solid. The heat in the mantle is mainly due to heat rising from the core. Through the process of **conduction**, heat flows from warmer objects to cooler objects until all are the same temperature. Knowing the ways that heat flows is important for understanding how the mantle behaves. So here, we return to our old friend **convection.**

Heat can flow in two ways within the Earth. If the material is solid, heat flows by conduction, and heat is transferred through the rapid collision among atoms. If a material is fluid and able to move—that is, it is a gas, liquid, or a solid that can move (like toothpaste)—heat can also flow by **convection**. In convection, currents form so that warm material rises and cool material sinks. This sets up a **convection cell** (below).



In a convection cell, warm material rises and cool material sinks. In mantle convection, the heat source is Earth's core.

Remember: **Convection** occurs when a pot of water is heated on a stove. The stove heats the bottom layer of the water, which makes it less dense than the water above it, so the warmer bottom water rises. Since the layer of water on the top of the pot is not near the heat source, it is relatively cool. As a result, it is denser than the water beneath it and so it sinks. Within the pot, convection cells become well established as long as there is more heat at the bottom of the pot than on the top. Convection cells also explain the global wind patterns and the development of thunderstorms, as we recently studied.

Convection cells are also found in the mantle. Mantle material is heated by the core and so it rises upwards. When it reaches the surface of the Earth, it moves horizontally. As the material moves away from the core's heat, it cools. Eventually the mantle material at the top of the convection cell becomes cool and dense enough that it sinks back down into the deeper mantle. When it reaches the bottom of the mantle, it travels horizontally just above the core. Then it reaches the location where warm mantle material is rising, and the mantle convection cell is complete.

Core

At the planet's center lies a dense metallic **core**. Scientists know that the core is metal for two reasons: The first is that some meteorites are metallic and they are thought to be representative of the core. The second is that the **density** of Earth's surface layers is much less than the overall density of the planet. We can calculate Earth's density using our planet's rotation. If the surface layers are less dense than the average for the planet, then the interior must be denser than the average. Calculations indicate that the core is about 85% iron metal with nickel metal making up much of the rest.

How Plates Move

We know that seafloor spreading moves the lithospheric plates around on Earth's surface but what drives seafloor spreading? The answer is a familiar one: **mantle convection**.

Imagine two sponges floating in a pot of water. If the water is still, the sponges will stay still as well. Now imagine you start heating the water. As the water heats, it becomes turbulent and unstable, even before it starts to boil. This is because the heat is causing **convection**. Heat makes the water at the bottom of the pot near the fire start to rise, while the cooler water near the surface will sink. This motion in the water will cause the sponges to start to move as well. Think of tectonic plates as these sponges. Rock in the mantle, heated by the earth’s core, is like the water heated by the fire below the pot. The rock slowly but surely rises from the heat, then cools off near the surface causing it to sink. Because of this, the continents on top of all that rock move! This is how **plate tectonics** are caused by **mantle convection**

Minor Assessment: Explain at least one example of convection that occurs in the phenomena studied by each of the following disciplines: Meteorology, Astronomy, and Geology. 3-4 sentences