INTRODUCTION TO GEOGRAPHY



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About the Book

This book is used as the basis for an online course introducing students to the field of geography. The course covers the basics of both physical and human geography and is aimed at non-majors.

Upon successful completion of the course, the student will be able to:

- Build geographic understanding of the world and explain the connections among peoples and places (spatial diversity and human-environment interaction)
- Use the tools of geography to help explain the world and solve problems (make and use maps and diagrams depicting spatial variation of phenomena)
- Map how the uneven distribution of energy leads to a diverse physical landscape including different climates, landforms, and resources.
- Map how the uneven distribution of resources leads to a diverse cultural landscape including languages, political and economic systems.
- Apply the tools of geography and spatial thinking to other disciplines such as conflict resolution, political sciences, economics, sociology, geology, chemistry and biology.

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Introduction

This text is used in an 10-11 week introductory course which provides an overview of both physical and human geography. The course begins with a discussion of the place of geography within the human body of knowledge, then moves to map reading, before going to physical geography and ends with human geography topics.

This e-text is based largely on two previously shared e-texts by Adam Dastrup:

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1: PHYSICAL GEOGRAPHY

1.1: Introduction to Geographic Science

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1.1: Introduction to Geographic Science

Learning Objectives

- Recognize the history and evolution of the geographic profession.
- Explain the science of geography today.
- Summarize the basic components of spatial thinking
- Explain the overarching concept of geospatial technology and the technologies it includes.

INTRODUCTION

When you think of geography do you think about memorizing capitals, rivers, mountains, and states or coloring maps? Sadly, this is how geography is taught too often in K12 schools. In reality, geography is one of the most high-tech scientific disciplines in the science community. **Geography** is the scientific study of the earth and is one of the original disciplines along with philosophy in trying to understand the world humans live in. The geographic discipline has two sub-categories, physical geography and cultural geography, which allows geographers the scientific credibility to look at cultural issues of economics, demographics, culture, language, religion, or urban planning. It also allows geographers to focus on climate, climate change, biogeography, geomorphology, or environmental issues of pollution, desertification, deforestation, or species extinction. This unique ability also allows geographic scientists to study how the cultural environment influences the physical environment and vice versa. Geography is a physical science and social science, but also has the academic credibility to study the interaction between the two.

What makes the scientific discipline of geography different from other science disciplines is its emphasis on space, place, and connection. The overarching question that geographers ask is “Where?”. The technology geographers and other scientists use to study the physical and cultural environments spatially and over time is geospatial technology. **Geospatial technology** is an umbrella term that encompasses global positioning systems (GPS), remote sensing (i.e. satellite imagery and aerial photography), and geographic information systems (GIS). Teaching a geography class without teaching about geospatial technology would be like a chemistry teacher teaching about chemistry without ever using the periodic table.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pb.libretexts.org/sfccintrogeography/?p=32

HISTORY OF THE GEOGRAPHIC DISCIPLINE

Geography is often times called the “mother of all sciences” because geography is one of the earliest known scientific disciplines that date back to the original Homo-sapiens who migrated out of eastern Africa, into Europe, Asia, and beyond. In fact, some would argue that spatial awareness and early mapping were more significant to the development and migration of humans out of Africa than language. There is no single, linear or historic pathway through the cultural development of geography because the discipline is inherently human. Humans have always had a need and desire to explore their surroundings, expand their influence and sometimes dominance over new lands.

Modern geography probably originated in Western Europe during the 16th century as the region experienced economic and social growth, as well as upheaval brought about by new navigational methods and colonization. Geography, as a formal discipline, came about as sailing and trade routes across the great oceans become more common. This required new knowledge in navigation, mathematics, literacy, science, medicine, warfare, and of course, cartography (map making). A **cartographer** is someone who is skilled in the science and art of map-making. Some scholars who research concepts of critical cartography have posited that modern mapping is grounded in power, dominance, control, war, racism, and the dismantling of foreign cultures. Thus, maps in the past, present, and future will play a powerful role in how we understand the world because maps help shape our sense of place, and those who create the maps often shape our historical, cultural, and political interactions with place.

Alexander von Humboldt and Carl Ritter, according to many in the field, took geography from a primarily navigation-oriented discipline to more scholarly pursuits. Both scholars wanted to understand the natural and human environments from a systematic and objective perspective as a way to explain specific regions of the world. Over time, academic and institutionalized organizations of geographic research grew throughout Europe. The need for skilled geographers and cartographers grew ever more important to countries because they provided the powerful and elite detailed surveys and spatial information about the physical and cultural environments they wanted to explore and exploit. This was especially true as colonial powers desired the resources (natural and human), and the prestige of controlling Africa in the 1800s.

Geography transformed from a discipline centered on navigation to a pathway for imperial exploration, and then to a discipline of imperial science. Sadly, many geographers took Charles Darwin’s ideas of evolution and natural selection and applied them to a perverted interpretation called **Social Darwinism**. This idea, first constructed by economists in Europe, implies that natural selection could easily be applied to social and political concepts. It was Social Darwinists that coined the term “survival of the fittest,” not Charles Darwin. Under this hypothesis, natural selection could be used to justify the need for “stronger” nation-states or races to dominate over “weaker” nation-states and races.

Social Darwinism later grew into scientific racism. This became a systematic problem throughout the discipline of geography because it justified European explorers and settlers’ ideas that they were genetically superior to other races, as well as entitled and destined to expand their civilizations and belief systems as they had been doing for over 400 years. This included European settlers in the Americas or “New World.”

World Wars I and II caused a major shift in geographic thought. By this time, most of the world had been navigated, explored, and in essence, colonized. Any new expansion would likely require colonial powers to conquer each other. Many geographers played a leading role in advising national leaders on Post-war Reconstruction and a new era of geography was born. Geographers understood the need to merge scientific thoughts in physical and cultural geography when trying to understand a region of the world and to value diversity and uniqueness within these regions grounded within spatial science.

Geographic Science Today

As stated earlier, geographers study both the physical, environmental, and cultural aspects of the world. Besides being called the “mother science,” some say that geographers “are a mile wide and an inch deep” because geographers have to know a lot about the physical, environmental, or cultural world, but may not go into the depth that other disciplines might. Since so many disciplines have branched off from geography, the discipline of geography has had to find its own focus, emphasis, and depth.

Physical geography focuses on natural origins and processes of the physical earth. Some physical geographers focus on environmental issues and are called **environmental geographers**, a sub-discipline of physical geography. Physical geographers focus on weather, climate and climate change, landforms, environmental pollution, river processes, and more. **Cultural geographers** emphasize human endeavors such as population, language, religion, culture and ethnicity, economics and development, geopolitics, urban planning, and more. Geographers in this line of science are often called **human geographers**.

Ultimately, the entire geography profession is focused on the spatial distribution or arrangement of the physical and cultural

world. One of the discipline's greatest strengths and contributions to science and society is their study of interrelationships between physical and cultural elements of the earth's environment. Maybe it's the interrelationship between river systems and soil, or climate and ecosystems, or even the connections between deforestation, species extinction, population growth, and poverty issues. The interconnectedness of all areas of geography often requires many geographers to train in both physical and cultural geography. In fact, probably the greatest strength of the science of geography is the discipline's ability to study the world spatially and look for the interconnections between the physical and cultural environments.

THE SCIENTIFIC PROCESS OF GEOGRAPHY

Geography is considered a science and thus also uses the scientific method for data collection, analysis, and interpretation. There is no true definition of the scientific method because it varies so much between scientific disciplines. There are various methods to acquire scientific knowledge from the physical sciences, biological sciences, social sciences, and everything in between. A simplified version of what most scientific disciplines follow are:

- Observe a particular feature, phenomenon, or event in the world that stimulates a series of questions and thought process.
- Develop an educated thought that tries to answer the questions posed, called a hypothesis.
- Design an experiment or way to "test" your hypothesis.
- Implement the experiment and observe the results using unbiased data and measurement techniques.
- Propose a solution, answer, or rule that explains the hypothesis and experiment.

Science is about probability and not absolutes. Scientists will regularly publish the results of their research in a scientific journal so that others can attempt to reproduce the same results. Sharing knowledge is a key component of science, and really for all of humanity. A **hypothesis** is an "educated idea" that tries to explain a particular aspect, feature, or event. In everyday conversations, a "theory" is a hunch or guess about something. In the scientific community, a **theory** represents the highest order of understanding for a body of information. When scientists talk about the theories of plate tectonics, evolution, climate change, or the Big Bang, it is not an idea or hunch scientists have about something. Climate scientists have a high probability that the recent warming of the planet has been caused by natural cycles and variations and human impacts like burning fossil fuels. But notice that scientists do not and cannot offer absolutes percentages or statements. Rather, they will point to what the "evidence suggests." What this means is that our understanding of climate change can and will change as more data collection and evidence comes to light. This applies to other important scientific theories such as evolution, the big bang, plate tectonics, and others.

Scientific and Geographic Inquiry



Sampling Lava

SCIENTIFIC INQUIRY

Science is a path to gaining knowledge about the natural world. The study of science also includes the body of knowledge that has been collected through **scientific inquiry**. To conduct a scientific investigation, scientists ask testable questions that can be systematically observed and careful evidenced collected. Then they use logical reasoning and some imagination to develop a testable idea, called a **hypotheses**, along with explanations to explain the idea. Finally, scientists design and conduct experiments based on their hypotheses.

Scientists seek to understand the natural world by asking questions and then trying to answer the questions with evidence and logic. A **scientific question** must be testable and supported by empirical data, it does not rely on faith or opinion. Our understanding of natural Earth processes help us to understand why earthquakes occur where they do and how to understand the consequences of adding excess greenhouse gases into the atmosphere. **Scientific research** may be done to build knowledge or to solve problems and lead to **scientific discoveries** and technological advances. **Pure (or abstract) research** often aids in the development of **applied research**. Sometimes the results of pure research may be applied long after the pure research was completed. Sometimes something unexpected is discovered while scientists are conducting their research. Some ideas are not testable. For example, supernatural phenomena, such as stories of ghosts, werewolves, or vampires, cannot be tested.

Scientists describe what they see, whether in nature or in a laboratory. Science is the realm of facts and observations, not moral judgments. Scientists might enjoy studying tornadoes, but their opinion that tornadoes are exciting is not important to learning about them. Scientists increase our technological knowledge, but science does not determine how or if we use that knowledge. Scientists learned to build an atomic bomb, but scientists didn't decide whether or when to use it. Scientists have accumulated data on warming temperatures; their models have shown the likely causes of this warming. But although scientists are largely in agreement on the causes of global warming, they can't force politicians or individuals to pass laws or change behaviors.

For science to work, scientists must make some assumptions. The rules of nature, whether simple or complex, are the same everywhere in the universe. Natural events, structures, and landforms have natural causes and evidence from the natural world can be used to learn about those causes. The objects and events in nature can be understood through careful, systematic study. Scientific ideas can change if we gather new data or learn more. An idea, even one that is accepted today, may need to be changed slightly or be entirely replaced if new evidence is found that contradicts it. Scientific knowledge can withstand the test of time because accepted ideas in science become more reliable as they survive more tests.

GEOGRAPHIC INQUIRY

Geography is the study of the physical and cultural environments of the earth. What makes geography different from other disciplines is its focus on spatial inquiry and analysis. Geographers also try to look for connections between things such as patterns, movement and migration, trends, and so forth. This process is called **geographic** or **spatial inquiry**. In order to do this, geographers go through a geographic methodology that is quite similar to the scientific method, but again with a geographic or spatial emphasis. This method can be simplified in a five step **geographic inquiry process**.

1. **Ask a geographic question.** Ask questions about spatial relationships in the world around you. At its most basic, ask "Where?"
2. **Acquire geographic data.** Identify data and information that you need to answer your question. Geographic data is data that includes and is applied to a location or a region.
3. **Explore geographic data.** Turn the data into maps, tables, and graphs, and look for patterns and relationships.
4. **Analyze geographic information.** Determine what the patterns and relationships mean with respect to your question.
5. **Act upon geographic information.** Use and apply the knowledge.

"Knowing where something is, how its location influences its characteristics, and how its location influences relationships with other phenomena are the foundation of geographic thinking. This mode of investigation asks you to see the world and all that is in it in spatial terms. Like other research methods, it also asks you to explore, analyze, and act upon the things you find. It also is important to recognize that this is the same method used by professionals around the world working to address social, economic, political, environmental, and a range of scientific issues." (ESRI)

When geographers use the term 'spatial' they mean the three dimensional aspects of earth; length, width, and height; not the extraterrestrial use of the term. All three of those terms, length width and height, are measured as a distance. Height is distance above or below a surface. Length and width are distances from a starting point but measured 90° in different directions. In this paragraph I've used key geographic concepts of 'distance' and 'direction'. Those concepts are critical in describing a location. Many geographic questions have some form of "how far" or "which direction" embedded in the question.

SPATIAL THINKING AND ANALYSIS

Geoliteracy

Above all else, geography is considered a spatial science. It is concerned with the spatial behavior of people, with the spatial relationships that are observed between places on the earth's surface, and with the spatial processes that create or maintain those behaviors and relationships. Geographers are concerned the intersections between space (aerial extent) and place. A geoliterate person is able to reason and make decisions by understanding the interactions (systems thinking), interconnections (how are places connected), and implications (reason out impacts of actions). If you are not yet able to think like that, you will be at a disadvantage to someone who can think that way.

Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this Video online

Video: definition and importance of geoliteracy

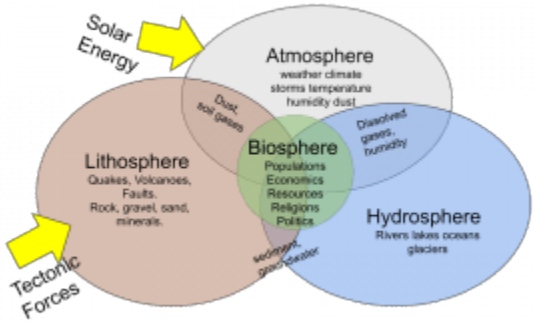
Imagine a company's purchasing agent placing an order for snow blowers based only on past sales, not knowing that the customers in the area have changed or not knowing if it's an El Nino or La Nina year.

Systems Thinking

A system is a set of connected components which work together and create an output when energy is added. The components are a series of storages and flows between them.

Sometimes the output is harmful to the production of the system, called a negative result. A different stimulus, or the same stimulus at different point in the system or different time, may increase or improve the system production, which would be a positive result. The positive result may be good for the system, but bad for humans and a negative result can be bad for the system but good for humans.

There are two major subsystems on earth and this course will look at components of both. Many people people investigate deeply into small parts of these systems, but a good geographer steps back frequently to see how the parts are connected to the whole system. The Human Subsystem is composed of the beliefs, institutions, and technologies of humans.



The Physical Subsystem

Place is a particular area or point on Earth that has a particular characteristic. Every place on earth has a unique location physically and conceptually. A **region** is an area on the earth's surface that has distinctive physical and cultural characteristics.

A very important concept in geography is **scale**, which is the relationship between the locations of something on the earth compared to the entire earth. Scale can range from the atomic level to the entire planet or even space.

Connection is the relationship between the physical or cultural components of the world, (or both), that crosses barriers and boundaries.

Location

Location is probably one of the most significant aspects of the discipline, which is a position of an object that could be put on a map. That location doesn't need to be on the Earth's surface, it can be below, within the oceans, the atmosphere, or even in space. Location can also be divided into nominal, relative, and absolute. **Nominal locations** are the names of a place. Examples include Washington D.C., the Rocky Mountains, the Nile River, or Florida. Nominal locations just specify a location's name and their scale can vary.

Relative location is a very common form of location. How often have you given directions to your house using landmarks rather than just your address? Relative location is the location of something relative to other features. You can understand a lot about a place based on what's around it.

The third kind of location is called **absolute location**, which is the particular location of something. This is usually based on some sort of geographic coordinate system like latitude and longitude. If you think about it, many navigation GPS systems use relative and absolute locations. If you were to type in an address and used your current location as the starting point into a mapping system like Google Maps, it will not only give you the location of your destination, it will also give you a few relative pathways to get there.

Direction

Next in our study of spatial thinking is direction and distance. **Direction** is the location of something relative to something else. If we refer back to our example with Google Maps, an online program will determine a direction based on your current location and your intended destination. **Relative direction** can change depending on your point of view. If you are facing someone and discuss a tree to your right, that same tree is to the left of another person. However, **absolute directions** won't change. If that same tree is to the north of you, it is also to the north of the other person. Some people have a preference for using directions that are either absolute or relative, and that preference may change depending on the situation. It could be better to give absolute directions to your house if people will be coming from different locations since some would turn left and other would turn right at the same intersection.

Distance

Distance is a mathematical concept and used to determine the space between two or more features using some form of measuring unit. A simple example of this would be using Google Maps to determine the distance from Salt Lake City, Utah to Portland, Oregon shown above, which is about 766 miles per hour. Distances using an agreed upon unit of measurement such as a mile or a kilometer are unchanging, they are **absolute distances**. But the time needed to travel that distance may change depending on whether you drive, fly or walk. Time is an example of **relative distance**. Delivery companies are interested in both types of distance because vehicles wear out based on absolute distance, but a customer requires an on-time delivery which is a form of relative distance.

Location, direction, and distance are central concepts in geography. You can not determine location without both distance and direction. ("Meet me northwest of here.")

Space

Geographers are also concerned with issues of space. In particular, they are concerned with what exists between spaces. Are the features between the spaces related or similar to each other or dissimilar? The **1st Law of Geography** states that points near each other are more likely to be related than points farther apart, but that isn't always the case. Networks are concerned with the

movement or flow of an object through space and time. This can apply to transportation, migration, trade, flow of rivers, glacier, or the atmosphere, and also the flow of cyber networks.

Networks are in fact a type of system and geographers often deal with systems analysis. In describing a system the geographer explains where something is coming from, where it is going, the rates and methods of movement. A systems analysis of global warming will investigate the sites where large volumes of carbon are stored such as the atmosphere or fossil fuels and how carbon moves among those sites such as burning the fuels or plants incorporating atmospheric carbon in their tissue. Once the processes of movement and the locations of storage are understood, the big question becomes “how do these changes affect humans who live in different locations?”.

A geographic explanation can either describe the characteristic of a single site, or it’s situation relative to other sites. The concepts of location, distance, direction are all included in spatial analysis. Descriptions of density, concentration, and pattern across the landscape are useful to understand what makes spaces unique.

Big Data

Data is everywhere, especial big data and spatial data. Big data refers to the fact that their is so much data that we can now not only understand the physical and cultural world, but we can start to predict behavior. Big data can determine who your friends are, what your buying habits are and what you are willing to impulse buy. It allows businesses to determine what your purchasing power is and what draws you. Scientists use it to understand complex systems such as ecological processes, weather patterns, and climate change.

Spatial data is now a form of big data. It’s collected every time you go to the grocery store and use their card to reduce the costs, when you click on a link on Facebook, or when you do any kind of search on a search engine like Google, Bing, or Yahoo!. It is used by your state department of transportation when you are driving on a freeway or when you use an app on a smart phone. Futurists believe that in the near future, face recognition technology will allow a sales representative know what types of clothes you like to buy based on a database of your recent purchases at their store and others.

Now there are two basic types of data you need to know: spatial and non-spatial data. **Spatial data**, also called **geospatial data**, is data that can be linked to a specific location on Earth. Geospatial data is becoming “big business” because it isn’t just data, but data that can be located, tracked, patterned, and modeled based on other geospatial data. Census information that is collected every 10 years is an example of spatial data. The geospatial data industry was already valued at over $400B USD in 2016 by AlphaBeta.

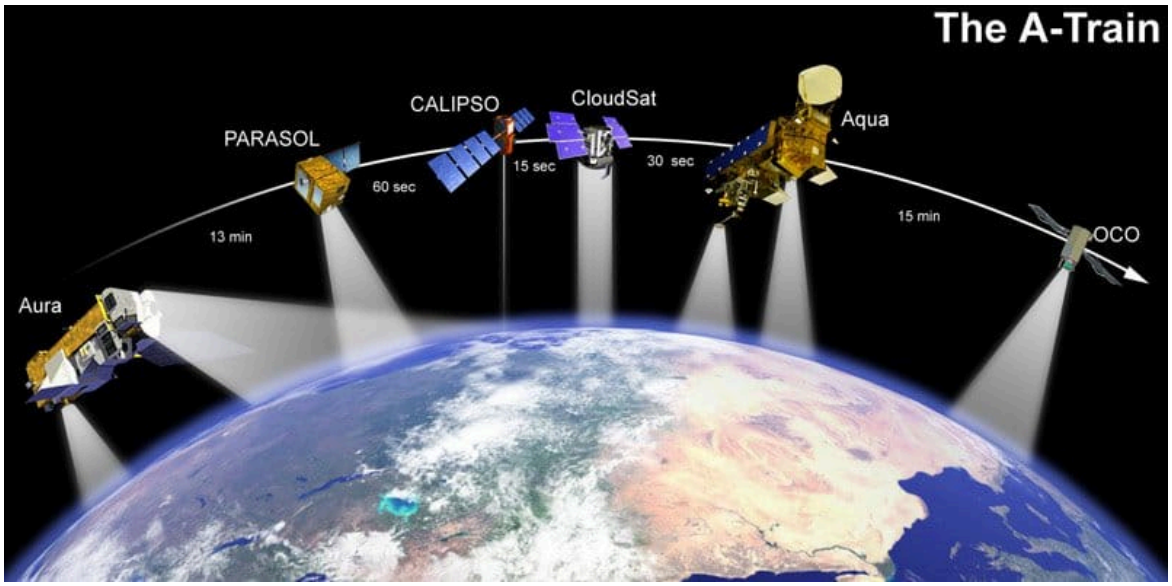
Non-spatial data is data that cannot be specifically traced to a specific location. This might include the number of people living in a household, enrollment within a specific course, or gender information. But non-spatial data can easily become spatial data if it can be linked in some way to a location. Geospatial technology specialists have a method called **geocoding** that can be used to give non-spatial data a geographic location. Once data has a spatial component associated with it, the type of questions that can be asked dramatically changes.

Here are some ways good quality geospatial data helps society:

https://geospatial.blogs.com/.a/6a00d83476d35153ef01b8d2cbf0af970c-320wi

Economic Impact of Geospatial Services

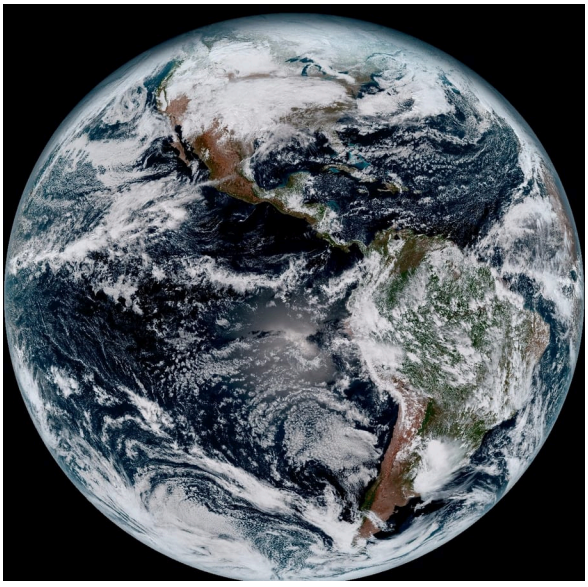
Geospatial Technology



Some Remote Sensing Satellites.

Remote Sensing

Remote sensing can be defined as human's ability to study objects without being in direct physical contact with them. So for example, your eyes are a form of *passive remote sensing* because they are "passively" absorbing electromagnetic energy within the visible spectrum from distant objects and your brain is processing that energy into information. There are a variety of remote sensing platforms or devices, but they can basically be categorized into the following that we will look at throughout the course.

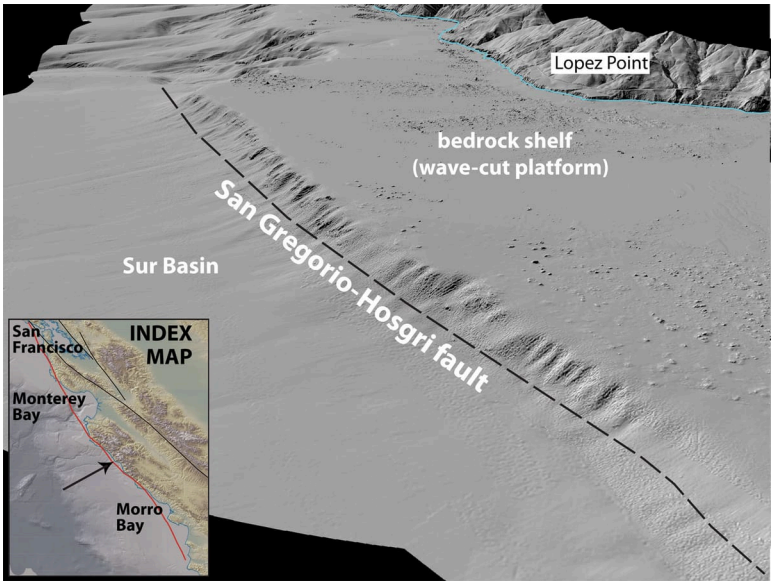


NOAA GOES-16 Full-disk Image of Earth

Nasa: Earth from Orbit

Satellite imagery is a type of remotely sensed imagery taken of the Earth's surface, which is produced from orbiting satellites that gather data via electromagnetic energy. Next is **areal photography**, which is film-based or digital photographs of the Earth, usually from an airplane or non-piloted drone. Images are either taken from a vertical or oblique position. Third is **radar**, which is an interesting form of remote sensing technology that uses microwave pulses to create imagery of features on Earth. This can be from a satellite image or ground-based Doppler radar for weather forecasting. Finally, a fast growing realm of remote sensing is

called **Light Detection and Ranging** or **Lidar**, which is a form of remote sensing that measures distance of objects using laser pulses of light.



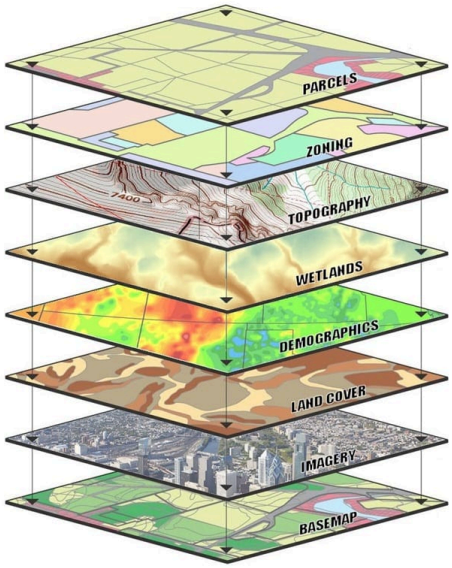
LIDAR imagery showing faulting in Big Sur.

Global Positioning Systems

Another type of geospatial technology is global positioning systems (GPS) and a key technology for acquiring accurate control points on Earth's surface. Now to determine the location of that GPS receiver on Earth's surface, a minimum of four satellites are required using a mathematical process called **triangulation**. Normally the process of triangulation requires a minimum of three transmitters, but because the energy sent from the satellite is traveling at the speed of light, minor errors in calculation could result in large location errors on the ground. Thus, a minimum of four satellites is often used to reduce this error. This process using the geometry of triangles to determine location is used not only in GPS, but a variety of other location needs like finding the epicenter of earthquakes.

A user can use a GPS receiver to determine their location on Earth through a dynamic conversation with satellites in space. Each satellite transmits orbital information called the **ephemeris** using a highly accurate atomic clock along with its orbital position called the **almanac**. The receiver will use this information to determine its distance from a single satellite using the equation D = rt, where D = distance, r = rate or the speed of light (299,792,458 meters per second), and t = time using the atomic clock. The atomic clock is required because the receiver is trying to calculate distance, using energy that is transmitted at the speed of light. Time will be fractions of a second and requires a "time clock" up the utmost accuracy.

Geographic Information Systems



A GIS is a set of layers where each layer shows different information.

A **geographic information system** (GIS) is a technology that brings together remote sensing data, GPS data points, spatial and non-spatial data, and spatial statistics into a single, dynamic system for analysis. A GIS is a powerful database system that allows users to acquire, organize, store, and most importantly analyze information about the physical and cultural environments. A GIS views the world as overlaying physical or cultural layers, each with quantifiable data that can be analyzed. A single GIS map of a national forest could have layers such as elevation, deciduous trees, evergreens, soil type, soil erosion rates, rivers and tributaries, major and minor roads, forest health, burn areas, regrowth, restoration, animal species type, trails, and more. Each of these layers would contain a database of information specific to that layer.

Nearly every discipline, career path, or academic pursuit uses geographic information systems because of the vast amount of data and information about the physical and cultural world. Disciplines and career paths that use GIS include: conservation, ecology, disaster response and mitigation, business, marketing, engineering, sociology, demography, astronomy, transportation, health, criminal justice and law enforcement, travel and tourism, news media, and the list could endlessly go on.

Now, GIS primarily works from two different spatial models: raster and vector. **Raster** based GIS models are images much like a digital picture. Each image is broken down into a series of columns and rows of pixels and each pixel is **georeferenced** to somewhere on Earth's surface is represents a specific numeric value – usually a specific color or wavelength within the **electromagnetic spectrum** . Most remote sensing images come into a GIS as a raster layer. The other type of GIS model is called a vector model. **Vector** based GIS models are based on the concept of points that are again georeferenced (i.e. given an x-, y-, and possibly z- location) to somewhere specific on the ground. From points, lines can be created by connecting a series of points and areas can be created by closing loops of vector lines. For each of these vector layers, a database of information can be attributed to it. So for example, a vector line of rivers could have a database associated with it such as length, width, stream flow, government agencies responsible for it, and anything else the GIS user wants tied to it. What these vector models represent is also a matter of **scale** . For example, a city can be represented as a point or a polygon depending on how zoomed in you are to the location. A map of the world would show cities as points, whereas a map of a single county may show the city as a polygon with roads, populations, pipes, or grid systems within it.

Now more then ever society has access to spatial information through the use of geospatial technology, which is directly influencing how we understand the physical and cultural environments we live in. In 2013 the Washington Post had two articles on how maps help us understand our world titled 40 Maps That Explain Our World and 40 More Maps That Explain Our World. The images below are satellite images from NASA and proved by NASA's Earth Observatory . Click on the thumbnails to see a large image and click on the those to get detailed information for each satellite image. All of the images in this eTextbook are free and licensed as Creative Commons . By clicking on any image, you will be directed to the original source.



Neptune Pass 2019



Neptune Pass wider in 2023

Neil deGrasse Tyson: What's Possible in 15 Years?



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SCIENTIFIC METHOD

SCIENTIFIC QUESTIONING

The most important thing a scientist can do is to ask questions. Act like a 5 year old!

- What makes Mount St. Helens more explosive and dangerous than the volcano on Mauna Loa, Hawaii?
- What makes the San Andreas fault different than the Wasatch Fault?
- Why does Earth have so many varied life forms but other planets in the solar system do not?
- What impacts could a warmer planet have on weather and climate systems?

Many of these questions compare and explain the differences between two named locations. Sometimes only one location is described and it's up to the reader to consider how the described characteristics differ compared to any other location of interest. For example a geographer could compare Seattle and Salt Lake City, or simply describe Seattle and let the reader compare Seattle with Salt Lake City, or Denver, or Spokane, or any city.

Earth science can answer testable questions about the natural world. What makes a question impossible to test? Some untestable questions are whether ghosts exist or whether there is life after death. A testable question might be about how to reduce soil erosion on a farm. A farmer has heard of a planting method called “no-till farming.” Using this process eliminates the need for plowing the land. The farmer’s question is: Will no-till farming reduce the erosion of the farmland?



Standard moldboard plow completely lifts and turns over the soil, burying plant material.



Contour Plowing: Plow and plant across the slope, along constant elevation, to stop water and soil movement.



No-till: Young g
previous stubbl

SCIENTIFIC RESEARCH

To answer a question, a scientist first finds out what is already known about the topic by reading books and magazines, searching the Internet, and talking to experts. This information will allow the scientist to create a good experimental design. If this question has already been answered, the research may be enough or it may lead to new questions. Example: The farmer researches no-till farming on the Internet, at the library, at the local farming supply store, and elsewhere. He learns about various farming methods. He learns what type of fertilizer is best to use and what the best crop spacing would be. From his research he learns that no-till farming can be a way to reduce carbon dioxide emissions into the atmosphere, which helps in the fight against global warming.

HYPOTHESIS

With the information collected from background research, the scientist creates a plausible explanation for the question. This is a hypothesis. The hypothesis must directly relate to the question and must be testable. Having a hypothesis guides a scientist in designing experiments and interpreting data. Example: The farmer’s hypothesis is this: No-till farming will decrease soil erosion on hills of similar steepness as compared to the traditional farming technique because there will be fewer disturbances to the soil.

DATA COLLECTION

To support or refute a hypothesis, the scientist must collect data. A great deal of logic and effort goes into designing tests to collect data so the data can answer scientific questions. Data is usually collected by experiment or observation. Sometimes improvements in technology will allow new tests to better address a hypothesis.

Observation is used to collect data when it is not possible for practical or ethical reasons to perform experiments. Written descriptions are qualitative data based on observations. This data may also be used to answer questions. Scientists use many different types of instruments to make quantitative measurements. Electron microscopes can be used to explore tiny objects or telescopes to learn about the universe. Probes make observations where it is too dangerous or too impractical for scientists to go. Data from the probes travels through cables or through space to a computer where it is manipulated by scientists.

Experiments may involve chemicals and test tubes, or they may require advanced technologies like a high-powered electron microscope or radio telescope. Atmospheric scientists may collect data by analyzing the gases present in gas samples, and geochemists may perform chemical analyses on rock samples.

A good experiment must have one factor that can be manipulated or changed. This is the independent variable. The rest of the factors must remain the same. They are the experimental controls. The outcome of the experiment, or what changes as a result of the experiment, is the dependent variable. The dependent variable "depends" on the independent variable.

Example: The farmer conducts an experiment on two separate hills. The hills have similar steepness and receive similar amounts of sunshine. On one, the farmer uses a traditional farming technique that includes plowing. On the other, he uses a no-till technique, spacing plants farther apart and using specialized equipment for planting. The plants on both hillsides receive identical amounts of water and fertilizer. The farmer measures plant growth on both hillsides. In this experiment:

- What is the independent variable?
- What are the experimental controls?
- What is the dependent variable?

The independent variable is the farming technique—either traditional or no-till—because that is what is being manipulated. For a fair comparison of the two farming techniques, the two hills must have the same slope and the same amount of fertilizer and water. These are the experimental controls. The amount of erosion is the dependent variable. It is what the farmer is measuring. During an experiment, scientists make many measurements. Data in the form of numbers is quantitative.

Data gathered from advanced equipment usually goes directly into a computer, or the scientist may put the data into a spreadsheet. The data then can be manipulated. Charts and tables display data and should be clearly labeled. Statistical analysis makes more effective use of data by allowing scientists to show relationships between different categories of data. Statistics can make sense of the variability in a data set. Graphs help scientists to visually understand the relationships between data. Pictures are created so that other people who are interested can see the relationships easily.

In just about every human endeavor, errors are unavoidable. In a scientific experiment, this is called experimental error. What are the sources of experimental errors? Systematic errors may be inherent in the experimental setup so that the numbers are always skewed in one direction. For example, a scale may always measure one-half ounce high. The error will disappear if the scale is re-calibrated. Random errors occur because a measurement is not made precisely. For example, a stopwatch may be stopped too soon or too late. To correct for this type of error, many measurements are taken and then averaged. If a result is inconsistent with the results from other samples and many tests have been done, it is likely that a mistake was made in that experiment and the inconsistent data point can be thrown out.

CONCLUSIONS

Scientists study graphs, tables, diagrams, images, descriptions, and all other available data to draw a conclusion from their experiments. Is there an answer to the question based on the results of the experiment? Was the hypothesis supported? Some experiments completely support a hypothesis and some do not. If a hypothesis is shown to be wrong, the experiment was not a failure. All experimental results contribute to knowledge. Experiments that do or do not support a hypothesis may lead to even more questions and more experiments.

Example: After a year, the farmer finds that erosion on the traditionally farmed hill is 2.2 times greater than erosion on the no-till hill. The plants on the no-till plots are taller and the soil moisture is higher. The farmer decides to convert to no-till farming for

future crops. The farmer continues researching to see what other factors may help reduce erosion.

THEORY

As scientists conduct experiments and make observations to test a hypothesis, over time they collect a lot of data. If a hypothesis explains all the data and none of the data contradicts the hypothesis, the hypothesis becomes a theory. A scientific theory is supported by many observations and has no major inconsistencies. A theory must be constantly tested and revised. Once a theory has been developed, it can be used to predict behavior. A theory provides a model of reality that is simpler than the phenomenon itself. Even a theory can be overthrown if conflicting data is discovered. However, a longstanding theory that has lots of evidence to back it up is less likely to be overthrown than a newer theory.

For an interactive animation of how Darwin used finches to explain the origin of species using the Galapagos islands finches, click here. Science does not prove anything beyond a shadow of a doubt. Scientists seek evidence that supports or refutes an idea. If there is no significant evidence to refute an idea and a lot of evidence to support it, the idea is accepted. The more lines of evidence that support an idea, the more likely it will stand the test of time. The value of a theory is when scientists can use it to offer reliable explanations and make accurate predictions.

Summary

Humans have long tried to interpret the earth in order to improve their chances of survival and ease of life. Different academic disciplines such as biology, history, geography, sociology all attempt to organize human understanding, but from different aspects. History organizes based on time, biology is based on groups of similar living organisms, sociology is based on groups of people. Geography organizes data by location. There is a scientific approach to understanding and explaining locations. The technology of organizing our understanding of locations has become much more sophisticated during the last few decades as remote sensing and geographic information systems have become more popular. Geography is not simply countries and capitals, it is a study of the spatial diversity of all characteristics of the earth including physical components such as volcanoes and hurricanes and the cultural components such as population density and economic development.

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1.2: Systems of Location

Learning Objectives

- Explain several systems of locating points on Earth

INTRODUCTION

Recall that the three key concepts of geography are distance, direction, and location. Geographers have developed several approaches to most effectively communicate those concepts. All three concepts are embedded within each system. You might think that the purpose of each system is to simply indicated location, in fact each system has direction and distance within it.

You are probably aware of the latitude and longitude system. An advantage of using latitude-longitude is that the concept can be applied to other spheres such as other planets. The concept of direction is easy to see in the latitude-longitude system because you must include cardinal directions when you write the location down. You write N (north) or S (south) for latitude and E (east) or W (west) with the longitude data. Distance, while part of the system, is more difficult for most map users to interpret with the latitude-longitude system because the distance is in degrees, minutes, and seconds which is conceptually difficult to convert into feet, miles, and kilometers.

In this section we will begin with the internationally understood system of latitude-longitude, often called the Geographic Grid then move on to other major systems including the Universal Transverse Mercator (UTM), the United States Public Lands Survey System (USPLSS), and the French Long Lot system. There are other systems used by different organizations, regions, and agencies, but these have the greatest importance in the US. Some of these systems are better and easier to use depending on what data you need.

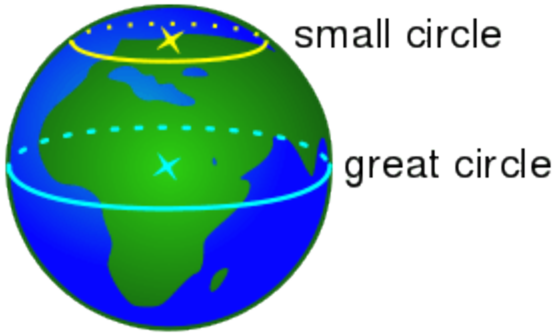
THE GEOGRAPHIC GRID

Geography is about spatial understanding, which requires an accurate grid system to determine absolute and relative location. **Absolute location** is the exact x- and y- coordinate on the Earth. **Relative location** is the location of something relative to other entities. For example, when you use your GPS in your smart phone or car, say Google Maps, you put in an absolute location. But as you start driving, the device tells you to turn right or left relative to objects on the ground: “Turn left on exit 202” is relative to the other exit points. Or if you give directions to your house, you often use relative locations to help them understand how to get to your house.

Great and Small Circles

Much of Earth’s grid system is based on the location of the North Pole, South Pole, and Equator. The poles are an imaginary line running from the axis of Earth’s rotation. The **plane of the equator** is an imaginary horizontal line that cuts the earth into two equal halves.

This brings up the topic of great and small circles. A **great circle** is any circle that divides the earth into a circumference of two equal halves. It’s also the largest circle that can be drawn on a sphere. There are an infinite number of great circles, but only one that connects two specific points. The line connecting any points along a great circle is also the shortest distance between those two points. Examples of great circles include the Equator, all lines of longitude, the line that divides the earth into day and night called the **circle of illumination or umbral line** , and the **plane of ecliptic**. The plane of the ecliptic is where the sun’s rays hit the surface of the earth at a 90° angle, or straight overhead. It shifts constantly but stays within the tropics and always intersects the equator. A plane flying from Seattle, WA to Paris, France will fly a great circle far to the north over Greenland even though both cities are nearly the same latitude. **Small circles** are circles that cut the earth, but not into equal halves. Examples of small circles include all lines of latitude except the equator.



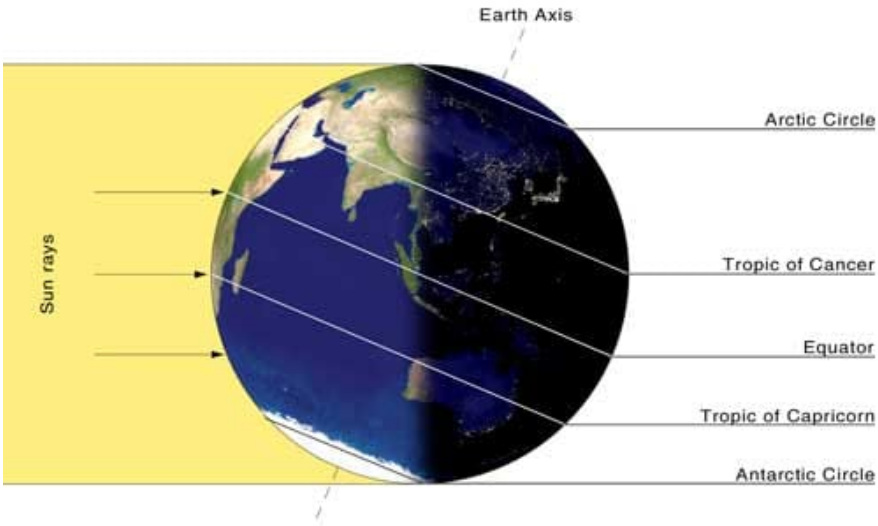
Great Circles Cut a Sphere Exactly in Half.

LATITUDE AND LONGITUDE

Latitude is an angular measurement north or south of the equator. So 30° north means a point that is 30° north of the equator. Latitude is also expressed in degrees, minutes, and seconds; 360° in a circle, 60 minutes (‘) in a degree, and 60 seconds (”) in a minute. When you use Google Earth, the coordinate locations are in this degrees/minutes/seconds format, although there is an option for showing only decimal degrees (33.5842°N instead of 33°35’3.12”N). Latitude varies from 0° (equator) to 90° north and south (the poles).

A line connecting all points of the same latitude is called a **parallel**, because the lines run parallel to each other. Lines of latitude that are 1° apart are always 111km apart. The only parallel that is also a great circle is the equator. All other parallels are small circles. The following are the most important parallel lines:

- Equator, 0° (since it’s the dividing line, there is no north or south)



Major Lines of Latitude. The Circle of Illumination or Umbral Line divide the sunlit half and the dark half. It is perpendicular to the Sun’s rays.

Tropic of Cancer, 23.5°N

- Tropic of Capricorn, 23.5°S
- Arctic Circle, 66.5°N
- Antarctic Circle, 66.5°S
- North Pole, 90°N (infinitely small circle)
- South Pole, 90°S (infinitely small circle)

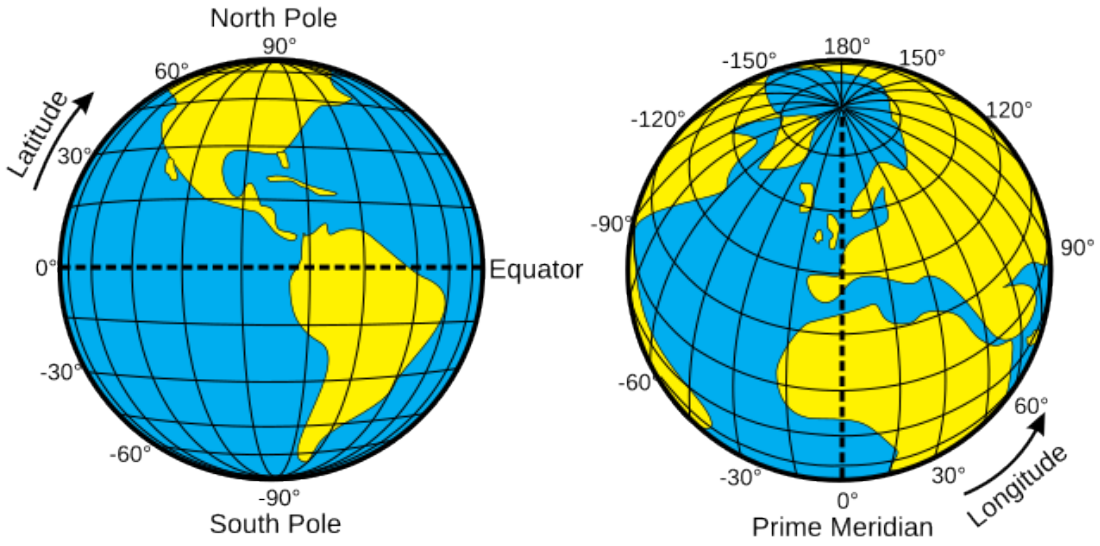
Latitude is also sometimes described as **zones of latitude**. Some of these zones of latitude include:

- Low latitude – generally between the equator and 30°N
- Mid-latitude – between 30° and 60°N and S
- High latitude – latitudes greater than about 60° N and S
- Equatorial – within a few degrees of the equator
- Tropical – within the tropics (between 23.5°N and 23.5°S
- Subtropical – slightly pole-ward of the tropics, generally around 25-30° N and S
- Polar – within a few degrees of the North or South Pole



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Longitude is the angular measurement east and west of the Prime Meridian (image on the right). Like latitude, longitude is measured in degrees, minutes, and seconds or in decimal degrees. Lines connecting equal points of longitude are called **meridians**. But unlike parallels, meridians do not run parallel to each other. Rather they are farthest apart from each other at the equator and merge toward each other toward the poles. At the equator, 1° change in longitude is 111 km in distance, but this decrease to 0 km at the poles. The problem with longitude is that there isn't a natural baseline like the equator is for latitude. For over a hundred years, nations used their own "prime meridian" which proved problematic for trade. But in 1883 an international conference in Washington D.C. was held to determine a global prime meridian. After weeks of debate, the Royal Observatory at Greenwich, England was determined as the **Greenwich Meridian** or also called the **prime meridian** for the world. So today, longitude starts at the Prime Meridian and measures east and west of that line.



Lines of Latitude are Parallels. Lines of Longitude are Meridians.

The proper notation of a point using latitude-longitude is always latitude first, longitude second and the direction (N/S and E/W) is required: 46°N 94.6°W

The range of longitude is from 0° to 180°. The meridian 180° east or west of the Prime Meridian is in the Pacific Ocean. This is a straight line that, along with the Prime Meridian, divides longitude into into either west or east. Most of the line, but not its entire length, is the **International Date Line**. The date line determines where the new day begins in the world. Now because of this, the International Date Line is not actually a straight line, rather it follows national borders so that a country isn't divided into two separate days (and we think hour time zones are a pain). On the map below, the International Date Line is to the right in a dark, black line. Note how it is drawn to make sure nations are not divided by the International Date Line.

Time Zones



Time Zones of the World are based on Lines of Longitude.



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This is also a good time to take a look at **time zones** around the world. On the map above, see the different time zones are in various colors. Since the earth rotates 360° in a 24 hour period, the earth rotates 15° every hour. In an ideal world, each time zone would follow lines of longitude every 15° (7.5° in each direction from the center of the time zone). Time zones are a human creation, with the purpose of making our lives easier by agreeing on a standard time within a specific region. Daily living is easier within a single time zone so the borders of times zones try to group together regions where people generally conduct their daily activities together. It would be terribly difficult if the time zone borders were strictly enforced and led to a city being cut in half with two different time zones.

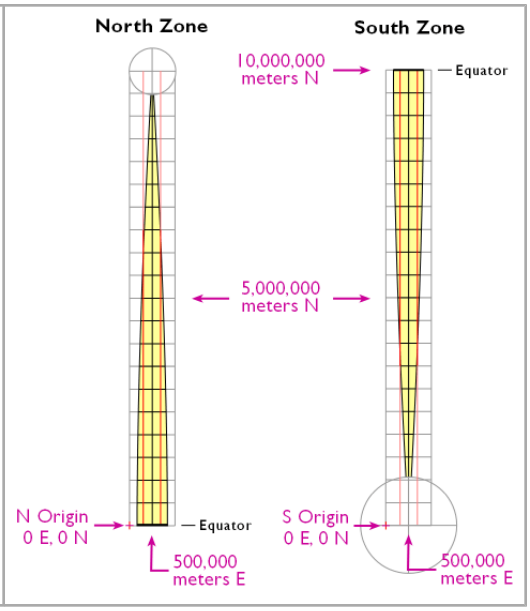
Greenwich, England was chosen in the mid-nineteenth century as the starting point of time worldwide. The reason was because at the time, England was the superpower both militarily and economically. So the meridian that ran through Greenwich became zero degrees or the **prime meridian**. Because of the earth's rotation in reference to the prime meridian, locations east of the new meridian meant time was ahead while locations west of the meridian were behind in time in reference to Greenwich, England.

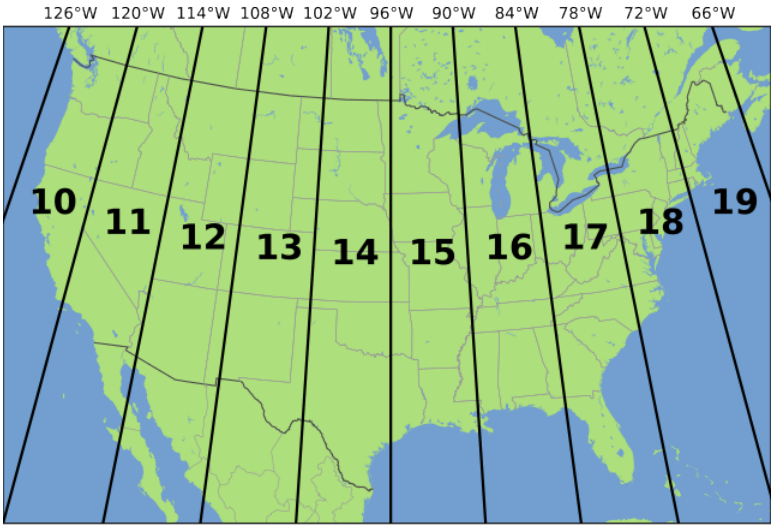
People have known how to calculate latitude for thousands of years by finding either the angle between the horizon and the North Star or between the horizon and the sun when the sun is at it's highest point in the sky (**solar noon**). Longitude was more difficult to determine, but once a reliable clock was developed, it became possible. Ultimately, when you combine parallel and meridian lines, you end up with a **geographic grid system** that allows you to determine your exact location on the planet. The method for finding your exact location is to determine the angle between the horizon and the sun at solar noon, then check the time on a clock that is set to the time in Greenwich. If the clock says it is not yet noon in Greenwich, but it is already solar noon at your location, then you are east of Greenwich.

UTM (Universal Transverse Mercator)

The UTM system was developed to be faster than the latitude-longitude system. It uses units of meters instead of degrees. This makes determining distances much easier because most of the world knows the length of one meter. The UTM system divides the world into 60 zones, each 6° of longitude in width and extends from 84°N to 80°S. Each zone is cut in half at the equator so zone 15 will have a north half and a south half. As each zone nears the poles, the zone becomes extremely narrow and multiple zones would be needed to get the job done. Moving from zone to zone is more difficult than staying within one zone, so the system resets near each pole. Few people spend time in these areas, so the emphasis of the rest of this section will be the main regions.

Each UTM zone in the northern hemisphere starts its northing value at the equator and stops at 84°N. UTM zones in the southern hemisphere start 10,000,000 m south of the equator and increase as you get closer to the equator. The first 10° of latitude (from the south pole to 80°S) is not include in standard UTM zones.





UTM Zone Numbers Increase from West to East.

UTM coordinates are written like standard Cartesian coordinates (X, Y). In UTM, the X element is called “Easting” and the Y element is “Northing”. The Easting and Northing distances start at a false origin located on the equator and 500,000 m west of the center of the zone for northern zones. For the southern zones the false origin is 10,000,000 m south of the equator or roughly the south pole. By using a different origin for the north and south halves, the coordinates always have positive values which makes the math much easier. The proper notation for a point on the center line of a zone and 1 km north of the equator in zone 15 is: 500,000 m E 1000 m N zone 15 north. Zone 1 starts at the 180° meridian and zone numbers increase in value to the east.

With very little effort, the UTM system becomes much easier to use than the latitude-longitude system.

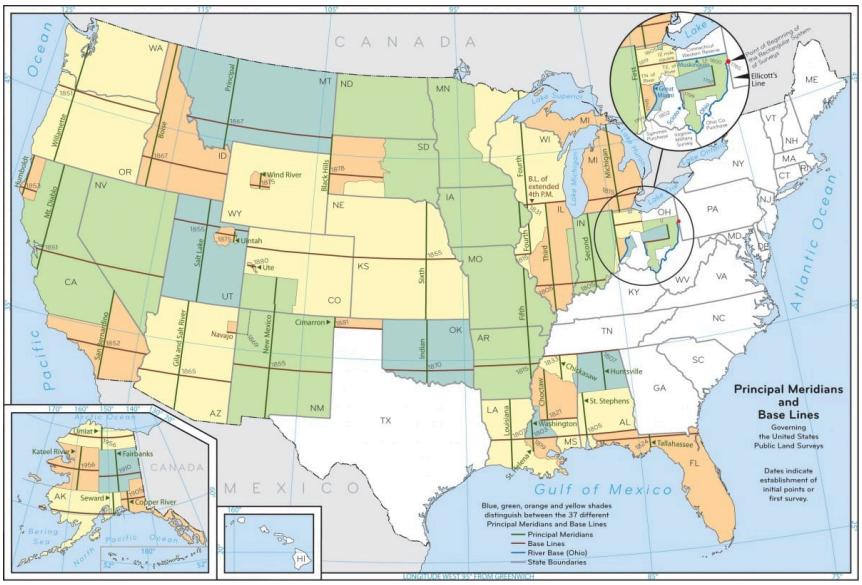


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USPLSS (United States Public Lands Survey System)

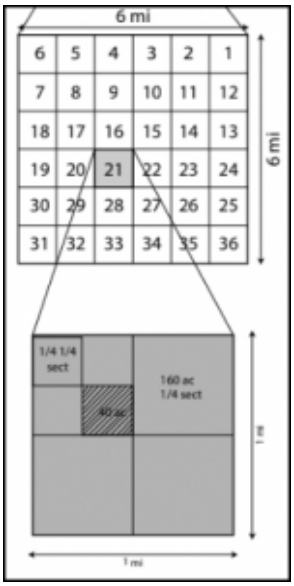
The USPLS system was developed in 1785 to systematize the distribution of lands in the Northwest Territory and was then extended to new lands as they were acquired by the US government. It gives an idea of the importance of land ownership that this system was developed several years before the US Constitution was written. The original 13 colonies already had private lands before the USPLS system was developed so those areas do not use the USPLS. Those lands used a much older system called Metes and Bounds. In the Metes and Bounds systems, boundaries were simply agreed upon by owners or they used landmarks to set boundaries. Often those landmarks were trees or rivers. Imagine the chaos after a fire or flood! The USPLS system reduces this chaos.

The USPLS system divides public lands owned by the federal government into squares and rectangles so the land can be more easily distributed to private citizens. Remember that historically many immigrants came to the US looking to own land which they could not do in their countries of origin. Surveyors set up Baselines running east-west and Meridians running north-south and then measured grids from those starting lines. A single pair of one Baseline and one Meridian might by be used for an area covering many states (from Arkansas to Minnesota) or a small part of one state (northeast Utah).



Baselines and Meridians of the PLSS

A common name for the USPLS System is “Township and Range” because the largest land divisions within the the system are called Townships or Ranges.



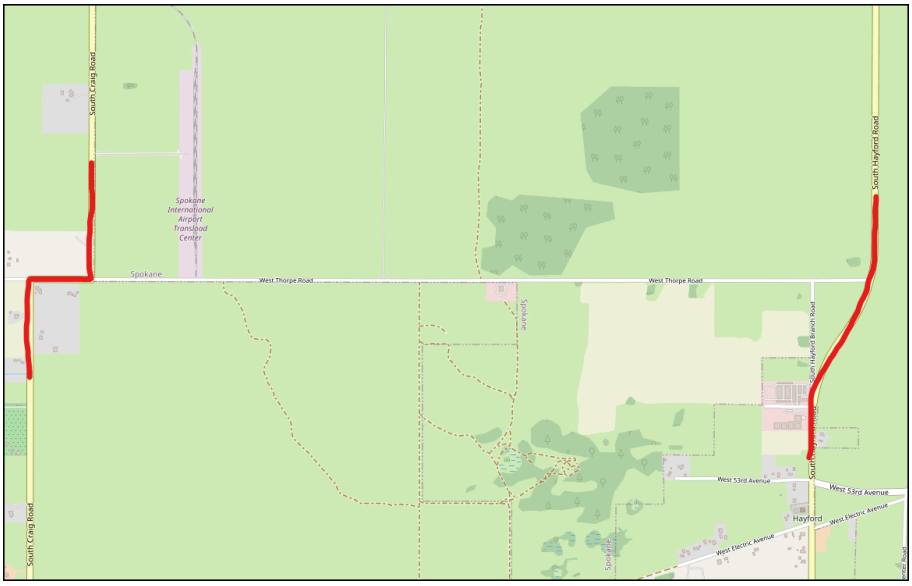
A Township (upper) and a Section (lower).

Townships are counted north or south of a Baseline and Ranges are counted east or west of a Meridian. A Township is a unit of land 6 miles by 6 miles (36 mi^2) but its legal description requires both a Township number and a Range number. Each township has 36 *sections* that are 1 mile by 1 mile (1 mi^2) which are 640 acres. Sections are always numbered as shown in the diagram.

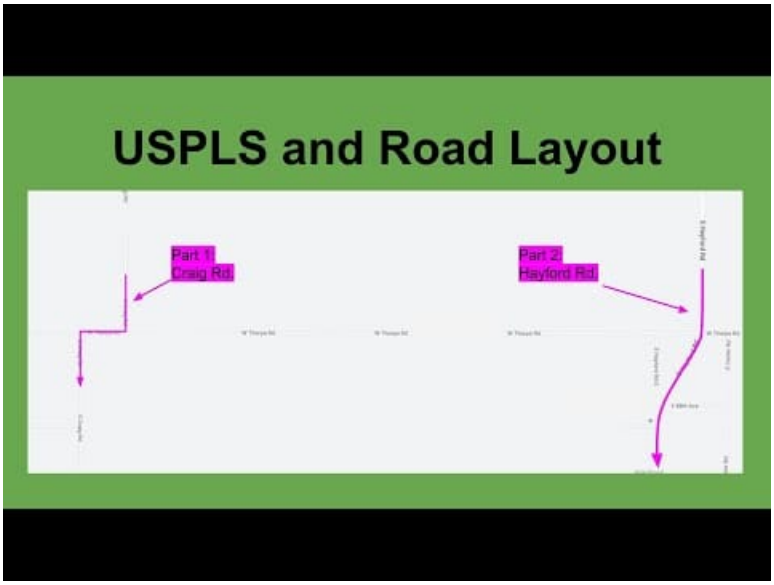
This system is still evident in American lives nearly every day. A quarter of a section is 160 acres which was the area of land distributed by the federal government in the first Homestead Act. Rural property might be sold in 5, 20, 40 acre units because sections are easily divided into those sizes. The legal description of the cross-hatched area in the figure might be: SE1/4 of NW1/3 of Sect 21 T.21N R 44E Washington. Note how the description starts at the smallest area and ends in the largest area.

Today as you drive along a paved country road it probably follows the line between two sections or townships. After driving a few miles the road bends then continues straight, or it may stop, forcing you to turn and drive a few hundred feet and then turn again before you can continue in the original direction. The bend or the stop-and-turn is because you changed townships and the original surveyors reset the starting point of the new township to reduce error. Hayford Rd., a busy road south of Airway Heights,

WA bends as it crosses into a new township at Thorpe Rd. Craig Road is less traveled and has two right-angle turns.



Craig Rd. and Hayford Rd. realign as they change townships. Thorp Rd. is the dividing line between townships. (Open Street Map)



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If you fly over Kansas and see irrigated fields, each irrigated circle occupies a quarter of a section. City and county planners also use the system. In large cities the major roads are often on section lines or half way in between.

French Long Lot

All of these systems of location are designed to help humans understand resources that humans use. Sometimes the scale of the resource is the entire Earth and the latitude-longitude system is very good. Sometime the resources is land, so the USPLS system was developed. In some areas settled by the French they realized that land is important for production, but water is critical for getting the harvest to market. In these areas, parcels of land are often long and skinny and nearly all the parcels meet a river. This is again a carry over from France where a person could only use river water if they owned land adjacent to the river. To give the greatest access to the river, the parcels became skinny but extended far from the river.

Points or Areas?

Finally, notice how both the latitude-longitude system and the UTM system both bring you to a point. The USPLS and French Long Lot systems each locate an area, not a point.

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1.3: Maps and Models

GRAPHICACY

Literacy refers to the ability to read, write, and use words. Geographers often find it more efficient to convey concepts by using maps and diagrams. ***Graphicacy*** refers to the ability to effectively use, interpret, and make maps and diagrams. The sciences regularly use diagrams. A graphically literate person should recognize the shortfalls and advantages of different types of diagrams. A graphically literate person can "read" images.

Maps are a specific type of image. Maps show how data and characteristics change across space. All geographic data has a spatial component. It must have some type of location information associated with the data. A column graph showing two or more cities and their corresponding burglary rates is a valid graphical depiction of geographic data. The geographic location data is each of the cities. However, as you plot more and more cities on the column graph, it becomes more difficult to read. Good graphics should make it easier for the user to get the desired information. Plotting several dozen, or several thousand, cities on a single column graph would become incomprehensible. A map is much easier to read.

MODELS

Maps are models of reality. As models, they simplify and generalize the actual situation. Map makers, called cartographers, must decide on the intended purpose of the map in order to determine what data is necessary to achieve the intended purpose. Data that is unnecessary or distracting should be removed. For instance a highway map of an entire state will not show individual trees because the trees are not necessary for determining the routes along roadways.

SCALE (Distance)

Scale is the degree of generalization of a map. There are three ways of indicating map scale: verbal scale, representative fraction, and graphical scale. The ***verbal scale*** is an old form, rarely used since about WWII. It is simply writing the scale in words: "One inch is approximately six miles".

The ***representative fraction (RF)*** scale is mathematically consistent across the map. To use the RF scale, you must have a ruler. The RF scale is written as a ratio (1:24,000) where there first number is always '1' and is the distance measured with a ruler on the map. Multiply that number by the second number (in the example it's 24,000) to find the true ground distance. Remember to consider significant figures when using the RF scale. The result is the actual ground distance between the two points, with the same units as you used with the ruler. Notice the RF scale has no units in it, so whichever units you use when measuring on the map (mm or cm or inches) is the same units on the ground.

An example: What is the ground distance between two intersection shown on a map? Map distance between intersections (use ruler): 4 inches. The map has an RF scale of 1:24,000.

(map distance) x (RF scale) = (ground distance)

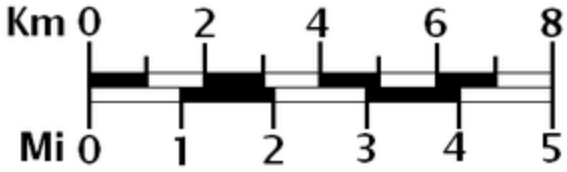
4 inches × 24,000 = 96,000 inches between the two intersections on the ground.

That's a lot of inches, so it may be useful to change to different units of length.

96,000 in x (1 ft/ 12in) = 8,000 ft

8,000 ft x (1 mi/ 5280 ft) = 1.5 mi

The third scale is a ***graphical scale***. This is especially common in the era of photo copiers. If a paper map is photographically enlarged or reduced, but the graphical scale is included in the same process, then the graphical scale is still accurate whereas the verbal and RF scales are no longer accurate after enlarging or reducing.



A Graphical Scale (Wikimedia)

To use a graphical scale, a ruler may be used, but it's not necessary. Any piece of paper will work. Place the edge of the paper along a line between the two points of interest and mark their locations on the edge of the paper. Now bring the paper to the graphical scale and note where the two points align on the scale.

Different maps have different scales. Maps are either large scale or small scale. There is no predefined limit where small scale shifts to large scale. It is a relative term. One map is smaller scale compared to (in relation to) a second map. Larger scale maps show less area in more detail than smaller scale maps. This is easier to explain using the RF scale. A map of RF scale 1:2 shows more detail than a map with scale 1:4. The first map is a larger scale than the second map. Mathematically, 1/2 is greater than 1/4. When we talk about large- and small-scale maps and geographic data, then, we are talking about the relative sizes and levels of detail of the features represented in the data. In general, the larger the map scale, the more detail is shown. Photographs and images do not have consistent scale throughout the entire displayed area. This can be corrected mathematically so that a single scale is correct. The correction, called **orthorectification**, alters the image so it appears as if the map user is directly overhead of all points on the map rather than overhead of one point and viewing other points from a slight angle. USGS topographic maps are developed from images that have been orthorectified.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pb.libretexts.org/sfccintrogeography/?p=54

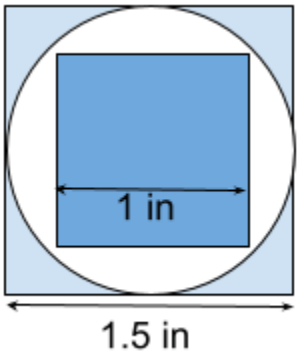
AREA

The area on the map relates to area on the ground based on the map scale. The USGS makes several series of maps using standard scales and there are inexpensive tools that you can buy to quickly estimate area on those standard map scales.

As with so many of life's problems, you probably won't know the answer before you start. But often you can find a region of possibilities. From basic geometry you know there are formulas for finding the area of regular shapes such as squares, circles, and polygons. Even if you've forgotten what the formulas are, you know they exist. The difficulty with natural shapes on maps is they are regular polygons and those formulas won't work.

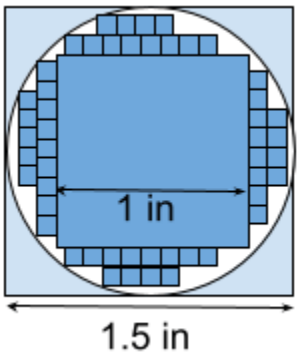
There are many methods for estimating the area of irregular shapes, but most of them work on the idea of finding the area of a simple shape such as a square or rectangle and fitting those in the irregular shape.

Find the maximum possible and an approximate minimum area for the shape.



The maximum area. Create a regular polygon (square, rectangle, maybe a circle) that is larger than the irregular shape. In the figure to the right, we are estimating the area of the circle. We can see that area of the circle is smaller than the area of the large square because the circle is entirely within the large square. A maximum area of the circle is 1.5 in x 1.5 in = 2.25 in^2. Note: the large square doesn't have to touch the circle, but getting it closer will narrow your error range.

Now find a minimum. First you know the shape exists in space because it's shown on the map. The area will certainly greater than zero. But you can do better. Put another, smaller, regular shape entirely within the irregular shape. Here the dark blue square is entirely within the circle. You know the area of the circle is greater than 1 in x 1 in = 1 in^2. NOTE: I wouldn't spend too much time on the minimum. I'd probably find the maximum then move on the the next step of using small squares.



To get a better estimate of the area of the irregular shape, use smaller squares! In this example the small squares are 0.1 in x 0.1 in. = 0.01 in^2. As drawn, even with the smaller squares, we know we will under estimate the area of the circle because all of the squares fit inside the circle and there's still white space visible and none of the light blue is covered. There might be a situation where it's important to know that you've under estimated the area. In another situation you may want to be sure you've over estimated (you don't want to run out of sod for the lawn) so you would make sure there's no white area visible by adding more small squares.

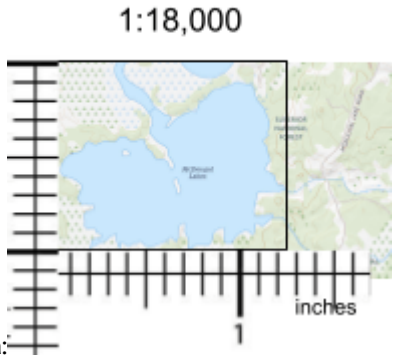
If you want a good estimate, but aren't concerned if you're either over- or underestimating, then draw small squares along the edge of the circle so some squares are more within the circle and others are more outside the circle and estimate when you have an entire square's worth. Three squares that are each only 1/3 within the circle will add up to 1 full square.

How small is too small? Once again it depends on the map scale, what your needs are, and the precision of other measuring tools. If you're drawing squares by hand even the thickness of the pencil might be a large portion of the area of the small circles. That's bad.

Here's an actual lake estimate:

Maximum area. McDougal lake is entirely within the square that measures 1 in x 1.25 in on the map. The scale is 1:18,000 or 1in =

0.2mi.



Convert from map length and area to ground area:

One side of the rectangle is: 1 in = 0.2 mi on the ground

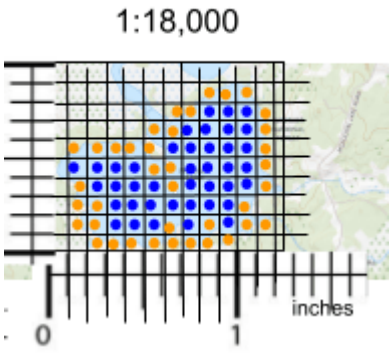
The side of the rectangle is: 1.25 in x 0.2 mi/in = 0.25 mi on the ground

Ground area covered by the rectangle is 0.2 mi x 0.25 mi = 0.05 mi^2

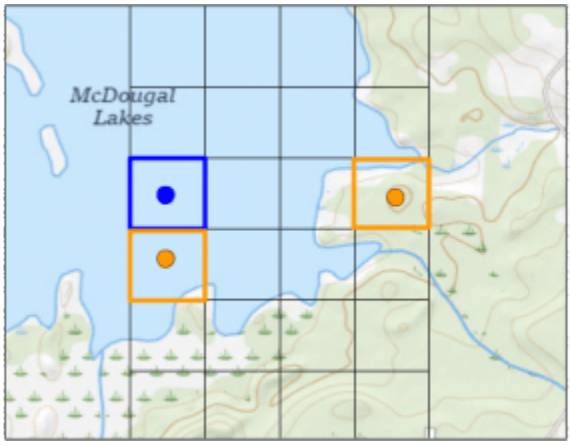
Ground area: 0.05mi^2 x 640ac/mi^2 = 32 acres (in the USA acres is a common unit of measuring surface area).

We now know the area of the lake is less than 32 acres.

In the image below, each small square is 0.1 in x 0.1 in so 0.02 mi x 0.02mi = 0.0004 mi^2 x 640ac/mi^2 = 0.256 ac (about 1/4 acre per square).



Each square with a blue dot is entirely water. There are 40 of them: 40 squares x 0.256ac /square = about 10 acres.



Each square with an orange dot has some water and some land. I estimate they are equivalent to about 31 fully water squares: 31 sq x 0.256 ac/sq = 7.9 acres.

In the image to the right the blue square and blue dot is 100% water. One of the orange squares is nearly all water while the other orange square is nearly all land. Estimate one as 90% water and the other as 10% water and you have one square at 100% water.

Total lake area estimate: 7.9 acres + 10 acres = 17.9 acres.

A second method (or check your work):

In the image with the small squares and dots, there are 10 rows of squares and 12.5 columns (the far right column is half-width), for 10 x 12.5 =125 squares.

We counted a total of 40 + 31 = 71 squares of water. 71 water squares/125 total squares x 32 acres = 18.2 acres of water. It's not exactly the same due to some rounding, but both estimates are valid.

Based on my personal knowledge of lakes in the mapped region, this seems like a plausible approximation.

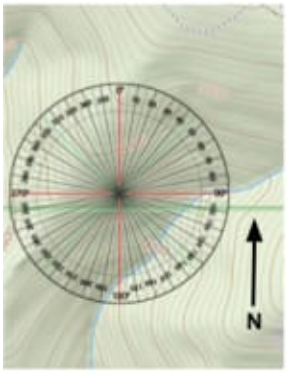
DIRECTION

Direction is one of the three key concepts in geography. When I would fill in as a bus dispatcher, drivers would occasionally call or radio to ask for directions. After a few calls, I got to know which drivers preferred to use street and building names and which drivers preferred to use compass directions and distances. Both methods work. Both drivers picked up and delivered passengers just fine.

Relative directions use local landmarks that presumably will be known or obvious to the person receiving the instructions. An example might be "Turn left at the tallest building in town. No other building comes close to its height." That example includes an obvious landmark, (the tallest building), and a relative direction (left). 'Left' is a relative direction because a person arriving at the building from the opposite direction would turn right instead of left.

Absolute directions use compass directions such as north, south, east, west. Technically, even those directions are relative to the earth's magnetic poles and and axis of rotation, but we won't quibble with that. From the previous example, the word 'left' could be changed to 'north'. With that change, everyone knows to turn north at the building and you don't need a second set of instructions for people arriving at the building from different directions. But you do need to know which way is north!

With the proper tools, and if your needs demand it, you can provide compass directions to fractions of a degree of arc just like degrees of latitude and longitude are divided into minutes and seconds or into decimal fractions of a degree. However, your tools such as the map scale and manufacturing tolerances of the compass or surveying instruments must be up to the task of such precision.



Align the 0°-180° line on the protractor to be parallel to north-south on the map.

If you're finding directions on a map, you don't truly need a compass. A protractor will work for an estimate within a few degrees when using a 1:24,000 scale map. Set your protractor on the map with the 0° marker aligned with the north direction of the map. On the map, draw a line connecting the two points you're interested in. Put the center of the protractor on one point, or anywhere along that line, but maintain the orientation of the protractor so 0° is still parallel to north. Read where the line intersects the numbers, the degrees, on the protractor. The line could intersect the protractor at two locations. Think which direction you're determining. You may want to start goin 135° (southeast) but if you reverse your direction, you be going 315° (northwest).

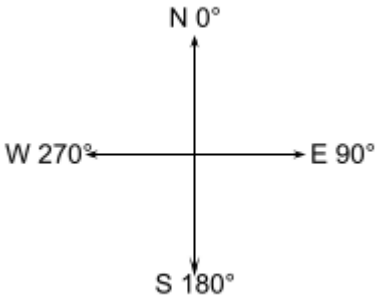
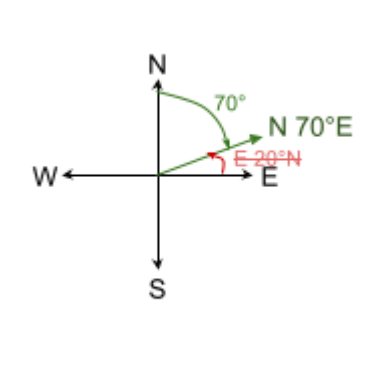


Compass aligned to follow a path of 135°.

Once you're outdoors, you'll need a compass. Find north so the red arrow on the compass overlaps the printed arrow on the rotating housing of the floating arrow. That housing has degree marks written on it. With one hand hold the housing to keep the arrows aligned. With the other hand rotate the base of the compass (usually transparent) until the direction arrow on the base aligns with the degree direction you want to follow. Walk the direction of the large arrow on the base while keeping the magnetic arrow hovering over the arrow in the housing.

Compass Directions: Azimuth or Bearing

There two methods to write a compass bearing, Azimuth or Bearing

• A compass AZIMUTH is where due north is always 0° and values increase clockwise. Due east is 90°, due south is 180°, due west is 270°. The maximum possible value for AZIMUTH is 360°, which is also due north, but is usually labeled as 0°. • It's understood that due north is always the starting point and values always increase clockwise, therefore there's no need for including a direction (north south east west) in the azimuth. • The yellow compass above has an azimuth of 135°	
• In a compass BEARING, N or S is given first, then a degree to an adjacent cardinal direction (E or W) is given second. • Example: A direction of 70° has a BEARING of N70°E. The dominant cardinal direction is N but you go east, specifically 70°. • Bearing: N70°E is correct. E 20°N is wrong. As azimuth that bearing is written: 70°	

SYMBOLS

Maps contain *symbols* to represent different portions of reality. Common types of symbols are point, line, and area symbols.

All three classes of symbols have variations that are better able to indicate changes in either quantity or quality of the represented characteristic. Quantity is often shown by changing the size of the symbol. If a circle represents a town, a larger circle indicates a larger population. To show different types of features (changes in quality), the shape of the symbol is changed. A circle can be a town, a small airplane represents an airport, and an anchor could be a harbor. Color intensity (shading) is often used for quantitative change, but changes in color hue (red or green) generally indicate a change quality.



Map Symbols change to depict Quantity or Quality of Characteristics.

As the scale and generalization of maps change, some symbolic representations of reality might change. For instance a small scale map of Iowa that is printed in a notebook would probably use a point symbol to indicate the location of cities. But a map of Des Moines, IA on the same size piece of paper would use an area symbol for the entire city.

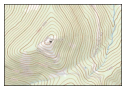
MAP TYPES

Scales and symbols are used in all types of maps. Maps are broadly categorized as either reference maps or as thematic maps. Reference map display a broad range of characteristics and try to give equal value to all of them. Topographic maps are a type of reference map that depict the lay of the land, including elevation and water bodies. Thematic maps often ignore the topography and landforms to better show other characteristics.

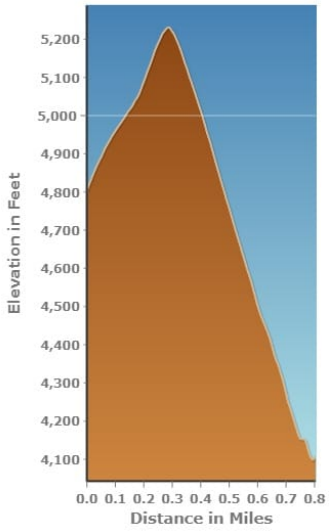
POINTS OF VIEW

Most maps are probably drawn in map view. (Stunning statement!) This is the overhead, from above, view. It's a good choice for showing how a characteristic changes or moves horizontally. US State highway maps are drawn in map view.

A profile view shows the vertical change of a characteristic. When you stand on the ground and look at buildings from the base to the roof, you're looking at their profile.



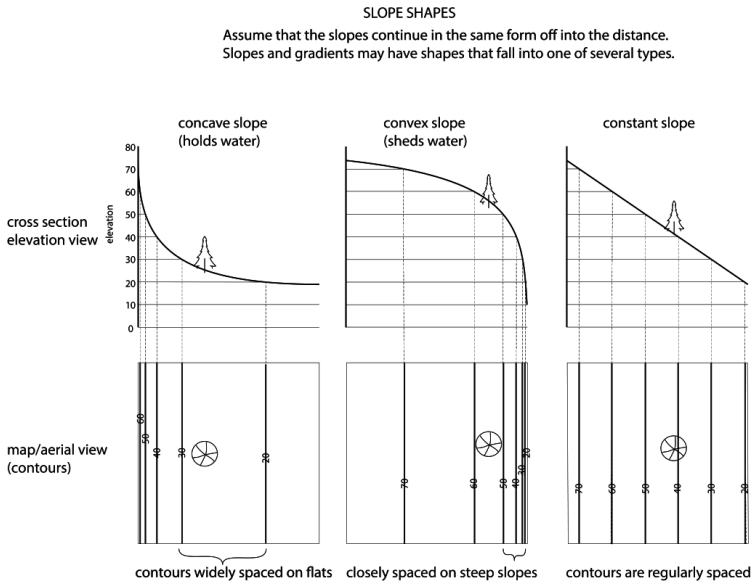
Topographic Map (Map View) with contour lines of equal elevation. (The National Map)



Elevation Profile from West to East through Mica Peak

TOPOGRAPHIC MAPS

Topographic maps use **isolines** to indication elevation. Isolines that specifically indicate elevation are called **contour lines**. Other maps use isolines to show atmospheric pressure. Those lines and called isobars.In the map above and left, the contour lines are a brown color. In general, isolines connect points of equal value. The value can be land surface elevation, depth to the lake or ocean floor, average annual precipitation, or depth of snow in a storm, for a few examples. When isolines are close together, there is a greater change in the characteristic over a short distance. When contour lines are close together, the land surface has a steeper slope. Proficiency with isolines is an important geographic skill. The image below shows how placement of isolines helps indicate slopes.



Isolines and shapes of slopes

When moving along the same contour line, the elevation remains the same. Moving from one isoline to a different isoline results in a different value. A weather map may indicate regions of similar temperature by using bands of different colors. Similar colors have similar temperatures, but different colored areas have different temperatures.

Isolines are also approximations of reality. A weather map of the entire state seems to tell you what the temperature is at all points. In fact, the temperature was measured only in a few locations and estimates of the temperature for all other points are indicated with the isolines. Isolines indicating temperature are called *isotherms*. The same process is used to make topographic maps. The USGS has a large number of points with known elevation and location. Using these points, called *benchmarks*, as a starting point, contours are drawn to indicate the slope of the land surface.

Isolines

Isolines are used to depicted many types of characteristics. Any point along the same line has the same value or quantity of the characteristic. The change in value as you move from one isoline to the immediate adjacent isoline is the interval, even if the value of the lines is only implied and not labeled on the map. To improve map clarity, not all isolines are labeled. Index isolines are labeled.

Here are names for some isolines that depict different characteristics:

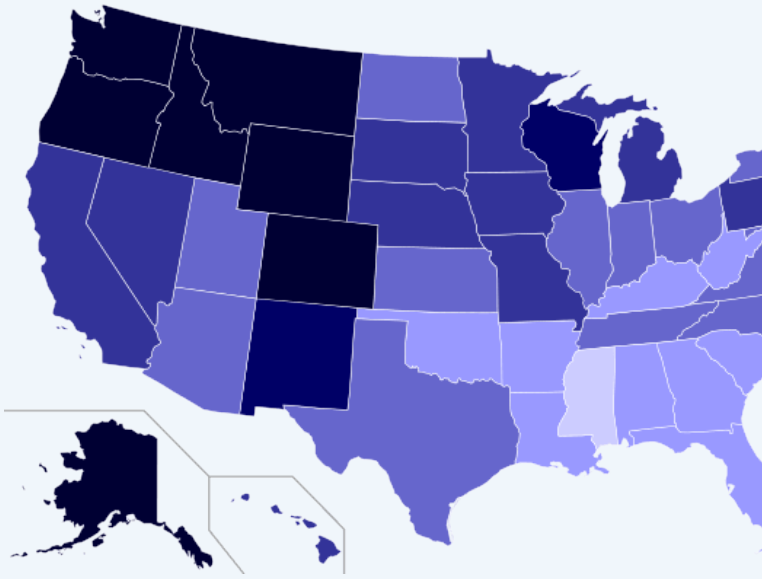
- Contour lines: land elevation
- Isobars: atmospheric (barometric) pressure
- Isotherms: temperature
- Isohyets: precipitation



USGS Benchmark for a location at Bryce Canyon

Examples of Thematic Maps


Thematic Map showing Languages of North America


Choropleth Map showing Craft Breweries per million people by state

THEMATIC MAPS

The two maps shown above are both **thematic maps**. Neither map shows landforms. The map on the left shows how languages were distributed spatially across North America, while the map on the right is showing how crime rates vary by state. They are both good maps. The language map uses color well because no single color stands out as more significant, all colors have the same shade indicating that all languages have similar importance. However, the map reader must beware that languages don't change as abruptly as the the map might indicate. As you move from southern Minnesota to northern Minnesota, don't expect an abrupt change in spoken languages from Sioux to Algic. Although such an abrupt change is possible, it isn't necessarily the case.

The craft brewery map is good because it uses shades of a single color and the data has been processed properly. The map shows

how a single data set (Craft Breweries per capita) changes so it uses a single color in different shades. People naturally associate darker shades with more of a value so the dark blue indicates that the Pacific Northwest has a more breweries per capita. The cartographer also processed the data to improve comparisons among states with different populations and population density. Good choropleth maps such as this use preexisting political boundaries (countries, states, counties) and show data in forms such as breweries per consistent number of people (per capita) or as per consistent unit of area (per mi^2).

Summary

Maps are models that simplify and generalize the real world. The amount of generalization is the scale of the map. Good use of map symbols can improve the interpretation of the map. There are broad categories of maps that are better suited to demonstrating broad categories of data.

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1.4: Map Projections

INTRODUCTION

Cartographers have known for centuries that the Mercator projection isn't an especially accurate way of viewing the world, and they've developed a number of mathematical tools for projecting the earth's spherical surface onto a two-dimensional map. But **there's no such thing as a perfect map projection!** Every projection has its advantages and disadvantages. To understand why, we have to venture back into mathematics.

PROPERTIES OF MAP PROJECTIONS

Let's consider what an ideal map would look like.

First, the map should be **contiguous** — there shouldn't be any interruptions in it. Just as any two points on the earth's surface can be connected by a line, someone should be able to draw a line between any two points on the map. We don't, in other words, want something like this:



The Goode Homolosine Map is Discontinuous (It's interrupted.)

For the remainder of this discussion we're going to consider only contiguous maps — maps that preserve topological characteristics.

In drawing these maps, there are four properties of the earth's surface we'd like to preserve.

Shape
: Shapes of regions should be drawn correctly, which means we have to preserve *local angles* — all angles at any point are preserved, the scale at any point is the same in every direction, and lines of latitude and longitude intersect at right angles. Maps that do this are called **conformal** maps.

Area
: The areas of regions on the map should be proportional to their areas on the earth's surface. Maps that preserve relative areas of regions are called **equal-area** maps.

Distance
: Distances between points on the map should be proportional to the distances between those points on the earth's surface. Maps that preserve distance are called **equidistant** maps.

Direction
: Directions from the center of the map to various points on the map should be shown correctly. Maps that do this are called **azimuthal** maps.

The problem is that achieving all four of these properties on a two-dimensional map is impossible. Mathematicians have proven this. Preserving any one requires distorting at least one other. (This makes cartographers SADD.)

DISTORTION ELLIPSES

Many types of map projections have been devised to suit particular purposes. No projection allows us to flatten the globe without distorting it, however. **Distortion ellipses** help us to visualize what type of distortion a map projection has caused, how much distortion has occurred, and where it has occurred. The ellipses show how imaginary circles on the globe are deformed as a result of a particular projection. If no distortion had occurred in the process of projecting the map shown below in Figure 2.29.1, all of the ellipses would be the same size, and circular in shape.

When positions on the graticule are transformed to positions on a projected grid, four types of distortion can occur: distortion of sizes, angles, distances, and directions. Map projections that avoid one or more of these types of distortion are said to preserve certain properties of the globe.

Equivalence

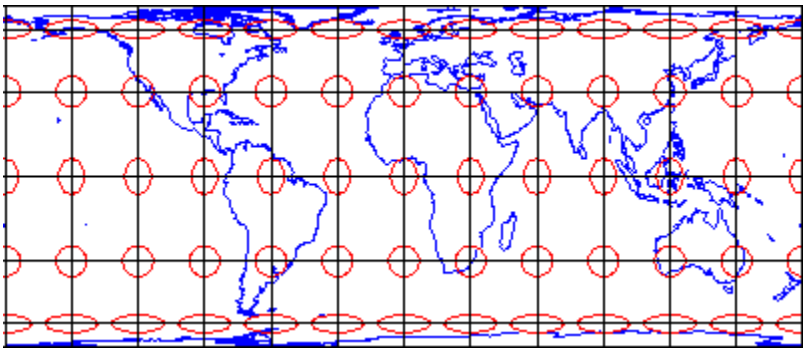


Figure 2.29.1 Equal-Area Distortion

So-called **equal-area** projections maintain correct proportions in the sizes of areas on the globe and corresponding areas on the projected grid (allowing for differences in scale, of course). Notice that the shapes of the ellipses in the Cylindrical Equal Area projection above (Figure 2.29.1) are distorted, but the areas each one occupies are equivalent. Equal-area projections are preferred for small-scale thematic mapping, especially when map viewers are expected to compare sizes of area features like countries and continents.

Conformality

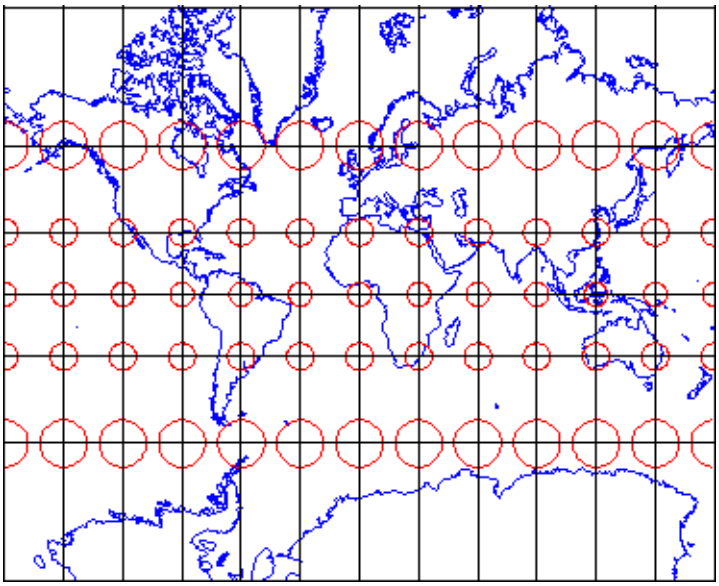


Figure 2.29.2 Conformal Projection Distortion

The distortion ellipses plotted on the **conformal** projection shown above in Figure 2.29.2 vary substantially in size, but are all the same circular shape. The consistent shapes indicate that conformal projections (like this Mercator projection of the world) preserve the fidelity of angle measurements from the globe to the plane. In other words, an angle measured by a land surveyor anywhere on the Earth's surface can be plotted on at its corresponding location on a conformal projection without distortion. This useful property accounts for the fact that conformal projections are almost always used as the basis for large scale surveying and mapping. Among the most widely used conformal projections are the Transverse Mercator, Lambert Conformal Conic, and Polar Stereographic.

Conformality and equivalence are mutually exclusive properties. Whereas equal-area projections distort shapes while preserving fidelity of sizes, conformal projections distort sizes in the process of preserving shapes.

Equidistance

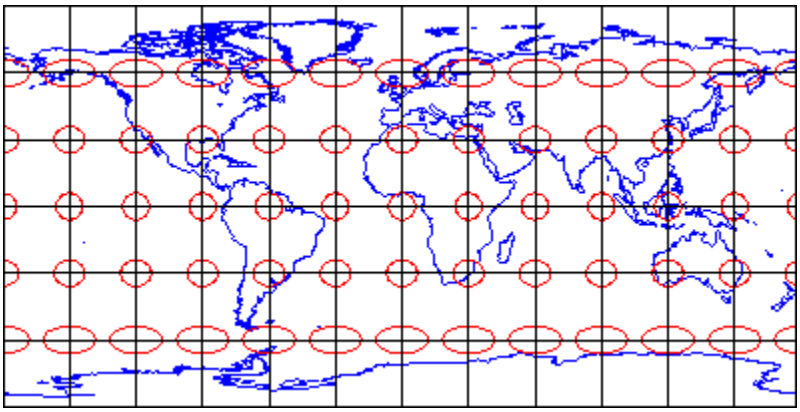


Figure 2.29.3 Equidistant projection distortion

Equidistant map projections allow distances to be measured accurately along straight lines radiating from one or two points only. Notice that ellipses plotted on the Cylindrical Equidistant (Plate Carrée) projection shown above (Figure 2.29.3) vary in both shape and size. The north-south axis of every ellipse is the same length, however. This shows that distances are true-to-scale along every meridian; in other words, the property of equidistance is preserved from the two poles. See chapters 11 and 12 of the online publication *Matching the Map Projection to the Need* to see how projections can be customized to facilitate distance measurements and to effectively depict ranges and rings of activity.

Azimuthality

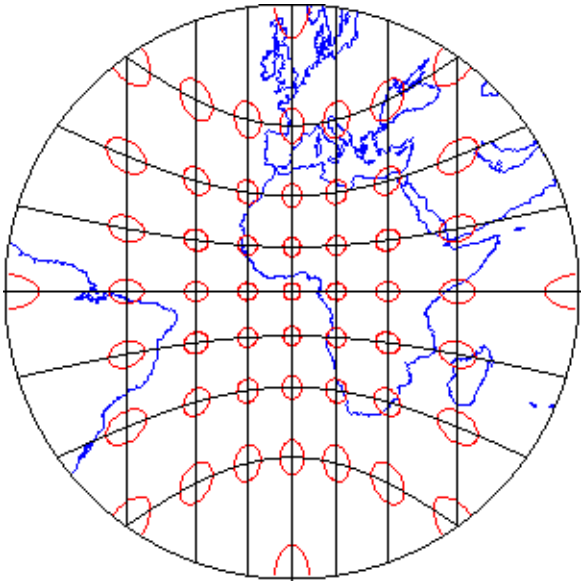


Figure 2.29.4 Azimuthal projection distortion

Azimuthal projections preserve directions (azimuths) from one or two points to all other points on the map. See how the ellipses plotted on the gnomonic projection, shown above in Figure 2.29.4, vary in size and shape, but are all oriented toward the center of the projection? In this example, that's the one point at which directions measured on the globe are not distorted on the projected graticule.

Compromise

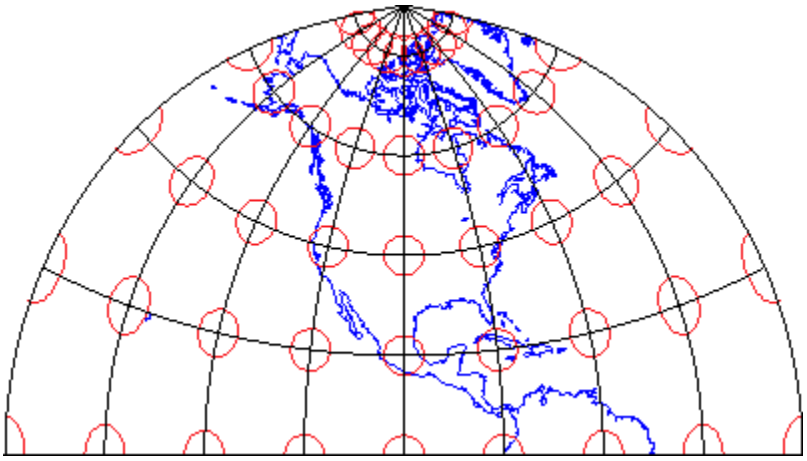


Figure 2.29.5 Polyconic projection distortion

Some map projections preserve none of the properties described above, but instead seek a compromise that minimizes distortion of all kinds. The example shown above in Figure 2.29.5 is the Polyconic projection, which was used by the U.S. Geological Survey for many years as the basis of its topographic quadrangle map series until it was superceded by the conformal Transverse Mercator. Another example is the Robinson projection, which is often used for small-scale thematic maps of the world.

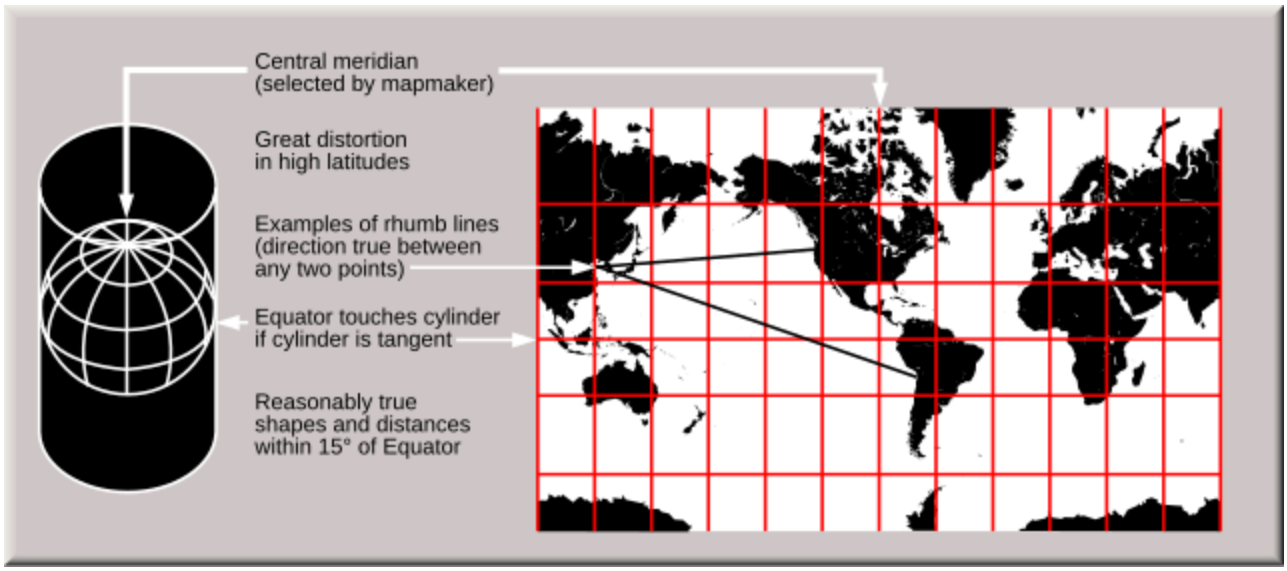
TYPES OF PROJECTIONS

Mapmakers and mathematicians have invented dozens of map projections — the possibilities are almost limitless. As new needs arise — such as the need to project satellite imagery onto a computer screen with minimal distortion — new projections are invented.

Most older and common projections are one of these three developable surfaces. Developable surfaces can be transformed from 2D to 3D back to 2D by joining or cutting along a straight line.

CYLINDRICAL

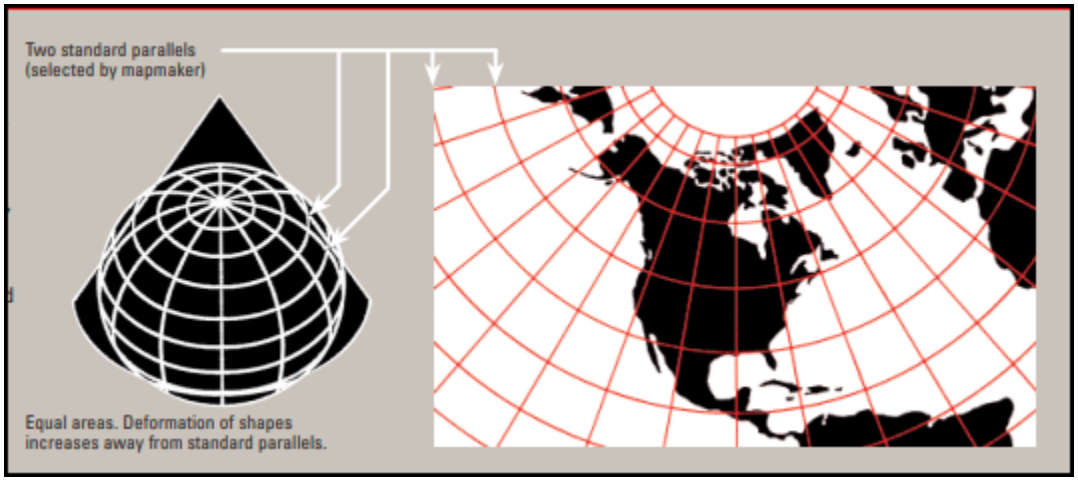
Cylindrical projections unwrap the earth's surface and project it onto the surface of a cylinder. The Mercator projection is cylindrical, as are several variations of it. This is the only projection that can show the entire world, except the poles, since the other two types can only show one hemisphere. This is the oldest projection and its greatest advantage is that a straight line between any two points is the true direction between them. The problem is the distance and area is inconsistent as you move around the map.



The Mercator is a Cylindrical Projection

CONICAL

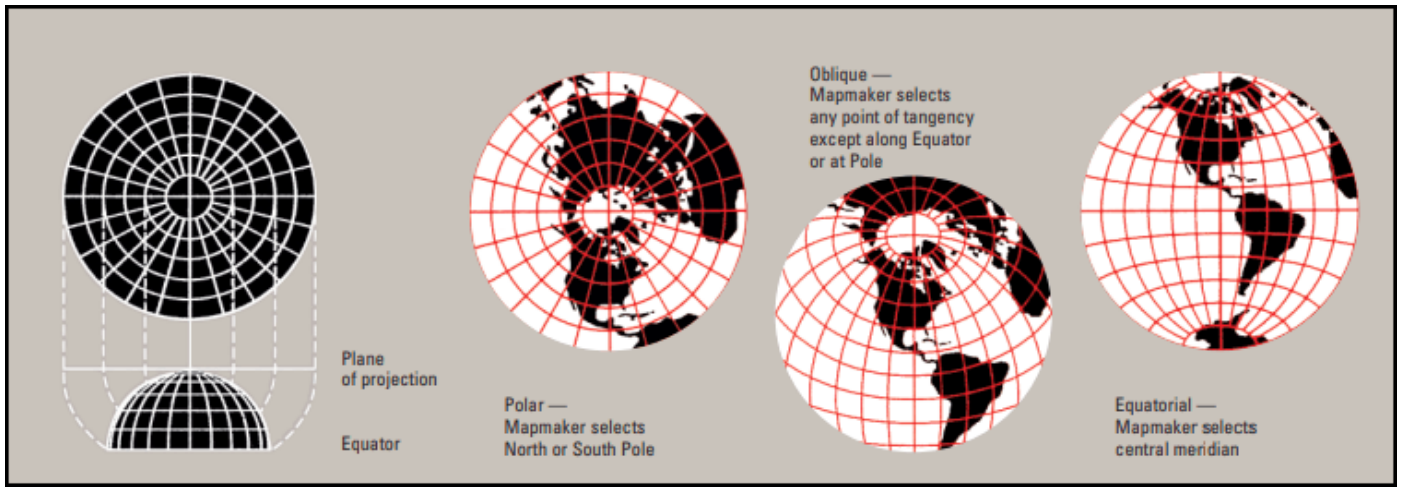
In a conical projection, the earth's surface is mathematically projected onto a cone. This is often used to show large regions in the mid-latitudes such as the entire US. The US National Map by the USGS uses this projection.



Albers Equal-Area Conical Projection

PLANAR (or AZIMUTHAL)

An azimuthal projection geometrically maps the earth's surface onto a plane. This is often used to show the distance from any direction to a single point. A city tourism bureau might use this projection with the city in the middle and circles around the city to indicate distance. Distances from any point to the center are correct but not from any other pair of points.



A Planar Azimuthal Projection

Cylindrical, Conical, and Planar projections are all developable surfaces. The planar projection is already a flat surface while the cylindrical and conical surfaces are 3D surfaces that can be cut in a straight line to yield a plane. The figures above show the most basic forms of each projection, but common changes to each projection include: slicing through the globe so the shape intersect the globe at more points, or angling the shape so it touches the globe at a different location.

PROJECTIONS AND PROPAGANDA

Interestingly, until the mid-twentieth century, publishers of maps and textbooks resisted using new projections (many of which were, by then, quite old). Why? Maybe because they wanted to stick with what was familiar to people — or maybe because Mercator fills a rectangular page so neatly and they didn't want to waste all that space in the corners.

Mercator does have its advantages, of course. It's perfect for wayfinding; it's the only projection for which straight lines on the map represent constant directions on the earth's surface. If point A is directly below point B on the map, then point A is due south of point B. But Mercator's distortions make it less than ideal for studying geography.

MERCATOR TROUBLE

Because Mercator misrepresents the true areas of nations and continents, it can lead to misunderstanding — intentional or unintentional. Here are two ways that Mercator promoted particular political interests in the second half of the twentieth century.

THE COLD WAR

During the Cold War, maps of "us" and "them" were often drawn to emphasize the threat represented by the USSR and its allies. The Mercator projection was the perfect choice for anti-communist cartographers: because the USSR was at such high latitudes, Mercator stretches it out of proportion to its true size. In the map below, the nations become a sprawling red menace:



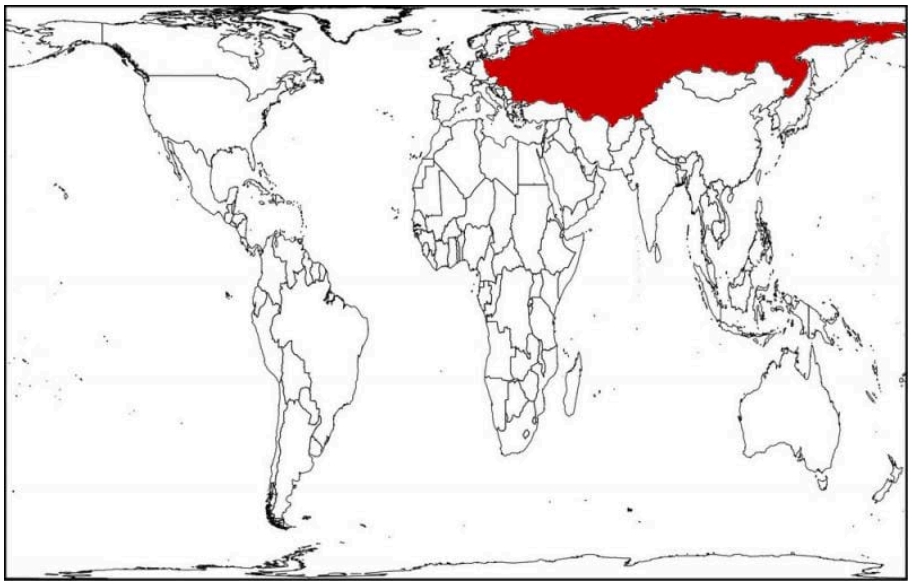
Mercator Projection of Warsaw Pact Members

Redrawn in Robinson projection — a popular compromise between equal-area and conformal mapping — the USSR becomes a little less menacing.



Robinson Projection of Warsaw Pact Members

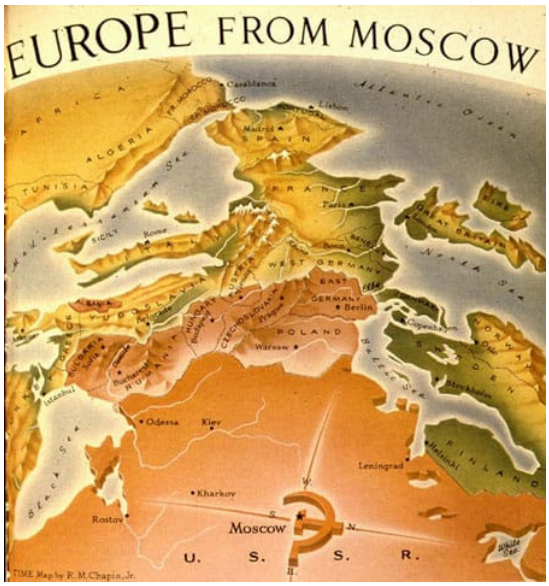
Now redraw it again in the Peters equal-area projection, and the USSR shrinks to its true size.



Peters Projection of Warsaw Pact Members

Suppose you were a U.S. voter in 1960. Which of these would be most likely to make you support an increase in military spending?

If that didn't convince you, cartographers could always offer a new perspective, as *Time*'s cartographer, R. M. Chapin, did in 1952:



Bias in Cartographic Design: RM Chapin for Time Magazine 1952

From this perspective, it's easy to imagine (red) armies sweeping across Western Europe.

NORTH AND SOUTH

One reason that Mercator wasn't replaced sooner is that its distortions make the world's most powerful nations appear larger, while poorer nations nearer the equator shrink. By the middle of the twentieth century, many people were pointing out that the Mercator projection made the powerful "North" appear more important than the poorer "South" and thus shaped people's attitudes — albeit unconsciously — about the world.

How bad is this misrepresentation? Europe, at 3.8 million square miles, is made to appear larger than South America at 6.9 million square miles. Africa is the second-largest continent (after Asia), but in the Mercator projection, it looks about as big as Greenland, which in reality is *one-fourteenth* Africa's size.

People who imagine Africa or South America as small will tend to underestimate not only the importance of those continents, but also their diversity. Many Americans think of “Africa” as a single place. In fact it encompasses a tremendous variety of cultures, ecosystems, and climatic regions; Africans speak more than 2,000 languages, and there is more genetic diversity among Africans than in all the rest of the world. Treating Africa as a cultural and political monolith would be absurd — and dangerous in an era of increasing globalization.

The Peters Projection

To correct the misconceptions promoted by the Mercator projection, Arno Peters, German map maker, historian and journalist, popularized an equal-area map projection in the early 1970s. Equal-area projections weren’t new, but the time was right, as African nations were winning their independence from colonial powers and many Europeans and Americans were growing weary of the Cold War.

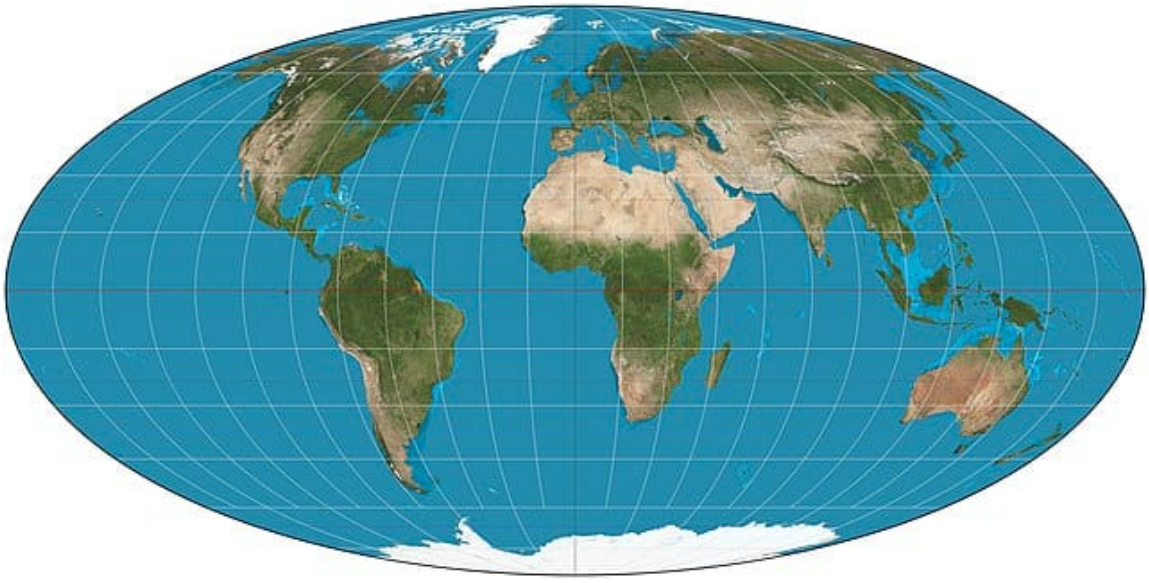
The Peters projection, like Mercator’s, is cylindrical, but it compresses the map near the poles, preserving the map’s rectangular appearance but making the relative areas of any two regions on the map proportional to their relative areas on the globe.

The Peters projection received a fair amount of criticism. Conservatives charged that it amounted to propaganda, and in fact it was used most often in a deliberate effort to change people’s perceptions of the globe — though, of course, to correct misperceptions created by earlier maps.

A more practical problem is that the Peters projection distorts the shape of the continents far more than Mercator, especially near the poles, so that Canada and Russia appear to have been run through a wringer. All cylindrical projections stretch out the regions near the poles; a cylindrical equal-area projection compensates for that not by removing that distortion but by adding a second one. As a result, it isn’t a particularly elegant solution to the problem of accurately portraying the world. It does, however, maintain the familiar (if completely inaccurate) rectangular outline of the Mercator map.

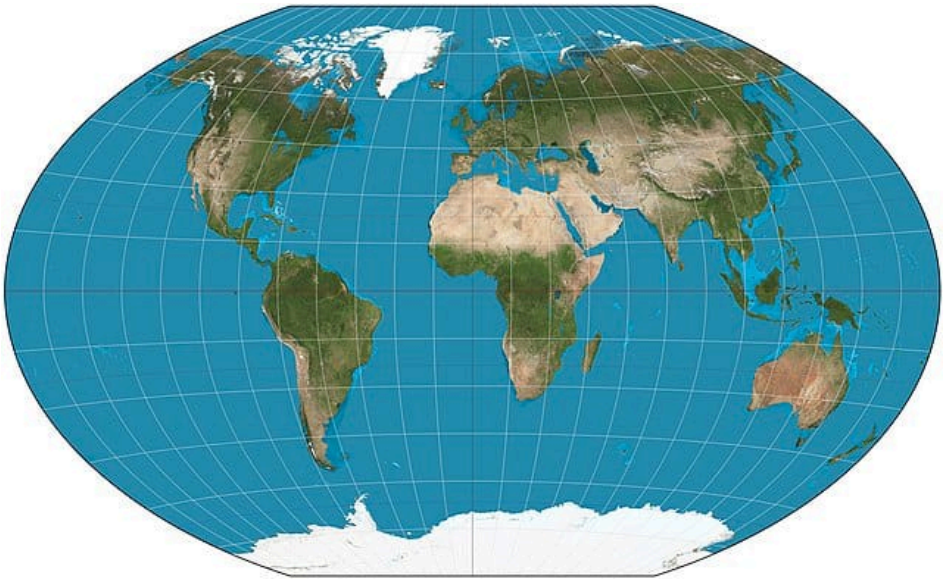
IMPROVEMENTS AND COMPROMISES

There are equal-area projections that don’t as badly distort the shapes of the continents, but they require giving up the rectangular map outline. The Molleweide projection, for example, is frequently used when accurately representing area is more important than describing shape — to show global distribution of populations or goods, for example.



Molleweide Equal Area Projection

The maps most used today in textbooks, magazines, and newspapers are compromises. Since 1998, *National Geographic* has used the Winkel Tripel projection — which is the average of two other projections — to show the whole earth.



The Winkel Tripel Projection attempts to minimize area, shape, size distortions

SUMMARY: THE RIGHT TOOL FOR THE JOB

When you're reading a map, then, it's important to be aware of the projection. What aspects of the map are represented accurately, and which are distorted — and are those choices appropriate to what's being communicated? Just as there is no perfect projection, there aren't necessarily any bad ones, either — just bad uses of them.

The Mercator projection, for example, has been revived in recent years to meet the needs of digital mapping. Equal-area maps are great for looking at the entire globe, but for street-level maps, you can't beat Mercator, in which a straight line always represents a consistent direction and a rectangular building will appear as a rectangle. And for street maps, Mercator's distortions are usually negligible. But if you want to "zoom out" to a global view — as Google Maps lets you do — you'll have to maintain the same projection all the way through. For Google Maps, then, the only choice was Mercator.

Credits

By David Walbert.

Distortion Ellipses: https://www.e-education.psu.edu/natu...port/html/1702

Most recent edits: 20 Mar 2023 Cameron McCormick

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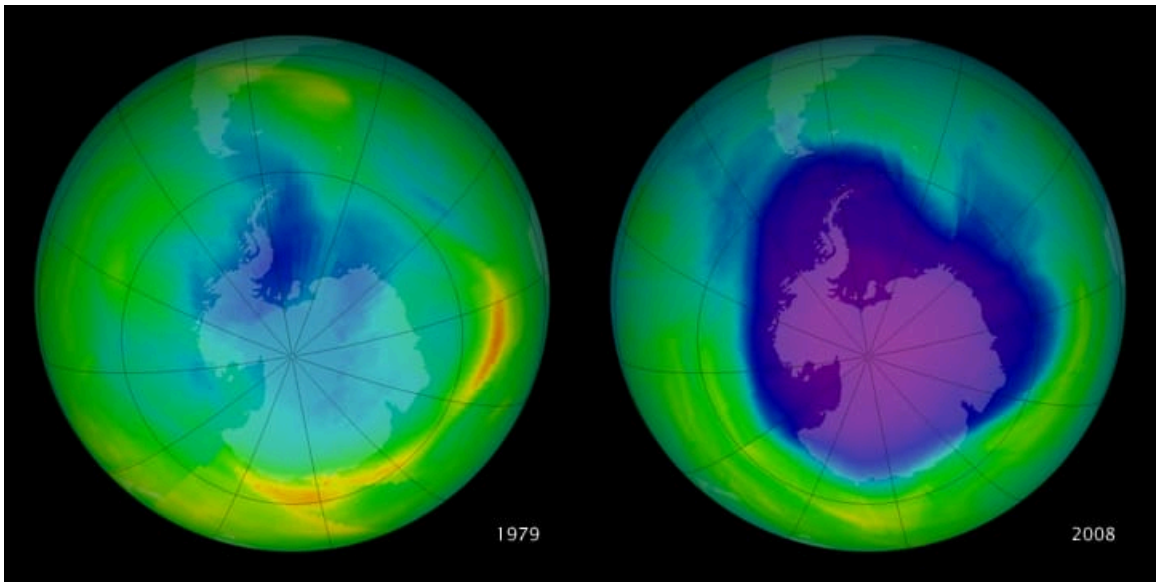
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1.5: The Atmosphere- Winds

Learning Objectives

- Understand the significance of the atmosphere.
- Describe the composition of the atmospheric gasses.
- Explain the major layers of the atmosphere and their importance.
- Analyze the relationships between energy, temperature, and heat.
- Describe how the Sun influences seasonality.
- Describe how heat is transferred around the planet.

SIGNIFICANCE OF THE ATMOSPHERE



Antarctic Ozone Hole 1979-2008. (Purple is low ozone, green is higher.)

Earth's atmosphere is a thin blanket of gases and tiny particles — together called air. We are most aware of air when it moves and creates wind. All living things need some of the gases in air for life support. Without an atmosphere, Earth would likely be just another lifeless rock. Earth's atmosphere, along with the abundant liquid water at Earth's surface, are the 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 reasons we are lucky to have an atmosphere.

INTERACTION WITH SOLAR ENERGY

The diversity of earth's surface is due to different concentrations of energy. The atmosphere is the location of the first interaction of solar energy with the earth. About 40% of the earth's total energy comes from the sun, the rest comes from within the earth. The atmosphere is key for distribution and redistribution of this solar energy.

Ozone is a molecule composed of three oxygen atoms, (O_3). Most oxygen molecules are only two oxygen atoms. Ozone in the upper atmosphere absorbs high-energy **ultraviolet (UV) radiation** 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.

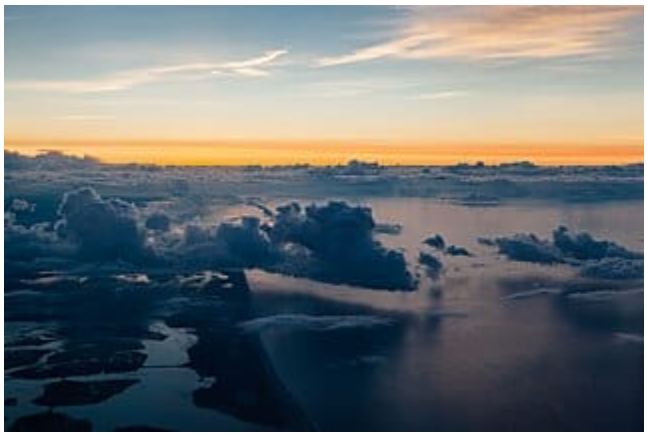
INDISPENSABLE FOR LIFE ON EARTH



Without the atmosphere, Earth would look a lot more like the Moon. Atmospheric gases, especially carbon dioxide (CO_2) and oxygen (O_2), are extremely important for living organisms. How does the atmosphere make life possible? How does life alter the atmosphere?

In **photosynthesis** plants use CO_2 and create O_2. Photosynthesis is responsible for nearly all of the oxygen currently found in the atmosphere. By creating oxygen and food, plants have made an environment that is favorable for animals. In respiration, animals use oxygen to convert sugar into food energy they can use. Plants also go through respiration and consume some of the sugars they produce.

CRUCIAL PART OF THE WATER CYCLE



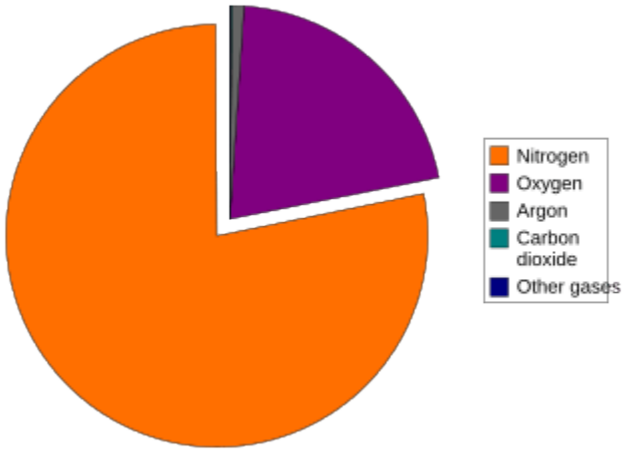
Atmospheric motion brings water from the ocean to the land

As part of the hydrologic cycle, water spends a lot of time in the atmosphere, mostly as water vapor. 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. Weather is the change 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 Tucson, Arizona, may include snow, the climate of Tucson is generally warm and dry.

MODERATES EARTH'S TEMPERATURE

Along with the oceans, the **atmosphere** keeps Earth's temperatures within an acceptable range. **Greenhouse gases** trap heat in the atmosphere so they help to moderate global temperatures. Without an atmosphere with greenhouse gases, Earth's temperatures would be frigid at night and scorching during the day. Important greenhouse gases include carbon dioxide, methane, water vapor, and ozone.

ATMOSPHERIC CHEMISTRY



Gasses in the Atmosphere

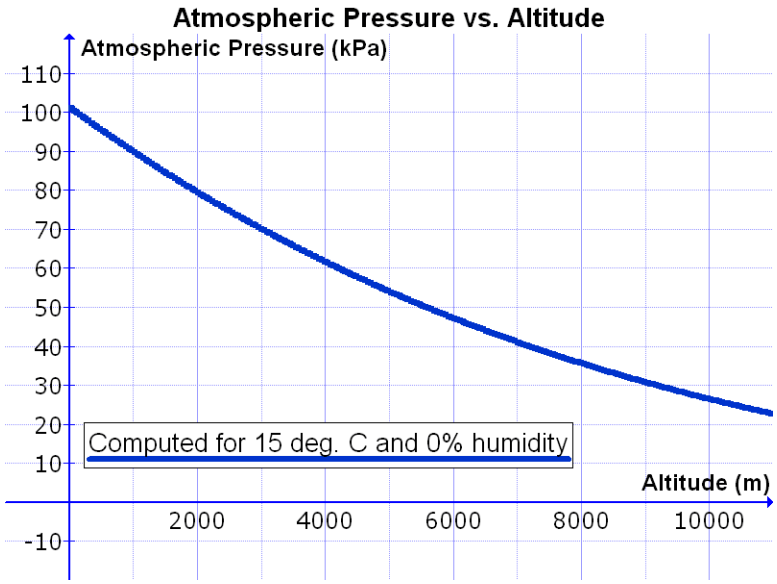
COMPOSITION OF THE ATMOSPHERE

Nitrogen and oxygen together make up 99 percent of the planet's atmosphere. The rest of the gases are minor components but sometimes are very important.

Humidity is the amount of water vapor in the air. Humidity varies from place to place and season to season. This fact is obvious if you compare a summer day in Atlanta, Georgia, where humidity is high, with a winter day in Phoenix, Arizona, where humidity is low. When the air is very humid, it feels heavy or sticky. Dry air usually feels more comfortable. Where around the globe is mean atmospheric water vapor higher and where is it lower and why? Higher humidity is found around the equatorial regions because air temperatures are higher and warm air can hold more moisture than cooler air. Of course, humidity is lower near the polar regions because air temperature is lower.

Some of what is in the atmosphere is not gas. Particles of dust, soil, fecal matter, metals, salt, smoke, ash, and other solids make up a small percentage of the atmosphere. Particles provide starting points (or nuclei) for water vapor to condense on and form raindrops. Some particles are pollutants, which are discussed in the Human Actions and the Atmosphere chapter.

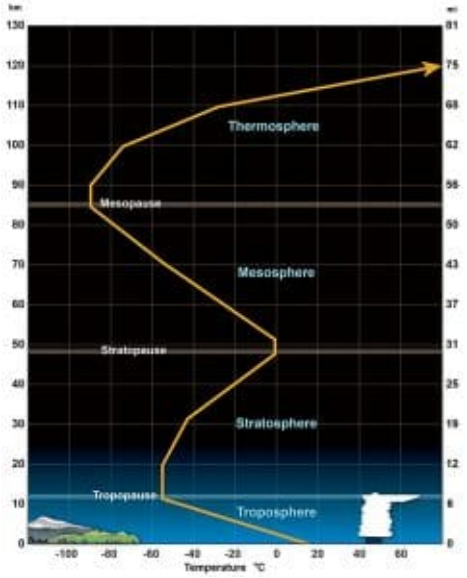
ATMOSPHERIC PRESSURE AND DENSITY



The Pressure drop with altitude. (kPa)

The atmosphere has different properties at different elevations above sea level, or **altitudes**. The air density (the number of molecules in a given volume) decreases with increasing altitude. This is why people who climb tall mountains, such as Mt. Everest, have to set up camp at different elevations to let their bodies get used to the decreased air. Why does air density decrease with altitude? Gravity pulls the gas molecules towards Earth's center. The pull of gravity is stronger closer to the center at sea level. Air is 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 force of the air weighing down over a unit of area is known as its **atmospheric pressure**. The reason why we are not crushed by this weight is because the molecules inside our bodies are pushing outward to compensate. Atmospheric pressure is felt from all directions, not just from above. At higher altitudes the atmospheric pressure is lower and the air is less dense than at higher altitudes. If your ears have ever "popped", you have experienced a change in air pressure. Gas molecules are found inside and outside your ears. When you change altitude quickly, like when an airplane is descending, your inner ear keeps the density of molecules at the original altitude. Eventually the air molecules inside your ear suddenly move through a small tube in your ear to equalize the pressure. This sudden rush of air is felt as a popping sensation. Although the density of the atmosphere changes with altitude, the composition stays the same with altitude, with one exception. In the ozone layer, at about 20 km to 40 km above the surface, there is a greater concentration of ozone molecules than in other portions of the atmosphere.

LAYERS OF THE ATMOSPHERE



Layers of the Atmosphere (NOAA)

The atmosphere is layered, corresponding with how the atmosphere's temperature changes with altitude. By understanding the way temperature changes with altitude, we can learn a lot about how the atmosphere works. While weather takes place in the lower atmosphere, interesting things, such as the beautiful aurora, happen higher in the atmosphere. Why does warm air rise? Gas molecules are able to move freely and if they are free to move about, as they are in the atmosphere, they can take up more or less space.

- When gas molecules are cool, they are sluggish and do not take up as much space. With the same number of molecules in less space, both air density and air pressure are higher.
- When gas molecules are warm, they move vigorously and take up more space. Air density and air pressure are lower.

Warmer, lighter air is more buoyant than the cooler air above it, so it rises. The cooler air then sinks down, because it is denser than the air beneath it. This is convection, which was described in the Plate Tectonics chapter.

The property that changes most strikingly with altitude is air temperature. Unlike the change in pressure and density, which decrease with altitude, changes in air temperature are not regular. A change in temperature with distance is called a **temperature gradient**.

The atmosphere is divided into layers based on how the temperature in that layer changes with altitude, the layer's temperature gradient. The temperature gradient of each layer is different. In some layers, temperature increases with altitude and in others it decreases. The temperature gradient in each layer is determined by the heat source of the layer. Most of the important processes

of the atmosphere take place in the lowest two layers: the troposphere and the stratosphere.

TROPOSPHERE



Cumulonimbus Clouds are Tall, Indicating Vertical Air Movement.

In Latin, *tropo* means 'turning' or 'changing'. The air in the troposphere moves horizontally and vertically and changes chemically. It is a turbulent region. The temperature of the **troposphere** is highest near the surface of the Earth and decreases with altitude. On average, the temperature gradient of the troposphere is 6.5°C per 1,000 m (3.6°F per 1,000 ft.) of altitude. What is the source of heat for the troposphere? Earth's surface is a major source of heat for the troposphere, although nearly all of that heat comes from the sun. Rock, soil, and water on Earth absorb the sun's light and radiate it back into the atmosphere as heat. The temperature is also higher near the surface because of the greater density of gases. The higher gravity causes the temperature to rise. Notice that in the troposphere warmer air is beneath cooler air. What do you think the consequence of this is? This condition is unstable. The warm air near the surface rises and cool air higher in the troposphere sinks. So air in the troposphere does a lot of mixing. This mixing causes the temperature gradient to vary with time and place. The rising and sinking of air in the troposphere means that all of the planet's weather takes place in the troposphere. Sometimes there is a temperature **inversion** , air temperature in the troposphere increases with altitude and warm air sits over cold air. Inversions are very stable and may last for several days or even weeks. They form:

- Over land at night or in winter when the ground is cold. The cold ground cools the air that sits above it, making this low layer of air denser than the air above it.
- Near the coast where cold seawater cools the air above it. When that denser air moves inland, it slides beneath the warmer air over the land.
- Since temperature inversions are stable, they often trap pollutants and produce unhealthy air conditions in cities. At the top of the troposphere is a thin layer in which the temperature does not change with height. This means that the cooler, denser air of the troposphere is trapped beneath the warmer, less dense air of the stratosphere. Air from the troposphere and stratosphere rarely mix.

STRATOSPHERE



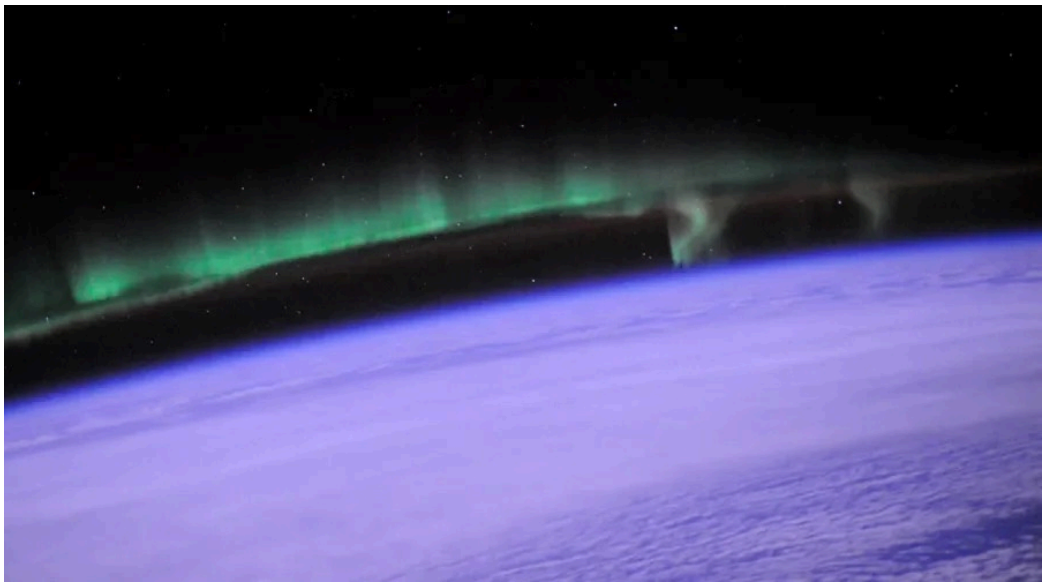
In contrast to the troposphere, the **stratosphere** is calm and stable. Air in the stratosphere is stable because warmer, less dense air sits over cooler, denser air. As a result, there is little mixing of air within the layer. Unlike the troposphere, the temperature in the stratosphere increases with increasing altitude. The stability in stratosphere is an advantage for p ilots like to fly in the lower portions of the stratosphere because there is little air turbulence. But that same stability means that a sh and gas from a large volcanic eruption may burst into the stratosphere, remains suspended there for many years.

The direct heat source for the stratosphere is radiation from the sun. The **ozone layer** is found within the stratosphere between 15 to 30 km (9 to 19 miles) altitude. The thickness of the ozone layer varies by the season and also by latitude. The ozone layer is extremely important because ozone gas in the stratosphere absorbs most of the sun's ultraviolet (UV) radiation. As the high energy, shortwave UV radiation hits ozone molecules, some of the energy is transformed into low-energy, longwave heat and warms the stratosphere. Shortwave UV radiation is harmful to life. High-energy UV light penetrates cells and damages DNA, leading to cell death (which we know as a bad sunburn). Organisms on Earth are not adapted to heavy UV exposure, which kills or damages them. Without the ozone layer to reflect UV radiation, most complex life on Earth would not survive long.

MESOSPHERE

Temperatures in the **mesosphere** decrease with altitude. Because there are few gas molecules in the mesosphere to absorb the sun's radiation, the heat source is the stratosphere below. The mesosphere is extremely cold, especially at its top, about -90°C (-130°F).The air in the mesosphere has extremely low density: 99.9% of the mass of the atmosphere is below the mesosphere. As a result, air pressure is very low. A person traveling through the mesosphere would experience severe burns from ultraviolet light since the ozone layer which provides UV protection is in the stratosphere below. There would be almost no oxygen for breathing. Stranger yet, an unprotected traveler's blood would boil at normal body temperature because the pressure is so low.

THERMOSPHERE



The Auroras Occur in the Thermosphere, the Outer Region of the Atmosphere.

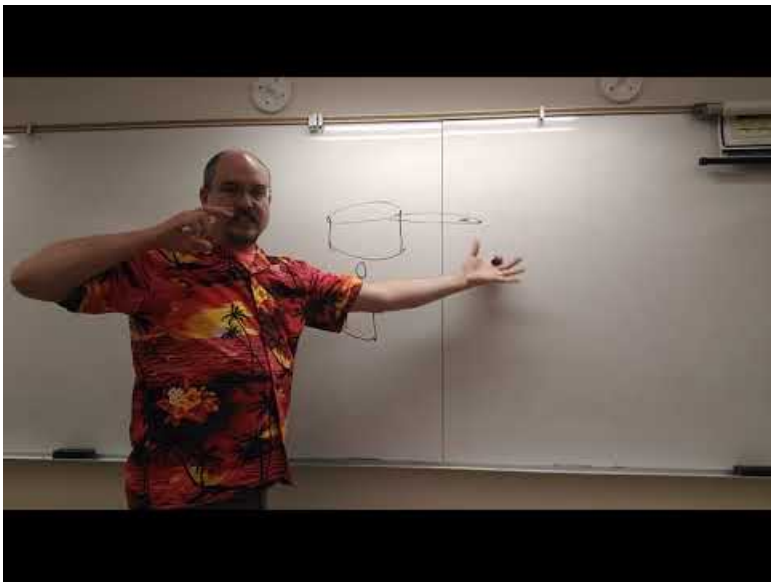
The density of molecules is so low in the **thermosphere** that one gas molecule can go about 1 km before it collides with another molecule. Since so little energy is transferred, the air feels very cold. Within the thermosphere is the **ionosphere**. The ionosphere gets its name from the solar radiation that ionizes gas molecules to create a positively charged ion and one or more negatively charged electrons. The freed electrons travel within the ionosphere as electric currents. Because of the free ions, the ionosphere has many interesting characteristics.

At night, radio waves bounce off the ionosphere and back to Earth. This is why you can often pick up an AM radio station far from its source at night. The Van Allen radiation belts are two doughnut-shaped zones of highly charged particles that are located beyond the atmosphere in the **magnetosphere**. The particles originate in solar flares and fly to Earth on the solar wind. Once trapped by Earth's magnetic field, they follow along the field's magnetic lines of force. These lines extend from above the equator to the North Pole and also to the South Pole then return to the equator. When massive solar storms cause the Van Allen belts to become overloaded with particles, the result is the most spectacular feature of the ionosphere — the nighttime **aurora**. The particles spiral along magnetic field lines toward the poles. The charged particles energize oxygen and nitrogen gas molecules, causing them to light up. Each gas emits a particular color of light.

There is no real outer limit to the **exosphere**, the outermost layer of the atmosphere; the gas molecules finally become so scarce that at some point there are no more. Beyond the atmosphere is the solar wind. The solar wind is made of high-speed particles, mostly protons and electrons, traveling rapidly outward from the sun.

There is no real outer limit to the **exosphere**, the outermost layer of the atmosphere; the gas molecules finally become so scarce that at some point there are no more. Beyond the atmosphere is the solar wind. The solar wind is made of high-speed particles, mostly protons and electrons, traveling rapidly outward from the sun.

ENERGY, TEMPERATURE, HEAT



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ENERGY

Energy travels through space or material. This is obvious when you stand near a fire and feel its warmth or when you pick up the handle of a metal pot even though the handle is not sitting directly on the hot stove. Invisible energy waves can travel through air, glass, and even the vacuum of outer space. These waves have electrical and magnetic properties, so they are called electromagnetic waves. The transfer of energy from one object to another through electromagnetic waves is known as radiation. Different wavelengths of energy create different types of electromagnetic waves.

- The wavelengths humans can see are known as “visible light.” These wavelengths appear to us as the colors of the rainbow. What objects can you think of that radiate visible light? Two include the sun and a light bulb.
- The longest wavelengths of visible light appear red. Infrared wavelengths are longer than visible red. Snakes can see infrared energy. We feel infrared energy as heat.
- Wavelengths that are shorter than violet are called ultraviolet.

Can you think of some objects that appear to radiate visible light, but actually do not? The moon and the planets do not emit light of their own; they reflect the light of the sun. **Reflection** is when light (or another wave) bounces back from a surface. **Albedo** is a measure of how well a surface reflects light. A surface with high albedo reflects a large percentage of light. A snow field has high albedo.

One important fact to remember is that energy cannot be created or destroyed — it can only be changed from one form to another. This is such a fundamental fact of nature that it is a law: the law of conservation of energy.

In photosynthesis, for example, plants convert solar energy into chemical energy that they can use. They do not create new energy. When energy is transformed, some nearly always becomes heat. Heat transfers between materials easily, from warmer objects to cooler ones. If no more heat is added, eventually all of a material will reach the same temperature.

TEMPERATURE

Temperature is a measure of how fast the atoms in a material are vibrating. High temperature particles vibrate faster than low temperature particles. Rapidly vibrating atoms smash together, which generates heat. As a material cools down, the atoms vibrate more slowly and collide less frequently. As a result, they emit less heat. What is the difference between heat and temperature?

- Temperature measures how fast a material’s atoms are vibrating.

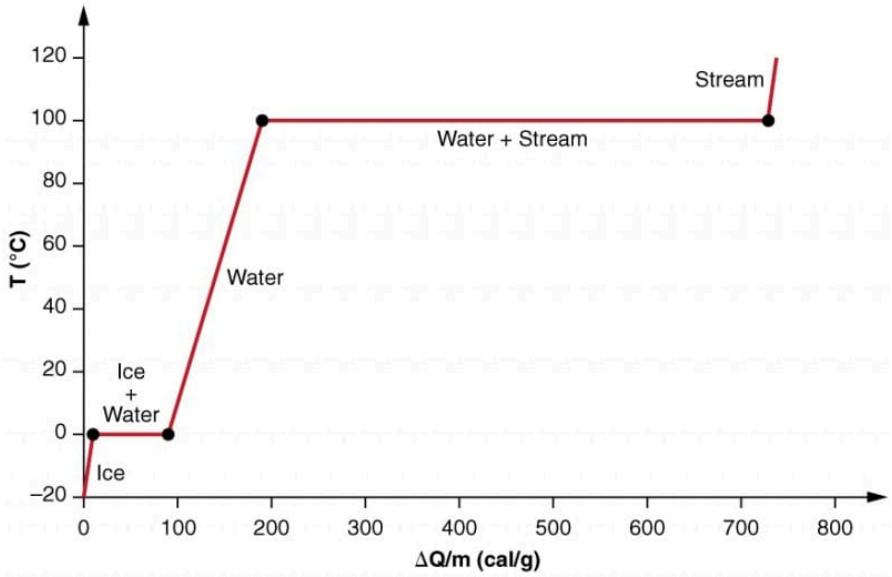
- Heat measures the material's total energy.

Which has higher heat and which has higher temperature: a candle flame or a bathtub full of hot water?

- The flame has higher temperature, but less heat, because the hot region is very small.
- The bathtub has lower temperature but contains much more heat because it has many more vibrating atoms. The bathtub has greater total energy.

HEAT

Heat is taken in or released when an object changes state, or changes from a gas to a liquid, or a liquid to a solid. This heat is called **latent heat**. When a substance changes state, latent heat is released or absorbed. A substance that is changing its state of matter does not change temperature. All of the energy that is released or absorbed goes toward changing the material's state.



Phase Change and Energy for Water

For example, imagine a pot of boiling water on a stove burner: that water is at 100°C (212°F). If you increase the temperature of the burner, more heat enters the water. The water remains at its boiling temperature, but the additional energy goes into changing the water from liquid to gas. With more heat the water evaporates more rapidly. When water changes from a liquid to a gas it takes in heat. Since evaporation takes in heat, this is called evaporative cooling. Evaporative cooling is an inexpensive way to cool homes in hot, dry areas.

Humid air masses transport not just the water molecules but also the energy required to evaporate those air molecules. The energy required to evaporate 1 g of water already at 100°C to gaseous vapor at 100°C is 540 calories. When that gaseous water condenses to liquid water, it releases 540 cal of energy to the immediate surroundings. For liquid water to freeze, it must release 80 cal. Solid ice must gain 80cal to melt. Then definition of a calorie of energy is the amount of energy required to raise the temperature of 1g water by 1°C from 3.5° to 4.5°C at standard air pressure. It is equivalent to 4.184 Joules of energy.

Substances also differ in their **specific heat**, the amount of energy needed to raise the temperature of one gram of the material by 1.0°C (1.8°F). Water has a very high specific heat, which means it takes a lot of energy to change the temperature of water. Let's compare a puddle and asphalt, for example. If you are walking barefoot on a sunny day, which would you rather walk across, the shallow puddle or an asphalt parking lot? Because of its high specific heat, the water stays cooler than the asphalt, even though it receives the same amount of solar radiation.

ENERGY FROM THE SUN

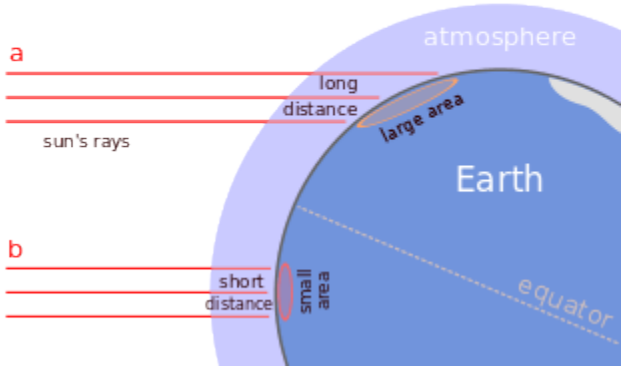
The earth constantly tries to maintain an energy balance with the atmosphere. Most of the energy that reaches the Earth's surface comes from the sun. About 44% of solar radiation is in the visible light wavelengths, but the sun also emits infrared, ultraviolet,

and other wavelengths. When viewed together, all of the wavelengths of visible light appear white. But a prism or water droplets can break the white light into different wavelengths so that separate colors appear. Of the solar energy that reaches the outer atmosphere, UV wavelengths have the greatest energy. Only about 7% of solar radiation is in the UV wavelengths. The three types are:

- UVC: the highest energy ultraviolet, does not reach the planet's surface at all.
- UVB: the second highest energy, is also mostly stopped in the atmosphere.
- UVA: the lowest energy, travels through the atmosphere to the ground.

The remaining solar radiation is the longest wavelength, infrared. Most objects radiate infrared energy, which we feel as heat. Some of the wavelengths of solar radiation traveling through the atmosphere may be lost because they are absorbed by various gases. Ozone completely removes UVC, most UVB and some UVA from incoming sunlight. Oxygen, carbon dioxide, and water vapor also filter out some wavelengths.

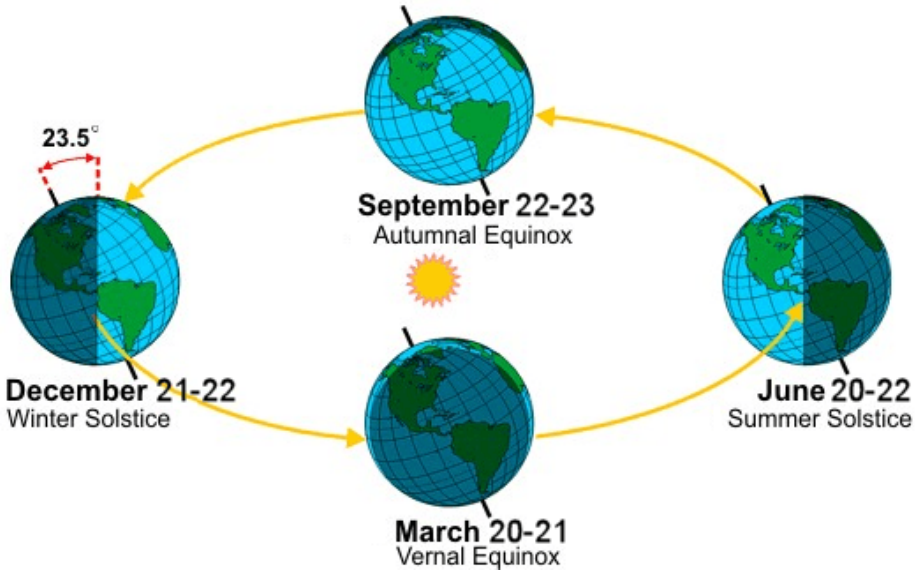
SOLAR RADIATION ON EARTH



Angle of incoming solar radiation. Energy is more concentrated near the equator.

Different parts of the Earth receive different amounts of solar radiation. Which part of the planet receives the most insolation? The sun's rays strike the surface most directly at the equator. Different areas also receive different amounts of sunlight in different seasons. What causes the seasons? The seasons are caused by the direction Earth's axis is pointing relative to the sun. The Earth revolves around the sun once each year and spins on its axis of rotation once each day. This axis of rotation is tilted 23.5 degrees relative to its plane of orbit around the sun. The axis of rotation is pointed toward Polaris, the North Star. As the Earth orbits the sun, the tilt of Earth's axis stays lined up with the North Star.

NORTHERN HEMISPHERE SUMMER



Dates of Equinoxes and Solstices and the relationship with the Sun.

The North Pole is tilted towards the sun and the sun's rays strike the Northern Hemisphere more directly in summer. At the summer solstice, June 21 or 22, the sun's rays hit the Earth most directly along the Tropic of Cancer (23.5°N); that is, the angle of incidence of the sun's rays there is zero (the angle of incidence is the deviation in the angle of an incoming ray from straight on). On the day of the summer solstice in the Northern Hemisphere, it is the winter solstice in the southern Hemisphere.

NORTHERN HEMISPHERE WINTER

Winter solstice for the Northern Hemisphere happens on December 21 or 22. The tilt of the North Pole points away from the sun. Light from the sun is spread out over a larger area in the northern hemisphere, but is more concentrated in the southern hemisphere. With fewer daylight hours in winter, there is also less time for the sun to warm the area. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere.

EQUINOX

Halfway between the two solstices, the sun's rays shine most directly at the equator, called an "equinox." The autumnal equinox happens on September 22 or 23 and the vernal or spring equinox happens March 21 or 22 in the Northern Hemisphere. Remember the equator is equidistant between the poles and the sun is over the equator on the equinox.

PARALLELISM

Wherever the earth is located during it's revolution around the the sun, it's axis is always parallel to it's axis at any other location in the orbit. That means sometimes the north pole is pointed towards the sun, sometimes the north pole is pointed away from the sun. If parallelism didn't happen, then one pole would always be pointed toward the sun and the other pole would never receive any sunlight. There would be no seasons. There would be a greater difference in energy from the coldest pole to the hottest latitude with direct sunlight.

HEAT TRANSFER IN THE ATMOSPHERE

Heat moves in the atmosphere the same way it moves through the solid Earth or another medium. What follows is a review of the way heat flows and is transferred, but applied to the atmosphere. **Radiation** is the transfer of energy between two objects by electromagnetic waves. Energy from the sun moves to the earth via radiation. Heat radiates from the ground into the lower atmosphere.

In **conduction**, heat moves from areas of more heat to areas of less heat by direct contact. Warmer molecules vibrate rapidly and collide with other nearby molecules, transferring their energy from one molecule to a different molecule. In the atmosphere, conduction is more effective at lower altitudes where air density is higher; transfers heat upward to where the molecules are spread further apart or transfers heat laterally from a warmer to a cooler spot, where the molecules are moving less vigorously.

Heat transfer by movement of heated materials is called **convection**. Heat that radiates from the ground initiates convection cells in the atmosphere. Warm air molecules move to an area with less heat, bringing the heat energy with them.

HEAT AT EARTH'S SURFACE

About half of the solar radiation that strikes the top of the atmosphere is filtered out before it reaches the ground. This energy can be absorbed by atmospheric gases, reflected by clouds, or scattered. Scattering occurs when a light wave strikes a particle and bounces off in some other direction.

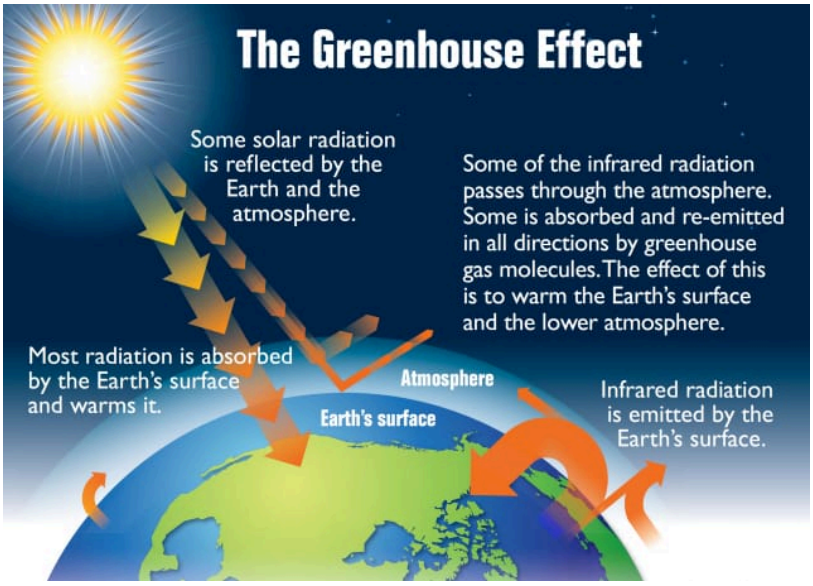
About 3% of the energy that strikes the ground is reflected back into the atmosphere. The rest is absorbed by rocks, soil, and water and then radiated back into the air as heat. These infrared wavelengths can only be seen by infrared sensors. Because solar energy continually enters Earth's atmosphere and ground surface, is the planet getting hotter? The answer is no (although the next section contains an exception) because energy from Earth escapes into space through the top of the atmosphere. If the amount that exits is equal to the amount that comes in, then average global temperature stays the same. This means that the planet's heat budget is in balance. What happens if more energy comes in than goes out? If more energy goes out than comes in?

To say that the Earth's heat budget is balanced ignores an important point. The amount of incoming solar energy is different at different latitudes). Where do you think the most solar energy ends up and why? Where does the least solar energy end up and why? The difference in solar energy received at different latitudes drives atmospheric circulation.

	Day Length

Sun Angle
Solar Radiation Albedo Equatorial Region Nearly same all year High High Low Polar Regions Night 6 months Low (sun always near horizon) Low (not much energy per m^2) High (most is reflected)

THE GREENHOUSE EFFECT



The exception to Earth's temperature being in balance is caused by greenhouse gases. But first the role of greenhouse gases in the atmosphere must be explained. Greenhouse gases warm the atmosphere by trapping heat. Some of the heat radiation out from the ground is trapped by greenhouse gases in the troposphere. Like a blanket on a sleeping person, greenhouse gases act as insulation for the planet. The warming of the atmosphere because of insulation by greenhouse gases is called the **greenhouse**

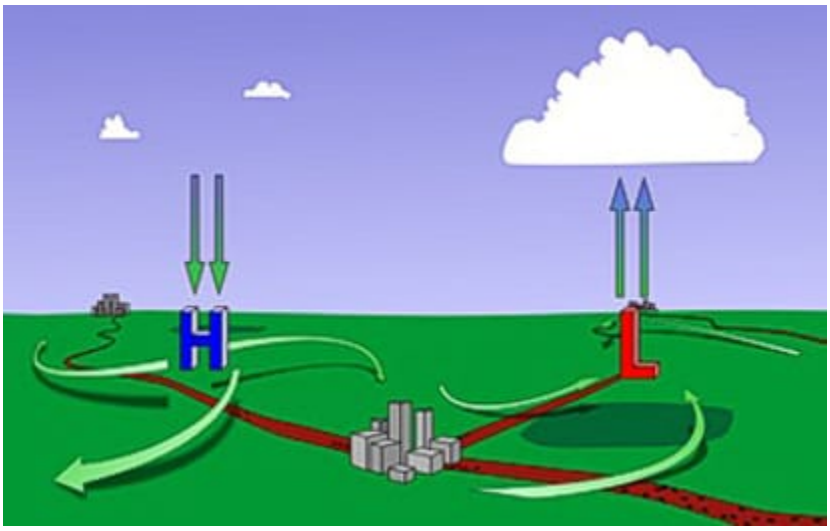
effect. Greenhouse gases are the component of the atmosphere that moderate Earth's temperatures. Greenhouse gases include CO_2, H_2O, methane, O_3, nitrous oxides (NO and NO_2), and chlorofluorocarbons (CFCs). All are a normal part of the atmosphere except CFCs. The table below shows how each greenhouse gas naturally enters the atmosphere.

Greenhouse Gas	Where It Comes From
Carbon dioxide	Respiration, volcanic eruptions, decomposition of plant material; burning of fossil fuels
Methane	Decomposition of plant material under some conditions, biochemical reactions in stomachs
Nitrous oxide	Produced by bacteria
Ozone	Atmospheric processes
Chlorofluorocarbons	Not naturally occurring; made by humans

Different greenhouse gases have different abilities to trap heat. For example, one methane molecule traps 23 times as much heat as one CO_2 molecule. One CFC-12 molecule (a type of CFC) traps 10,600 times as much heat as one CO_2. Still, CO_2 is a very important greenhouse gas because it is much more abundant in the atmosphere. Human activity has significantly raised the levels of many of greenhouse gases in the atmosphere. Methane levels are about 2 1/2 times higher as a result of human activity. Carbon dioxide has increased more than 35%. CFCs have only recently existed.

What do you think happens as atmospheric greenhouse gas levels increase? More greenhouse gases trap more heat and warm the atmosphere. The increase or decrease of greenhouse gases in the atmosphere affect climate and weather the world over.

AIR PRESSURE



Air moves Out from High pressure, In to a Low Pressure.

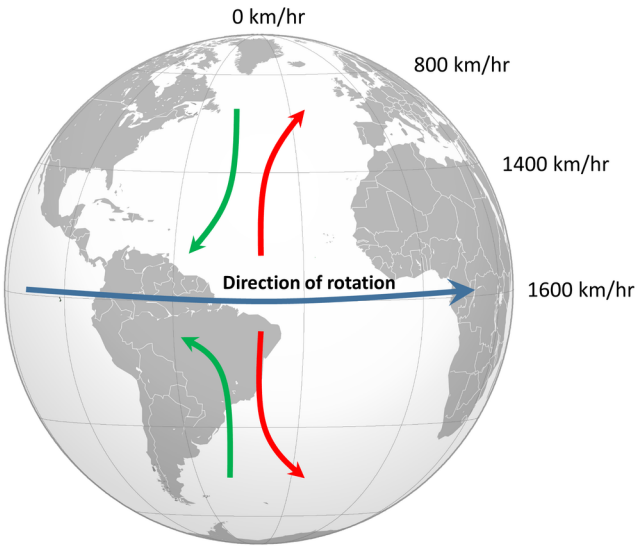
Natural processes are always moving energy from high concentration to low concentration. Material at the top of a mountain has

great potential energy so natural processes generally move that material to the valley bottom which has less potential energy. Air movement happens because there is an uneven distribution of energy in the atmosphere. The energy can be in several forms or expressed in several ways such as heat, humidity, kinetic, potential among others.

A few basic principles go a long way toward explaining how and why air moves: Warm air rising creates a **low pressure zone** at the ground. Air from the surrounding area moves into the space left by the rising air. Air flows horizontally at the top of the troposphere; horizontal flow is called **advection**. The air cools until it descends. Where the descending air reaches the ground, it creates a **high pressure zone**. Air flowing from areas of high pressure to low pressure creates **winds**. The greater the pressure difference between the pressure zones, and the closer together they are, the faster the wind flow. The difference in air pressure, which initiates air movement, is the **pressure gradient force**. Once the air is moving, two additional factors influence the direction of air flow. First, all movement is slowed because of **friction**. Second, air movement over long distances is influenced by the **Coriolis effect.** This gives a total of three components that influence wind direction over long distances.



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Coriolis Effect deflects winds to the right in the northern hemisphere, to the left in the southern hemisphere. At the equator, the earth is rotating 1600 km/h, but more slowly as you get closer to the poles.

The Coriolis effect happens because the fluid air moves at a different speed than the solid earth. At the equator the earth is

moving at about 1000 miles per hour. (Circumference is about 24,000 miles, 24 hours per day, so speed is about 1000 mile per hour). But the speed slows as you near the poles. (Draw a circle 1 m in diameter centered on the north pole and the circumference is 3.14 m so the rotational speed is 3.14 m per *day*, not even per hour). Air moving from the tropics towards the equator comes from a region where the earth moves more slowly and arrives at a region where the earth is moving at its greatest speed. Therefore the earth near the equator moves faster than the arriving air. Since the earth rotates from the west to the east but the air doesn't move as fast (because of insufficient friction) the air actually gets left behind the earth. Humans, however, are solid and move the same speed as the earth so we feel an apparent wind from the east to the west. The general air flow near the equator is from east to west, which is why hurricanes move from Africa to the Caribbean. Going the other direction, air moving from the tropics towards the poles leaves a region that is rotating relatively quickly and arrives at a slower region. Here the air moves generally from the west to the east. In most of the US and Europe our weather comes from the west. These winds are the prevailing westerlies. In the northern hemisphere air appears to be deflected to the right of its initial destination. In the southern hemisphere air is deflected to the left.



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Winds are:

Horizontal air flow, not vertical

Influenced by 1) pressure gradient force, 2) friction, 3) Coriolis effect

Named by the direction they come from

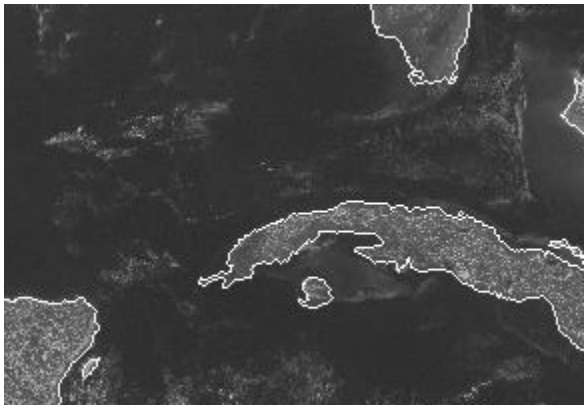
Convection happens because of difference in density. Air density is influenced mostly by heat and humidity. Warmer air holds more water vapor and water molecules have less mass than nitrogen and oxygen molecules so warm, moist air rises while cool, dry air sinks. Convection in the atmosphere creates the planet's weather. When warm air rises and cools in a low pressure zone, it may not be able to hold all the water it contains as vapor. Some water vapor may condense to form clouds or precipitation. When cool air descends, it warms (like the brakes on a car). 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. These global scale are very important to economics, interaction among societies, climate and many other issues. We will return to Global Atmospheric Circulation, but first we'll look at smaller, local pressure systems that create localized winds and affect the weather and climate of a local area.

LOCAL WINDS

Local winds result from air moving between small low and high pressure systems. The Coriolis effect is minimal over the shorter distances. High and low pressure cells are created by a variety of conditions. Some local winds have very important effects on the

weather and climate of some regions.

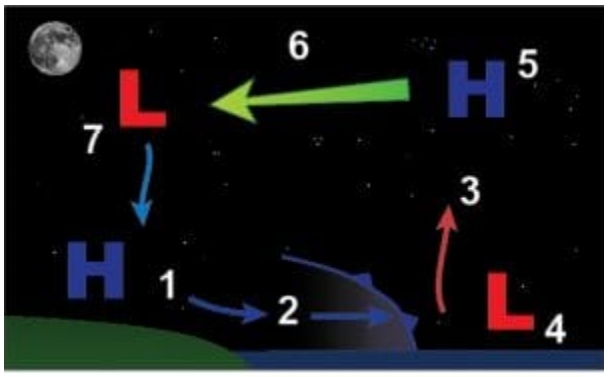
LAND AND SEA BREEZES



Sea Breezes Coming onto Cuba Create a Line of Clouds over the Island.

Since water has a very high specific heat, it maintains its temperature well. So water heats and cools more slowly than land. If there is a large temperature difference between the surface of the sea (or a large lake) and the land next to it, high and low pressure regions form. This creates local winds. **Sea breezes** blow from the cooler ocean over the warmer land in summer. The image to the right depicts the situation during the late afternoon or generally during the summer. The land has warmed and conduction has transferred heat into the air over the land and creates low pressure on land. Sea breezes then blow onto shore at about 10 to 20 km (6 to 12 miles) per hour and lower air temperature much as 5 to 10°C (9 to 18°F).

Land breezes blow from the land to the sea in winter. The high and low pressure centers switch places so warmer air from the ocean rises and then sinks on land. Land and sea breezes create the pleasant climate for which Southern California is known. The effect of land and sea breezes are felt only about 50 to 100 km (30 to 60 miles) inland. This same cooling and warming effect occurs to a smaller degree during day and night, because land warms and cools faster than the ocean. The land breezes are significant in southern California in the fall because they bring fast moving, dry winds which dry out the vegetation and increase the risk of wildfire.



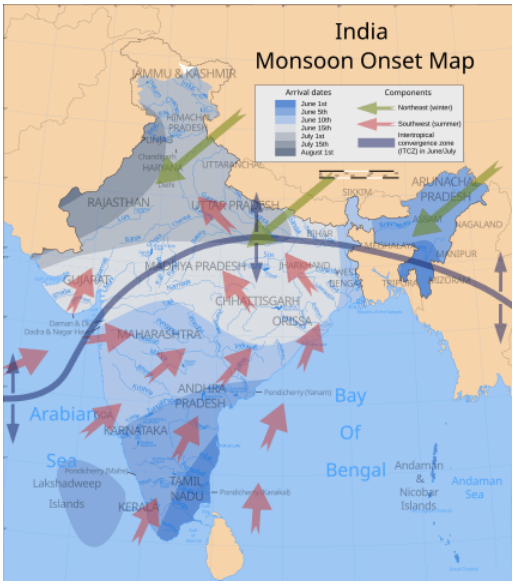
A Land Breeze Happens as Land cools in the evening faster than water cools.

MOUNTAIN AND VALLEY BREEZES

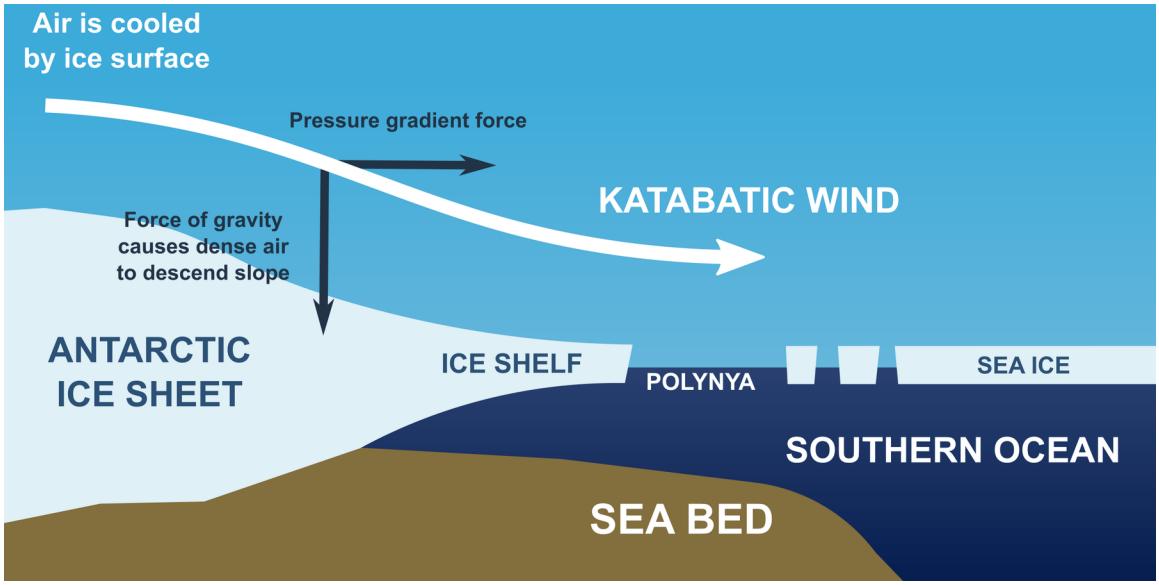
Temperature differences between mountains and valleys create mountain and valley breezes. During the day, air on mountain slopes is heated more than air at the same elevation over an adjacent valley. As the day progresses, warm air rises and draws the cool air up from the valley, creating a **valley breeze**. At night the mountain slopes cool more quickly than the nearby valley, which causes a **mountain breeze** to flow downhill.

In the mountainous Western US, firefighters try to put out fires at night because the air is coming down slopes and is less likely to spread into new fuels.

MONSOONAL WINDS



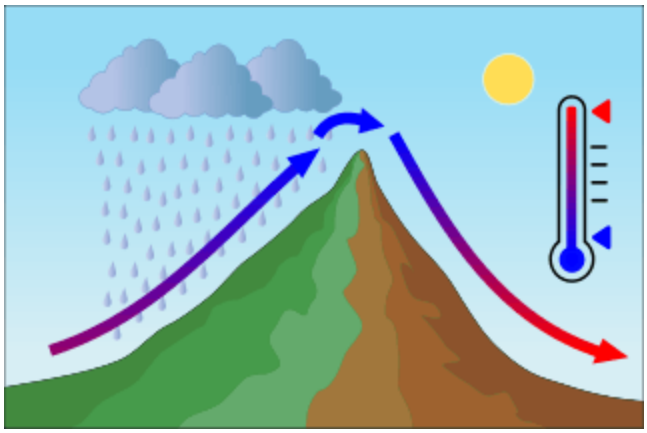
Monsoon winds are larger scale versions of land and sea breezes; they blow from the sea onto the land in summer and from the land onto the sea in winter. This seasonal reversal of wind direction is the true definition of a monsoon, even though most people think “monsoon” means only rain. Monsoon winds occur where very hot summer lands are next to the sea. Thunderstorms are common during monsoons. The most significant monsoon in the world occurs each year over the Indian subcontinent. More than two billion residents of India and southeastern Asia depend on monsoon rains for their drinking and irrigation water. Back in the days of sailing ships, seasonal shifts in the monsoon winds carried goods back and forth between India and Africa.



Katabatic Winds from Antarctica

KATABATIC WINDS

Katabatic winds move up and down slopes, but they are stronger mountain and valley breezes. Katabatic winds form over a high land area, like a high plateau. The plateau is usually surrounded on almost all sides by mountains. In winter, the plateau grows cold. The air above the plateau grows cold and sinks down from the plateau through gaps in the mountains. Wind speeds depend on the difference in air pressure over the plateau and over the surroundings. Katabatic winds form over many continental areas. Extremely cold katabatic winds blow over Antarctica and Greenland.



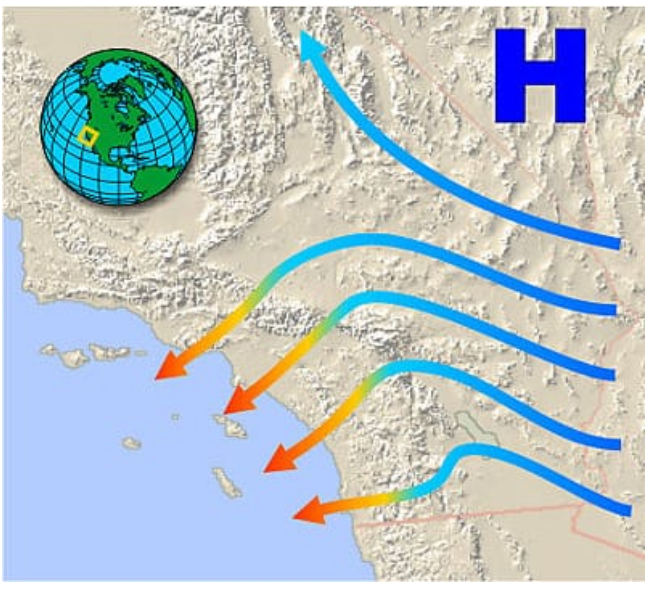
Chinooks are warm dry winds that come down the leeward side of mountains.

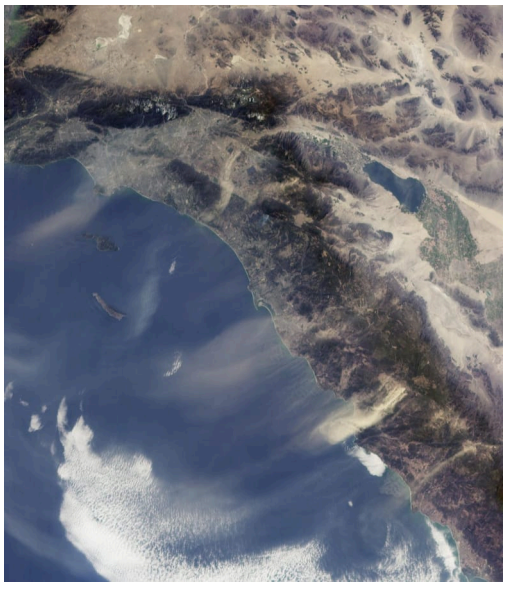
CHINOOK WINDS

Chinook winds, also called **Foehn winds**, develop when air is forced up over a mountain range. This takes place, for example, when the westerly winds bring air from the Pacific Ocean over the Sierra Nevada Mountains and the Cascade range. As the relatively warm, moist air rises over the windward side of the mountains, it cools and contracts. If the air is humid, it may form clouds and drop rain or snow. When the air sinks on the leeward side of the mountains, it forms a high pressure zone. The windward side of a mountain range is the side that receives the wind; the leeward side is the side where air sinks. The descending air warms and creates strong, dry winds. Chinook winds can raise temperatures more than 20°C (36°F) in an hour and they rapidly decrease humidity. Snow on the leeward side of the mountain disappears quickly. If precipitation falls as the air rises over the mountains, the air will be dry as it sinks on the leeward size. This dry, sinking air causes a **rainshadow effect**, which creates many of the world's deserts.

SANTA ANA WINDS

Santa Ana winds are created in the late fall and winter when the Great Basin east of the Sierra Nevada cools, creating a high pressure zone. The high pressure forces winds downhill and in a clockwise direction (because of Coriolis). The air pressure rises, so temperature rises and humidity falls. The winds blow across the Southwestern deserts and then race downhill and westward toward the ocean. Air is forced through canyons cutting the San Gabriel and San Bernardino mountains. The Santa Ana winds often arrive at the end of California's long summer drought season. The hot, dry winds dry out the landscape even more. If a fire starts, it can spread quickly, causing large-scale devastation.





DESERT WINDS



A Haboob in Texas

High summer temperatures on the desert create high winds, which are often associated with monsoon storms. Desert winds pick up dust because there is not as much vegetation to hold down the dirt and sand. A **haboob** forms in the downdrafts on the front of a thunderstorm. **Dust devils**, also called whirlwinds, form as the ground becomes so hot that the air above it heats and rises. Air flows into the low pressure and begins to spin. Dust devils are small and short-lived but they may cause damage. On July 5, 2011 Phoenix, Arizona experienced a large-scale haboob that was captured by many people using their smartphones and cameras. The video below on the left is of that event. The video on the lower right is of a giant dust devil.

GLOBAL ATMOSPHERIC CIRCULATION (GAC)

GLOBAL ATMOSPHERIC PRESSURE

Because more solar energy hits the equator, the air warms and forms a low pressure zone. At the top of the troposphere, half of the air moves toward the North Pole and half toward the South Pole. As it moves along the top of the troposphere, it cools. The air cools, becomes more dense and begins to sink which creates a high pressure zone where it hits the ground. At the ground air spreads outwards from a high pressure center. Some air moves back toward the low pressure at the equator. This describes the convection cells immediately north and south of the equator. If the Earth did not rotate, there would probably be one convection cell in the northern hemisphere and one in the southern with air rising at the equator and sinking only at each pole. 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.

Let's look at atmospheric circulation in the Northern Hemisphere as a result of the Coriolis Effect. Air rises at the equator, but as it 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 is moving.) At about 30°N latitude, the air from the equator meets 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 zone. 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.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. Ultimately, because there are three large-scale convection cells in the Northern Hemisphere and are repeated in the Southern Hemisphere, the model to understand these patterns is called the **three-cell model.**

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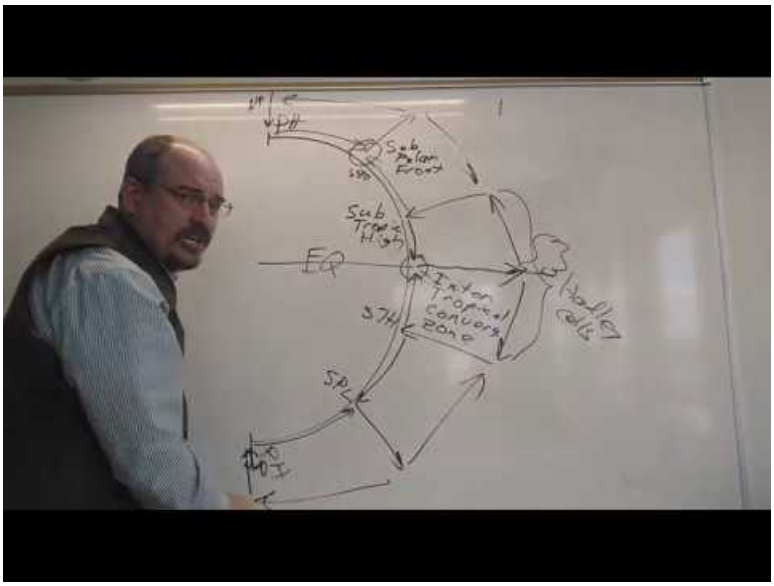
GLOBAL WIND PATTERNS

Global winds blow in belts encircling the planet. The global wind belts are enormous and the winds are relatively steady. These

winds are the result of air movement at the bottom of the major atmospheric circulation cells, where the air moves horizontally from high to low pressure. Technology today allows anyone to see global wind patterns in real-time, such as Earth Wind Map. Take a look at the Earth Wind Map and determine what patterns you can see occurring in the atmosphere in real-time. Are low pressure systems rotating counter-clockwise in the Northern Hemisphere? Are high pressure systems rotating clockwise in the Northern Hemisphere? Can you see the global wind patterns over the Atlantic and Pacific Oceans? Also notice how the winds flow faster over water than over continents because of land friction. Let's look at the global wind belts in the Northern Hemisphere. In the **Hadley cell** air should move north to south, but it is deflected to the right by Coriolis. So the air blows from northeast to the southwest. This belt is the trade winds, so called because at the time of sailing ships they were good for trade.

In the **Ferrel cell** air should move south to north, but the winds actually blow from the southwest. This belt is the westerly winds or westerlies. Why do you think a flight across the United States from San Francisco to New York City takes less time than the reverse trip?

Finally, in the **Polar cell**, the winds travel from the northeast and are called the polar easterlies The wind belts are named for the directions from which the winds come. The westerly winds, for example, blow from west to east. These names hold for the winds in the wind belts of the Southern Hemisphere as well.



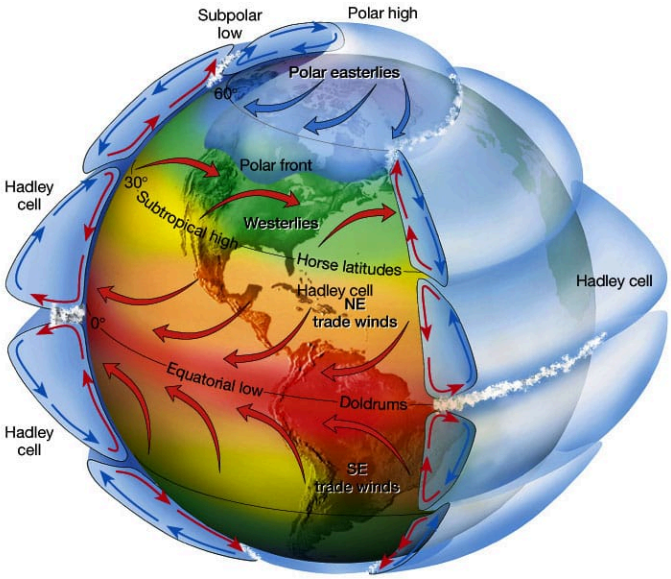
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GLOBAL WINDS AND PRECIPITATION

Besides their effect on the global wind belts, the high and low pressure areas created by the six atmospheric circulation cells determine in a general way the amount of precipitation a region receives. In low pressure regions, where air is rising, rain is common. In high pressure areas, the sinking air causes evaporation and the region is usually dry. More specific climate effects will be described in the chapter about climate.





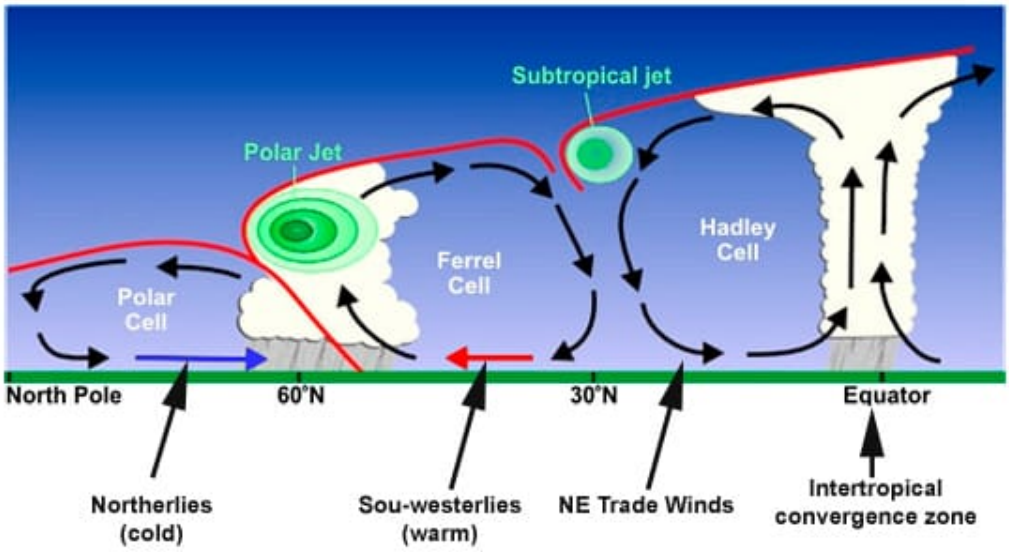


THE POLAR FRONT AND JET STREAMS

The **polar front** is the junction between the Ferrell and Polar cells. At this low pressure zone, relatively warm, moist air of the Ferrell Cell runs into relatively cold, dry air of the Polar cell. The weather where these two meet is extremely variable, 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. 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 just as the angle of the sun in the sky migrates north and south. The polar jet stream, known as "the jet stream," moves south in the winter and north in the summer.



Three Circulation Cells and the associated jet streams.

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1.6: Atmosphere- Air Masses and Storms

Learning Objectives

- Describe the various aspects and elements of weather and atmospheric water.
- Explain how air masses and weather fronts together form mid-latitude cyclones.
- Describe the three phases a thunderstorm goes through in it's life cycle.
- Determine the causes and geographic location of most tornadoes around the world.
- Describe the genesis of hurricanes formation
- Compare the difference between blizzards lake effects, and heat waves.

WEATHER AND ATMOSPHERIC WATER

ELEMENTS OF WEATHER

If someone across country asks you what the weather is like today, you need to consider several factors. Air temperature, humidity, wind speed, the amount and types of clouds, and precipitation are all part of a thorough weather report. In this chapter, you will learn about many of these features in more detail. **Weather** is what is going on in the atmosphere at a particular place at a particular time. Weather can change rapidly. A location's weather depends on air temperature; air pressure; fog; humidity; cloud cover; precipitation; wind speed and direction. All of these are directly related to the amount of energy that is in the system and where that energy is. The ultimate source of this energy is the sun. **Climate** is the average of a region's weather over time. The climate for a particular place is steady, and changes only very slowly. Climate is determined by many factors, including the angle of the Sun, the likelihood of cloud cover, and the air pressure. All of these factors are related to the amount of energy that is found in that location over time.



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HUMIDITY

Humidity is the amount of water vapor in the air in a particular spot. We usually use the term to mean **relative humidity** , the percentage of water vapor a certain volume of air is holding relative to the maximum amount it can contain. If the humidity

today is 80%, it means that the air contains 80% of the total amount of water it can hold at that temperature. What will happen if the humidity increases to more than 100%? The excess water condenses and forms precipitation. Since warm air can hold more water vapor than cool air, raising or lowering temperature can change air's relative humidity. The temperature at which air becomes saturated with water is called the air's dew point. This term makes sense, because water condenses from the air as dew if the air cools down overnight and reaches 100% humidity.

CLOUDS



Clouds have a big influence on weather by preventing solar radiation from reaching the ground; absorbing warmth that is re-emitted from the ground; and as the source of precipitation. When there are no clouds, there is less insulation. As a result, cloudless days can be extremely hot, and cloudless nights can be very cold. For this reason, cloudy days tend to have a lower range of temperatures than clear days.

There are a variety of conditions needed for clouds to form.

- First, clouds form when air reaches its dew point. This can happen in two ways:
  - (1) Air temperature stays the same but humidity increases. This is common in locations that are warm and humid.
  - (2) Humidity can remain the same, but temperature decreases. When the air cools enough to reach 100% humidity, water droplets form. Air cools when it comes into contact with a cold surface or when it rises. Rising air creates clouds when it has been warmed at or near the ground level and then is pushed up over a mountain or mountain range or is thrust over a mass of cold, dense air. Water vapor is not visible unless it condenses to become a cloud.
- Water vapor needs a nucleus to condense on, such as dust, smoke, or a salt crystal. This forms a tiny liquid droplet. Billions of these water droplets together make a cloud.

Clouds are classified in several ways. The most common classification used today divides clouds into four separate cloud groups, which are determined by their altitude and if precipitation is occurring or not.

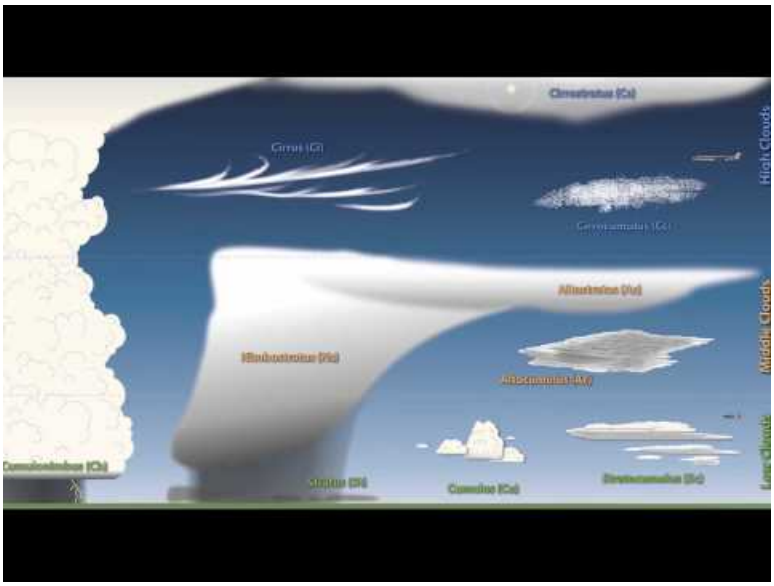
High-level clouds form from ice crystals where the air is extremely cold and can hold little water vapor. Cirrus, cirrostratus, and cirrocumulus are all names of high clouds. Cirrocumulus clouds are small, white puffs that ripple across the sky, often in rows. Cirrus clouds may indicate that a storm is coming.

Middle-level clouds, including altocumulus and altostratus clouds, may be made of water droplets, ice crystals or both, depending on the air temperatures. Thick and broad altostratus clouds are gray or blue-gray. They often cover the entire sky and usually mean a large storm, bearing a lot of precipitation, is coming.

Low-level clouds are nearly all water droplets. Stratus, stratocumulus and nimbostratus clouds are common low clouds. Nimbostratus clouds are thick and dark that produce precipitation. Clouds with the prefix 'cumulo-' grow vertically instead of horizontally and have their bases at low altitude and their tops at high or middle altitude. Clouds grow vertically when strong

unstable air currents are rising upward. Common clouds include cumulus humilis, cumulus mediocris, cumulus congestus, and cumulonimbus.

To learn more about the various types of cloud formations from the National Oceanic and Atmospheric Administration (NOAA), click here .



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FOG



Radiation Fog in the Evening

Fog is a cloud located at or near the ground . When humid air near the ground cools below its dew point, fog is formed. The several types of fog that each form in a different way. **Radiation fog** forms at night when skies are clear and the relative humidity is high. As the ground cools, the bottom layer of air cools below its dew point. Tule fog is an extreme form of radiation fog found in some regions. San Francisco, California, is famous for its summertime **advection fog**. Warm, moist Pacific Ocean air blows over the cold California current and cools below its dew point. Sea breezes bring the fog onshore. **Steam fog** appears in autumn when cool air moves over a warm lake. Water evaporates from the lake surface and condenses as it cools, appearing like steam. Warm humid air travels up a hillside and cools below its dew point to create **upslope fog**.

PRECIPITATION

Precipitation is an extremely important part of weather. Some precipitation forms in place. The most common precipitation comes from clouds. Rain or snow droplets grow as they ride air currents in a cloud and collect other droplets. They fall when they become heavy enough to escape from the rising air currents that hold them up in the cloud. One million cloud droplets will combine to make only one rain drop ! If temperatures are cold, the droplet will hit the ground as a snowflake.



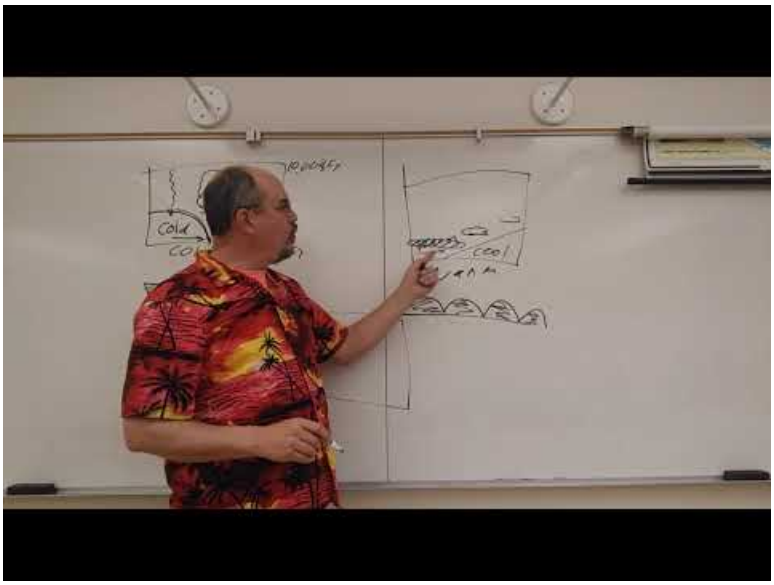
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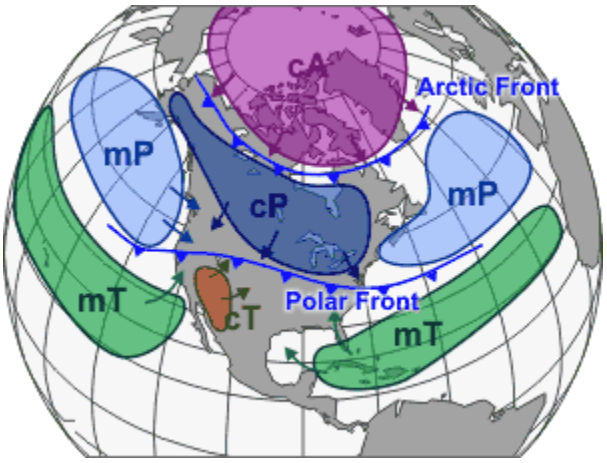
AIR MASSES

An **air mass** is a large body of air that has similar characteristics of *temperature* and *humidity* within it. An air mass acquires these characteristics above an area of land or water known as its source region. When the air mass sits over a region for several days, or longer, it picks up the distinct temperature and humidity characteristics of that region.



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AIR MASS FORMATION

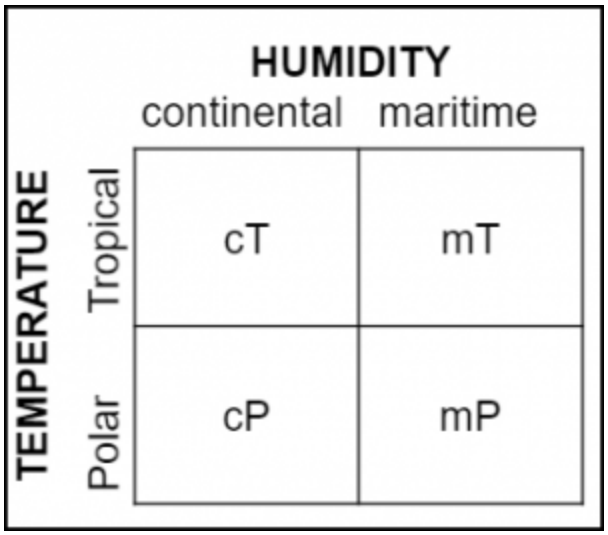


Major Air Mass Source Regions of North America

Where an air mass receives it's characteristics of temperature and humidity is called the **source region**. Air masses are slowly pushed along by high-level winds, when an air mass moves over a new region, it shares its temperature and humidity with that region. The temperature and humidity of a particular location depends partly on the characteristics of the air mass that sits over it. Storms arise if the air mass and the region it moves over have different characteristics. For example, when a colder air mass moves over warmer ground, the bottom layer of air is heated. That air rises, forming clouds, rain, and sometimes thunderstorms.

A temperature inversion happens when a warmer air mass travels over colder ground, the bottom layer of air cools and, because of its high density, is trapped near the ground. Normally, higher altitude air is cooler than lower altitude air, but in a temperature inversion, warmer air is above cooler air.

In general, cold air masses tend to flow toward the equator and warm air masses tend to flow toward the poles. This brings heat to cold areas and cools down areas that are warm. It is one of the many processes that act towards balancing out the planet's temperatures. Air masses are slowly pushed along by high-level winds. When an air mass moves over a new region, it shares its temperature and humidity with that region. So the temperature and humidity of a particular location depends partly on the characteristics of the air mass that sits over it. Air masses are classified based on their temperature and humidity characteristics. Below are examples of how air masses are classified over North America.



Major Air Mass Types in mid-Latitudes

- Maritime tropical (mT) – moist, warm air mass
- Continental tropical (cT) – dry, warm air mass
- Maritime polar (mP) – moist, cold air mass
- Continental polar (cP) – dry, cold air mass

WEATHER FRONTS

When two air masses meet together, the boundary between the two is called a **weather front**. At a front, the two air masses have different densities, based on temperature and humidity, and do not easily mix. One air mass rises above the other, creating a low pressure zone. If the lifted air is moist, there will be condensation and precipitation. Winds are common at a front. The greater the temperature and humidity difference between the two air masses, the stronger the winds will be. Fronts are the main cause of stormy weather. There are four types of fronts. Three are mobile and one is stationary. Fronts are named by the type of new arriving air mass. A cold front is when a cold air mass is displacing a warmer air mass.

STATIONARY FRONTS

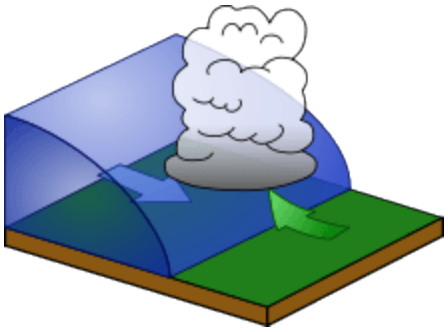
At a **stationary front** the air masses do not move. A front may become stationary if an air mass is stopped by a barrier, such as a mountain range. A stationary front may bring days of rain, drizzle, and fog. Winds usually blow parallel to the front, but in opposite directions. After several days, the front will likely break apart. If the wind picks up documents and envelopes, it's called a stationery front, not to be confused with a stationary front.



Map Symbol of a Stationary Front

COLD FRONTS

Along the cold front, the denser, cold air pushes up the warm air, causing the air pressure to decrease. If the humidity is high enough, some types of cumulus clouds will grow. High in the atmosphere, winds blow ice crystals from the tops of these clouds to create cirrostratus and cirrus clouds. At the front, there will be a line of rain showers, snow showers, or thunderstorms with blustery winds. A **squall line** is a line of severe thunderstorms that forms along a cold front. Generally, a cold front has a steeper angle where the air masses meet and the warm air is forced up both high and faster. This creates tall clouds which quickly release energy in as small space. Expect brief downpours. Behind the front is the cold air mass. This mass is drier so precipitation stops. The weather may be cold and clear or only partly cloudy. Winds may continue to blow into the low pressure zone at the front. The weather at a cold front varies with the season.



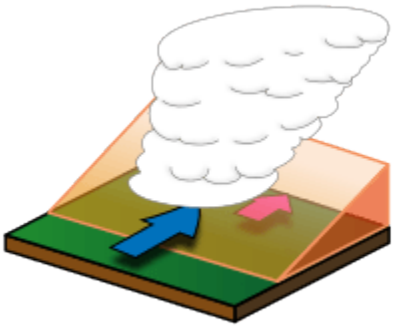
A Cold Front has steep slope with tall clouds.

- spring and summer: The air is unstable so thunderstorms or tornadoes may form.
- spring: If the temperature gradient is high, strong winds blow.
- autumn: Strong rains fall over a large area.
- winter: The cold air mass is likely to have formed in the frigid arctic so there are frigid temperatures and heavy snows.



Map Symbol of a Cold Front

WARM FRONTS



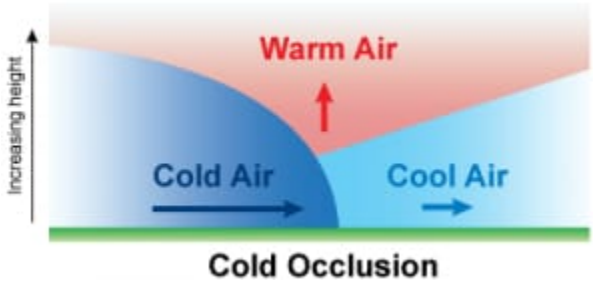
A Warm Front has a gentle slope with clouds over a broad area.

Along a **warm front**, a warm air mass slides over a cold air mass. When warm, less dense air moves over the colder, denser air, the atmosphere is relatively stable. The transition from cold air to warm air takes place gradually over a long distance compared to a cold front so the first signs of changing weather appear long before the front is actually over you. Initially, the air is cold: the cold air mass is above you and the warm air mass is above it. High cirrus clouds mark the transition from one air mass to the other. Over time, cirrus clouds become thicker and cirrostratus clouds form. As the front approaches, altocumulus and altostratus clouds appear and the sky turns gray. In winter, snowflakes fall. The clouds thicken and nimbostratus clouds form. Snowfall increases. Winds grow stronger as the low pressure approaches. As the front gets closer, the cold air mass is just above you but the warm air mass is not too far above that. The weather worsens. As the warm air mass approaches, temperatures rise and snow turns to sleet and freezing rain. Warm and cold air mix at the front, leading to the formation of stratus clouds and fog.



Map Symbol of a Warm Front

OCCLUDED FRONTS



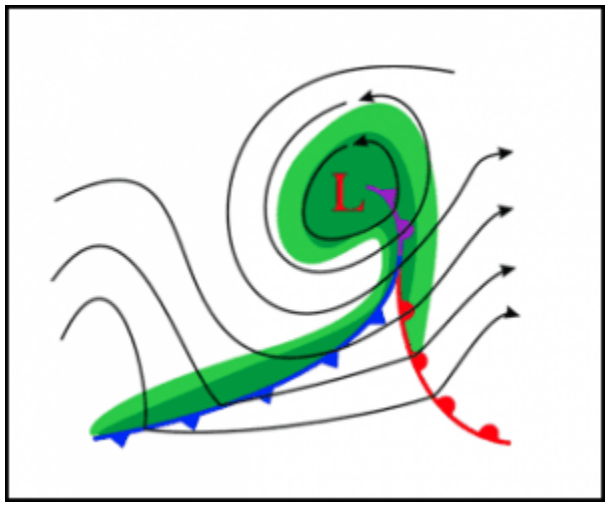
Occluded Front: The Warm Air is lifted off the ground, unstable.

An **occluded front** usually forms around a low pressure system. The occlusion starts when a cold front catches up to a warm front. The air masses, in order from front to back, are cold, warm, and then cold again. The Coriolis Effect curves the boundary where the two fronts meet towards the pole. If the air mass that arrives third is colder than either of the first two air masses, that air mass slips beneath them both. This is called a cold occlusion. If the air mass that arrives third is warm, that air mass rides over the other air mass. This is called a warm occlusion. The weather at an occluded front is especially fierce right at the occlusion. Precipitation and shifting winds are typical. A single occluded front in the fall and winter can impact a region from Hudson Bay to the Gulf Mexico and produce several feet of snow in severe cases.



Map Symbol of an Occluded Front

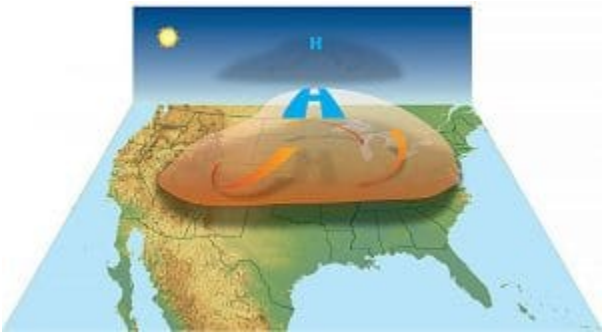
At the center of each air mass is typically a high pressure. Where these air masses meet is a weather front. When they meet, one mass rises and creates a local low pressure along the front. This means that weather is typically sunny within air masses, but their temperatures could vary with the season and humidity could vary based on the source region of the air mass.



Often, several weather fronts interact with other fronts. Together, they form a larger rotating system called a mid-latitude cyclone. This type of cyclone will be discussed later in this chapter, but as an introduction it is a low pressure system that is usually mixing warmer air from the south (in the Northern Hemisphere) and colder air from the north.

EXTREME WEATHER

HEAT WAVES



Heat Dome. High Pressure keeps hot air near surface.

Even more insidious are the deadliest weather phenomena, a **heat wave**. A heat wave is different for different locations; it is a long period of hot weather, at least 86° F (30° C) for at least three days in cooler locations but much more in hotter locations. Heat waves have increased in frequency and duration in recent years. In the image to the right, a high pressure zone kept the jet stream further north than normal for August which allow hot air to shift far north.

THUNDERSTORMS



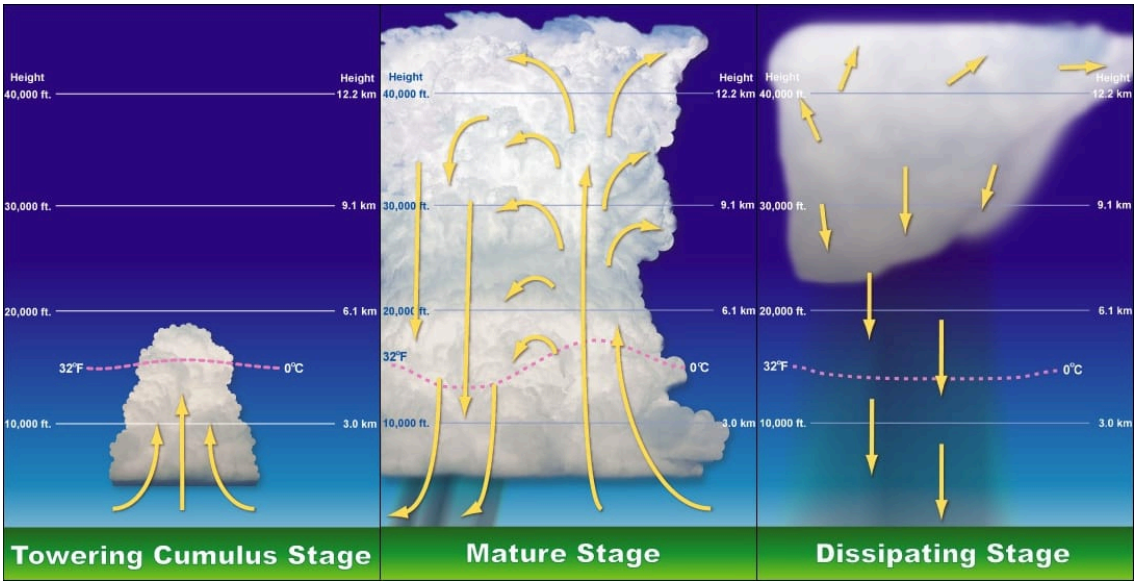
Weather happens every day, but only some days have storms. Storms vary immensely depending on whether they're warm or cold, coming off the ocean or off a continent, occurring in summer or winter, and many other factors. The effects of storms also vary depending on whether they strike a populated area or a natural landscape. Hurricane Katrina is a good example, since the flooding after the storm severely damaged New Orleans, while a similar storm in an unpopulated area would have done little damage. **Thunderstorms** are extremely common: Worldwide there are 14 million per year; that's 40,000 per day! Most drop a lot of rain on a small area quickly, but some are severe and highly damaging. They form when ground temperatures are high, ordinarily in the late afternoon or early evening in spring and summer. The two figures below show two stages of thunderstorm buildup.

THUNDERSTORM GENESIS

All thunderstorms go through a three-stage life cycle. The first stage is called the **cumulus stage**, where an air parcel is forced to rise, cool, and condense and develop into a cumulus cloud. Water vapor condenses at the altitude called the Lifting Condensation Level. The exact altitude for condensation varies depending on temperature and humidity (relative humidity) of the rising air parcel. The process of water vapor condensing into liquid water releases large quantities of latent heat, which makes the air within

the cloud warmer, and unstable. The instability causes the cloud to continue to grow upward like a hot air balloon. These rising air parcels, called updrafts, prevent small water droplets from falling from the cloud. But once the water droplets become too large heavy for the updrafts to hold up, the moisture begins to fall as precipitation and downdrafts happen within the cloud. The downdrafts also begin to pull cold, dry air from outside the cloud toward the ground in a process called **entrainment**. Once the precipitation begins to fall from the cloud, the storm has reached the **mature stage**. During this stage, updrafts and downdrafts exist side-by-side and the cumulonimbus is called a **cell**. If the updrafts reach the top of the troposphere, the cumulus cloud will begin to spread outward creating a defined **anvil**. At the same time, the downdrafts spread within the cloud and at first make the cloud become wider, but eventually overtaking the updrafts. Cool downdrafts form when precipitation and the cool air from entrainment are dragged down to the lower regions of a thunderstorm. It is also during the mature stage when the storm is most intense producing strong, gusting winds, heavy precipitation, lightning, and possibly small hail.

Once the downdrafts overtake the updrafts, which also prevents the release of latent heat energy, the thunderstorm will begin to weaken into the third and final stage, called the **dissipating stage**. During this stage, light precipitation and downdrafts become the dominate feature within the cloud as it weakens. In all, only twenty percent of the moisture within the cloud fell as precipitation whereas the other eighty percent evaporates back into the atmosphere.





A Maturing Cumulonimbus cloud.

With severe thunderstorms, the downdrafts are so intense that when they hit the ground it sends warm air from the ground upward into the storm. The warm air gives the convection cells more energy. Rain and hail grow huge before gravity pulls them to Earth. Severe thunderstorms can last for hours and can cause a lot of damage because of high winds, flooding, intense hail,

and tornadoes. Thunderstorms can form individually or in squall lines along a cold front. In the United States, squall lines form in spring and early summer in the Midwest where the maritime tropical (mT) air mass from the Gulf of Mexico meets the continental polar (cP) air mass from Canada. So much energy collects in cumulonimbus clouds that a huge release of electricity, called **lightning**, may result. The electrical discharge may be between one part of the cloud and another, two clouds, or a cloud and the ground. Lightning heats the air so that it expands explosively. The loud clap is thunder. Light waves travel so rapidly that lightning is seen instantly. Sound waves travel much more slowly, so a thunderclap may come many seconds after the lightning is spotted. Thunderstorms kill approximately 200 people in the United States and injure about 550 Americans per year, mostly from lightning strikes. Have you heard the common misconception that lightning doesn't strike the same place twice? In fact, lightning strikes the New York City's Empire State Building about 100 times per year..

Tornadoes

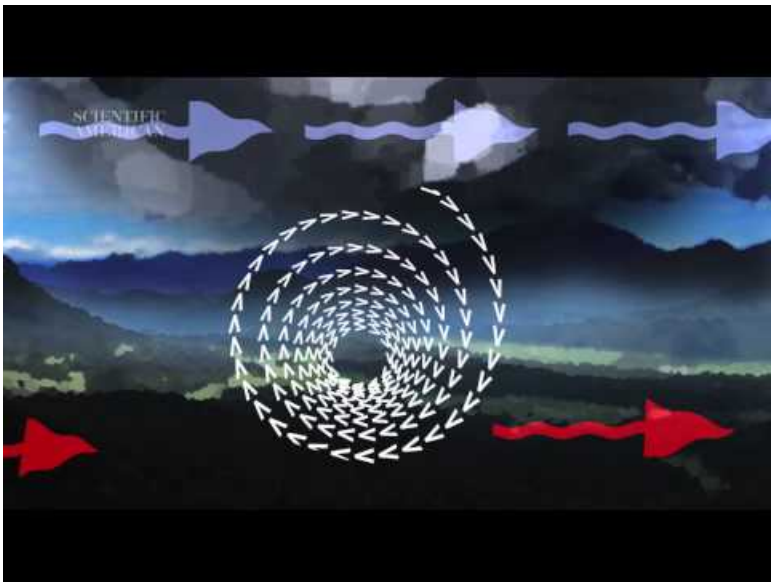


Tornadoes, also called twisters, are fierce products of severe thunderstorms. As air in a thunderstorm rises, the surrounding air races in to fill the gap, forming a funnel. A tornado lasts from a few seconds to several hours. The average wind speed is about 177 kph (110 mph), but some winds are much faster. A tornado travels over the ground at about 45 km per hour (28 miles per hour) and goes about 25 km (16 miles) before losing energy and disappearing.

An individual tornado strikes a small area, but it can destroy everything in its path. Most injuries and deaths from tornadoes are caused by flying debris. In the United States an average of 90 people are killed by tornadoes each year. The most violent two percent of tornadoes account for 70% of the deaths by tornadoes. Tornadoes form at the front of severe thunderstorms. Lines of these thunderstorms form in the spring where where maritime tropical (mT) and continental polar (cP) air masses meet. Although there is an average of 770 tornadoes annually, the number of tornadoes each year varies greatly.



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In late April 2011, the situation was ripe for the deadliest set of tornadoes in 25 years. In addition to the meeting of cP and mT mentioned above, the jet stream was blowing strongly in from the west. The result was more than 150 tornadoes reported throughout the day. The entire region was alerted to the possibility of tornadoes in those late April days. But meteorologists can only predict tornado danger over a very wide region. No one can tell exactly where and when a tornado will touch down. Once a tornado is sighted on radar, its path is predicted and a warning is issued to people in that area. The exact path is unknown because tornado movement is not very predictable.

Since 2007, the intensity of tornadoes is assigned with the Enhanced Fujita Scale, which assigns a value based on both wind speed and damage. Prior to 2007, the (non-Enhanced) Fujita scale used only wind speed. However humans aren't necessarily interested in wind speed, we want to know what the impact of the wind will be. So the Enhanced Fujita Scale includes building damage.

The average diameter of tornadoes is about 50 meters, with the record largest being 2.5 miles. The clouds above the funnel cloud

will be much larger.

EF-Scale	3 Second Gust (mph)	Damage
EF0 (Gale)	65-85	Light – tree branches fall and chimneys may collapse
EF1 (Weak)	86-110	Moderate – mobile homes, automobiles pushed aside
EF2 (Strong)	111-135	Considerate – roofs torn off houses, large trees uprooted
EF3 (Severe)	136-165	Severe – houses torn apart, trees uprooted, cars lifted
EF4 (Devastating)	166-200	Devastating – houses leveled, cars thrown
EF5 (Incredible)	Over 200	Incredible – structures fly, cars become missiles

Cyclones

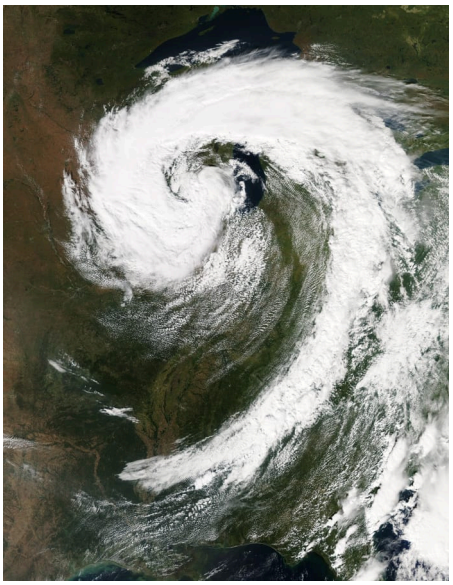
Cyclones can be the most intense storms on Earth. A **cyclone** is a system of winds rotating counterclockwise in the Northern Hemisphere around a low pressure center. In the Southern Hemisphere a cyclone rotates clockwise. The swirling air rises and cools, creating clouds and precipitation.

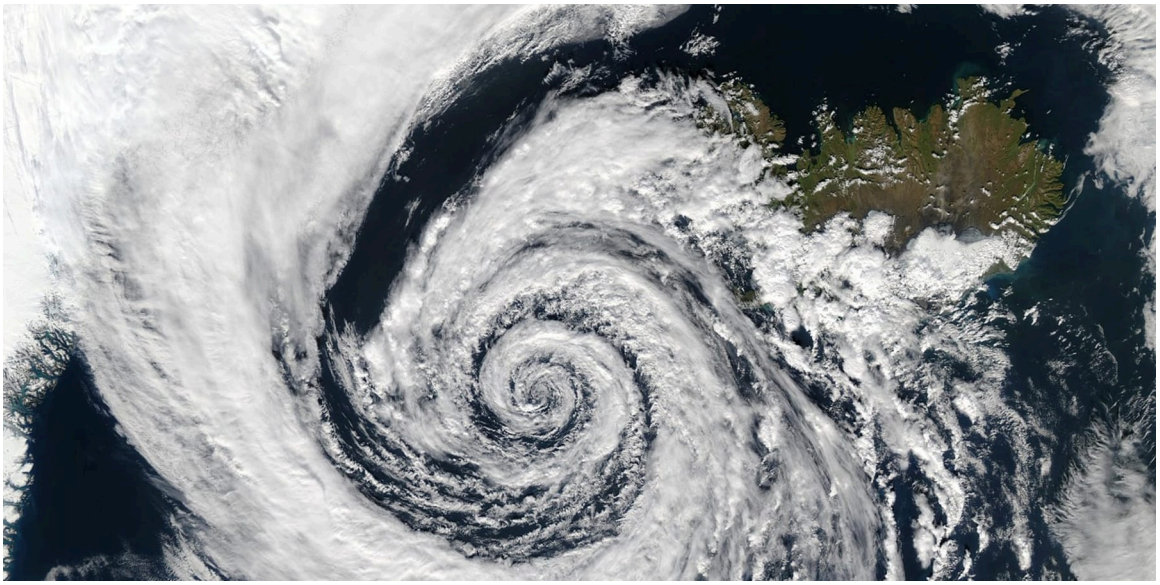
There are two types of cyclones: middle latitude (mid-latitude) cyclones and tropical cyclones. Mid-latitude cyclones are the main cause of winter storms in the middle latitudes. Tropical cyclones are also known as hurricanes.

An **anticyclone** is the opposite of a cyclone. An anticyclone's winds rotate clockwise in the Northern Hemisphere around a center of high pressure. Air comes in from above and sinks to the ground. High pressure centers generally have clear weather.

MID-LATITUDE CYCLONES

Mid-latitude cyclones, sometimes called **extratropical cyclones**, form at the polar front when the temperature difference between two air masses is large. These air masses blow past each other in opposite directions. Coriolis Effect deflects winds to the right in the Northern Hemisphere, causing the winds to strike the polar front at an angle. Warm and cold fronts form next to each other. Most winter storms in the middle latitudes, including most of the United States and Europe, are caused by mid-latitude cyclones. The warm air at the cold front rises and creates a low pressure cell. Winds rush into the low pressure and create a rising column of air. Since the rising air is moist, rain or snow falls. Mid-latitude cyclones form in winter in the mid-latitudes and move eastward with the westerly winds. These two- to five-day storms can reach 1,000 to 2,500 km (625 to 1,600 miles) in diameter and produce winds up to 125 km (75 miles) per hour. Like tropical cyclones, they can cause extensive beach erosion and flooding. Mid-latitude cyclones are especially fierce in the mid-Atlantic and New England states where they are called **nor'easters**, because they come from the northeast. About 30 nor'easters strike the region each year.





Cyclones in the Northern and Southern Hemispheres.

TROPICAL CYCLONES: HURRICANES



Humberto (NOAA 2019)

Tropical cyclones have many names. They are called hurricanes in the North Atlantic and eastern Pacific oceans, typhoons in the western Pacific Ocean, tropical cyclones in the Indian Ocean, and willi-willi's in the waters near Australia. By any name, they are the most damaging storms on Earth. Hurricanes arise in the tropical latitudes (between 10° and 25 ° N) in summer and

autumn when sea surface temperature are 28°C (82°F) or higher. The warm seas create a large humid air mass. The warm air rises and forms a low pressure cell, known as a tropical depression. Thunderstorms materialize around the tropical depression. If the temperature reaches or exceeds 28° C (82° F) the air begins to rotate around the low pressure. As the air rises, water vapor condenses, releasing energy from latent heat. If wind shear (upper atmosphere winds) is low, the storm builds into a hurricane within two to three days. Hurricanes are huge with high winds. The exception is the relatively calm eye of the storm where air is rising upward. Rainfall can be as high as 2.5 cm (1″) per hour, resulting in about 20 billion metric tons of water released daily in a hurricane. The release of latent heat generates enormous amounts of energy, nearly the total annual electrical power consumption of the United States from one storm. Hurricanes can also generate tornadoes.



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Hurricanes are strange creatures because they are deadly monsters, yet have a gentle, but cold heart. The anatomy of a hurricane is fairly simple, though the processes involved are quite complex. As a low pressure disturbance forms, the warm, moist air rushes towards the low pressure in order to rise upward to form towering thunderstorms. Around the low pressure disturbance is a wall of clouds called an **eye wall** . Within the eye wall, the wind speeds are greatest, the clouds are the tallest, atmospheric pressure

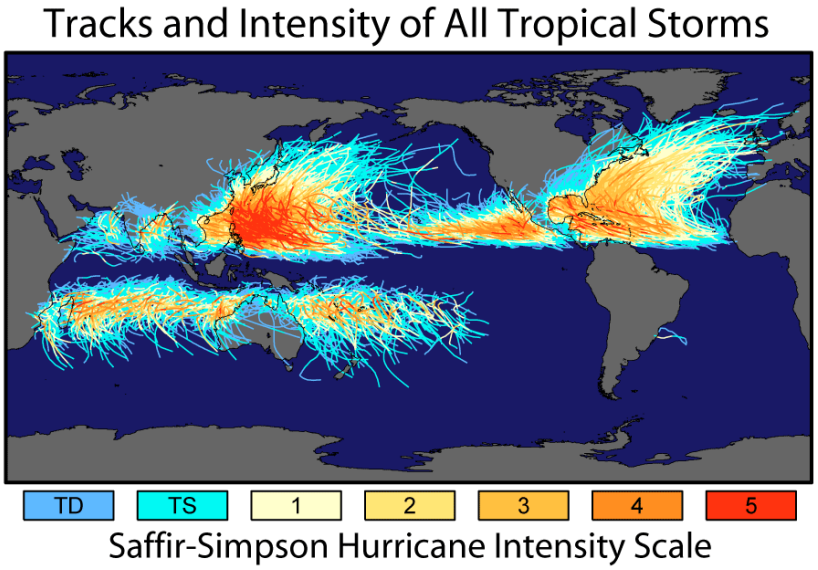
is at its lowest, and precipitation is most intense.

At the center or heart of the hurricane is called the **eye**. Within the eye of a hurricane, winds are light, precipitation is minimal, and occasionally the skies above are clear. It is the calm region of the tropical storm, but that is what makes it so dangerous. Many people tend to go outside as the eye moves overhead because they believe the storm is over. But what some don't realize is that "round two" is coming from behind.

Moving away from the eye wall are organized, intense thunderstorms, called **spiral rain bands**, that rotate around and toward the storm's eye wall. These rain bands are the first

Hurricanes are assigned to categories based on their wind speed. The categories are listed on the **Saffir-Simpson Scale**.

Category	**MPH**	**Estimated Damage**
1 (Weak)	74-95	Above normal; no read damage to structures
2 (Moderate)	96-110	Some property damage; considerable damage to vegetation
3 (Strong)	111-130	Some buildings damaged; mobile homes destroyed
4 (Very strong)	131-156	Complete roof failure on small residences; major beach erosion of beach areas
5 (Devastating)	Over 156	Complete roof and some building failure on most residential and industrial buildings



Location of Tropical Cyclones

Hurricanes move with the prevailing winds. In the Northern Hemisphere, they originate in the trade winds and move to the west. When they reach the latitude of the westerlies, they switch direction and travel toward the north or northeast. Hurricanes may cover 800 km (500 miles) in one day. Damage from hurricanes comes from the high winds, rainfall, and storm surge. **Storm surge** occurs as the storm's low pressure center comes onto land, causing the sea level to rise unusually high. A storm surge is often made worse by the hurricane's high winds blowing seawater across the ocean onto the shoreline. Flooding can be devastating, especially along low-lying coastlines such as the Atlantic and Gulf Coasts. Hurricane Camille in 1969 had a 7.3 m (24 foot) storm surge that traveled 125 miles (200 km) inland. Hurricanes typically last for 5 to 10 days. Over cooler water or land, the hurricane's latent heat source shut downs and the storm weakens. When a hurricane disintegrates, it is replaced with intense rains and tornadoes.

There are about 100 hurricanes around the world each year, plus many smaller tropical storms and tropical depressions. As people develop coastal regions, property damage from storms continues to rise. However, scientists are becoming better at predicting

the paths of these storms and fatalities are decreasing. There is, however, one major exception to the previous statement: Hurricane Katrina.

For over a decade, the conversation in the United States over hurricanes was directed toward Hurricane Katrina. But in late October 2012, a Category 3 hurricane called Hurricane Sandy, sometimes called Superstorm Sandy, struck the eastern coast of the United States. It is estimated that the storm system caused $68 billion in damage and killed nearly 300 people.

What made Hurricane Sandy different from most tropical storms was how powerful it was so late in the hurricane season. The concern is that as the planet warms from anthropogenic (human-enhanced) climate change, the oceans will likely warm up allow hurricanes to become stronger, travel farther toward the poles, and the hurricane season last longer.

To view an interactive map on hurricanes created by the National Oceanic and Atmospheric Administration, click here . Map is only operational during active hurricane season.

WEATHER, CLIMATE, AND LANDFORMS

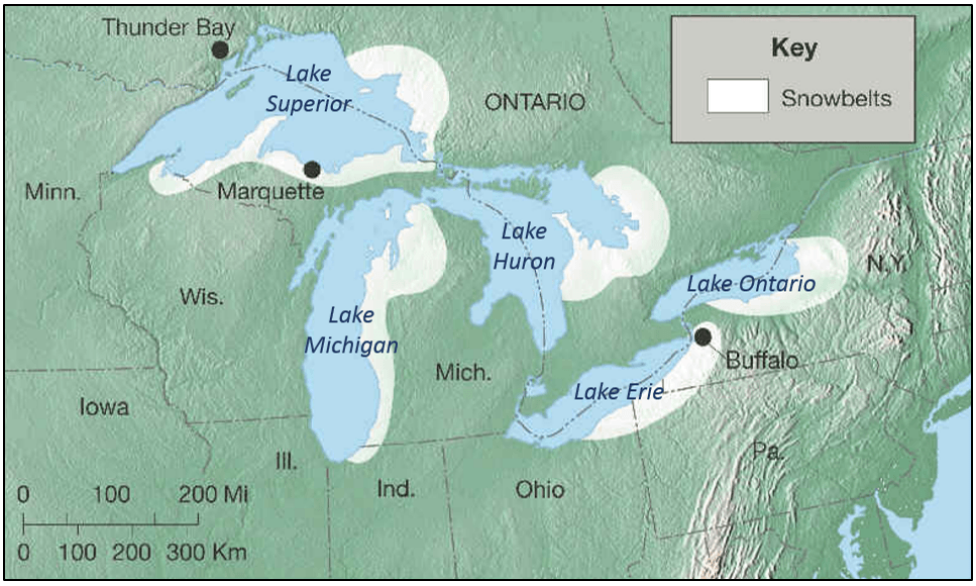
BLIZZARDS AND LAKE EFFECTS

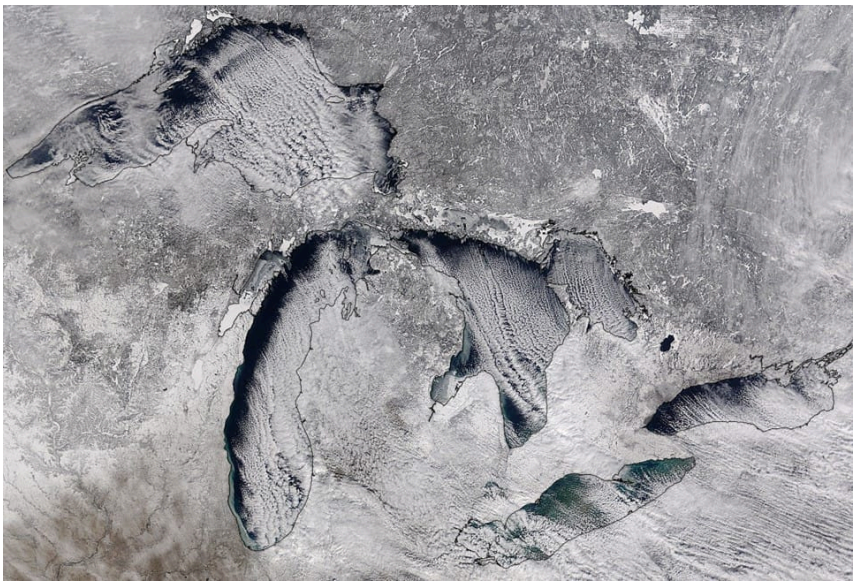
A **blizzard** is distinguished by certain conditions:

- Temperatures below –7°C (20° F); –12°C (10° F) for a severe blizzard.
- Winds greater than 56 kmh (35 mph); 72 kmh (45 mph) for a severe blizzard.
- Snow so heavy that visibility is 2/5 km (1/4 mile) or less for at least three hours; near zero visibility for a severe blizzard.

Blizzards happen across the middle latitudes and toward the poles, usually as part of a mid-latitude cyclone. Blizzards are most common in winter, when the jet stream has traveled south and a cold, northern air mass comes into contact with a warmer, semitropical air mass. The very strong winds develop because of the pressure gradient between the low pressure storm and the higher pressure west of the storm. Snow produced by the storm gets caught in the winds and blows nearly horizontally. Blizzards can also produce **sleet** or **freezing rain**.

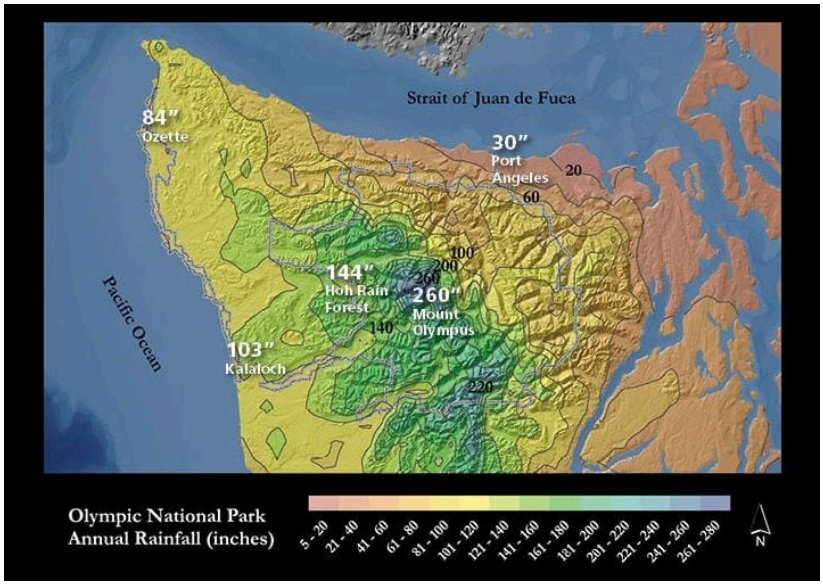
In winter, a continental polar air mass travels down from Canada. As the frigid air travels across one of the Great Lakes, it warms and absorbs moisture. When the air mass reaches the leeward side of the lake, it is very unstable and it drops tremendous amounts of snow. This **lake-effect snow** falls on the snowiest, metropolitan areas in the United States: Buffalo and Rochester, New York. If the lakes have frozen over, then there's less moisture moving from the lakes to the air mass, and there's less snow.





RAINSHADOW (OROGRAPHIC EFFECT)

Air masses coming off the ocean to the land are generally humid, especially if the ocean is warm. That humid air has enough energy to keep water in vapor form but as air rises, it loses energy and cools. If the air rises high enough the air loses enough energy, some of the water vapor will condense and form clouds, perhaps leading to precipitation. One way air rises is when it's forced to go up and over a mountain. Air coming down the opposite side is gaining kinetic energy (going faster) and is able to hold water in vapor form. The ocean side of the the mountain gets precipitation while the land side is dryer.



Precipitation Map for Olympic Peninsula (NPS)

COLLECTING WEATHER DATA

Weather forecasts are better than they ever have been. According to the World Meteorological Organization (WMO), a 5-day weather forecast today is as reliable as a 2-day forecast was 20 years ago! This is because forecasters now use advanced technologies to gather weather data, along with the world's most powerful computers. Together, the data and computers produce complex models that more accurately represent the conditions of the atmosphere. These models can be programmed to predict how the atmosphere and the weather will change. Despite these advances, weather forecasts are still often incorrect. Weather is extremely difficult to predict because it is a complex and chaotic system.

To make a weather forecast, the conditions of the atmosphere must be known for that location and for the surrounding area. Temperature, air pressure, and other characteristics of the atmosphere must be measured and the data collected.

THERMOMETER

Thermometers measure temperature. In an old-style mercury thermometer, mercury is placed in a long, very narrow tube with a bulb. Because mercury is temperature sensitive, it expands when temperatures are high and contracts when they are low. A scale on the outside of the thermometer matches up with the air temperature. Some modern thermometers use a coiled strip composed of two kinds of metal, each of which conducts heat differently. As the temperature rises and falls, the coil unfolds or curls up tighter. Other modern thermometers measure infrared radiation or electrical resistance. Modern thermometers usually produce digital data that can be fed directly into a computer.

BAROMETER

Meteorologists use **barometers** to measure air pressure. A barometer may contain water, air, or mercury, but like thermometers, barometers are now mostly digital. A change in barometric pressure indicates that a change in weather is coming. If air pressure rises, a high pressure cell is on the way and clear skies can be expected. If pressure falls, a low pressure cell is coming and will likely bring storm clouds. Barometric pressure data over a larger area can be used to identify pressure systems, fronts, and other weather systems.

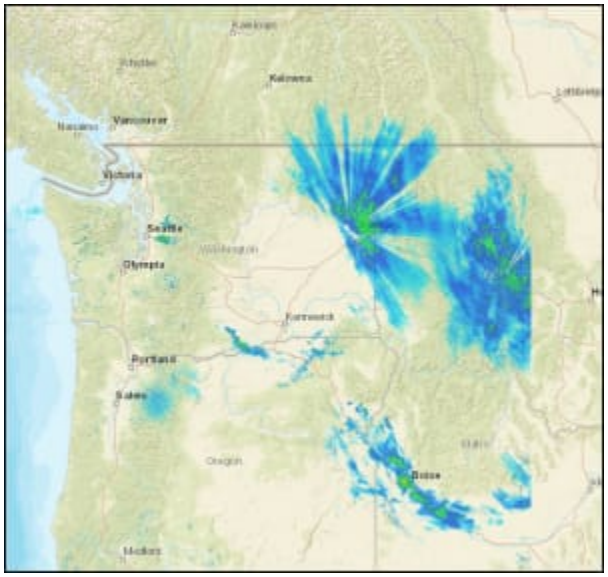
WEATHER STATIONS



Weather Station at WSU, Pullman, WA.

Weather stations contain some type of thermometer and barometer. Other instruments measure different characteristics of the atmosphere such as wind speed, wind direction, humidity, and amount of precipitation. These instruments are placed in various locations so that they can check the atmospheric characteristics of that location. According to the WMO, weather information is collected from 15 satellites, 100 stationary buoys, 600 drifting buoys, 3,000 aircraft, 7,300 ships, and some 10,000 land-based stations. The official weather station used by the National Weather Service is called the Automated Surface Observing System (ASOS).RADIOSONDESA **radiosonde** is a balloon that measures atmospheric characteristics, such as temperature, pressure, and humidity as it moves through the air. Radiosondes in flight can be tracked to obtain wind speed and direction. Radiosondes use a radio to communicate the data they collect to a computer. Radiosondes are launched from about 800 sites around the globe twice daily to provide a profile of the atmosphere. Radiosondes can be dropped from a balloon or airplane to make measurements as they fall. This is done to monitor storms, for example, since they are dangerous places for airplanes to fly.

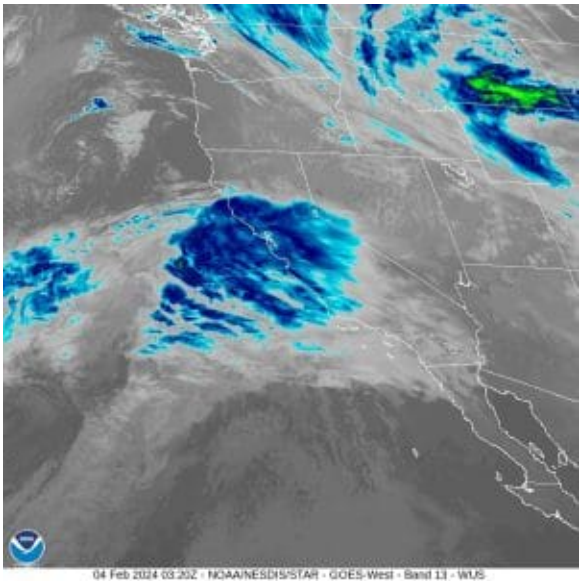
RADAR



Radar for Pacific Northwest. The star pattern around Spokane is centered on the radar instrument.

Radar stands for Radio Detection and Ranging. A transmitter sends out radio waves that bounce off the nearest object and then return to a receiver. Weather radar can sense many characteristics of precipitation: its location, motion, intensity, and the likelihood of future precipitation. Doppler radar can also track how fast the precipitation falls. Radar can outline the structure of a storm and can be used to estimate its possible effects.

SATELLITES



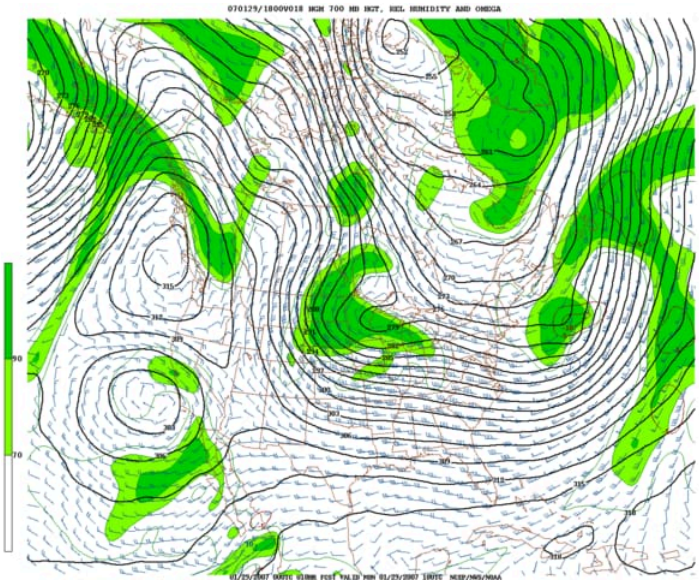
Weather satellites have been increasingly important sources of weather data since the first one was launched in 1952 and are the best way to monitor large scale systems, such as storms. Satellites are able to record long-term changes, such as the amount of ice cover over the Arctic Ocean in September each year. They also observe all energy from all wavelengths in the electromagnetic spectrum. The flagship of the National Weather Service is the Geostationary Operational Environmental Satellites (GOES). These satellites are the ones you see on the nightly news where it looks like the clouds are moving, but not the planet. That is because these satellites are “geo-fixed” on a particular location over Earth rotating around the planet as fast as Earth’s rotation at a distance of over 23,000 miles above the planet. There are basically three different types of GOES: visible, infrared, and water vapor. Visible light images record storms, clouds, fires, and smog. Infrared images record clouds, water and land temperatures, and features of the ocean, such as ocean currents**.** The final type of GOES imagery is water vapor. This type of imagery looks at the moisture content in the upper-half of the atmosphere. This is important for determining if clouds can grow to great heights

like cumulonimbus thunderstorms.

The other type of satellite commonly used in weather forecasting is called a Polar Orbiting Environmental Satellites (POES). These types of satellites fly much lower to the earth, only about 530 miles, and orbit the planet pole-to-pole. You've probably seen these satellites at night when you see one crossing the sky. Look for their direction and odds are they are moving northward or southward toward each pole.

Just like the weather satellites on the news, you've seen these images often when you are looking at natural disasters like hurricanes or volcanic eruptions, wars like have occurred in Afghanistan, Iraq, or recently in Syria. Even the Malaysian flight that "disappeared" in the Indian Ocean for weeks was ultimately discovered using polar orbiting satellites. Common types of these satellites include: Landsat, MODIS, and the Tropical Rainfall Measuring Mission (TRMM).

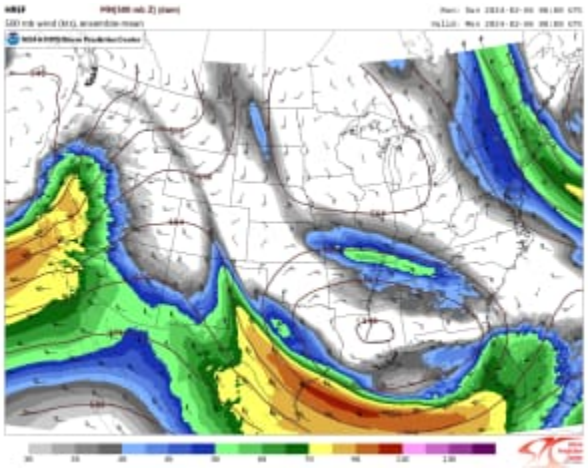
NUMERICAL WEATHER PREDICTION



The most accurate weather forecasts are made by advanced computers, with analysis and interpretation added by experienced meteorologists. These computers have up-to-date mathematical models that can use much more data and make many more calculations than would ever be possible by scientists working with just maps and calculators. Meteorologists can use these results to give much more accurate weather forecasts and climate predictions. In Numerical Weather Prediction (NWP), atmospheric data from many sources are plugged into supercomputers running complex mathematical models. The models then calculate what will happen over time at various altitudes for a grid of evenly spaced locations. The grid points are usually between 10 and 200 km apart. Using the results calculated by the model, the program projects weather further into the future. It then uses these results to project the weather still further into the future, as far as the meteorologists want to go. Once a forecast is made, it is broadcast by satellites to more than 1,000 sites around the world. NWP produces the most accurate weather forecasts, but as anyone knows, even the best forecasts are not always right. Weather prediction is extremely valuable for reducing property damage and even fatalities. If the proposed track of a hurricane can be predicted, people can try to secure their property and then evacuate.



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Windspeeds at 500mbar pressure. Pineapple Express hitting California

Once conditions have been plotted, points of equal value can be connected by isolines. Weather maps can have many types of connecting lines. For example:

- **Isotherms**, likes connecting points of equal temperature. They spatially show temperature gradients and can indicate the location of a front. In terms of precipitation, what does the 0°C (32°F) isotherm show?
- **Isobars** are lines of equal average air pressure at sea level. Closed isobars represent the locations of high and low pressure cells.
- **Isotachs** are lines of constant wind speed. Where the minimum values occur high in the atmosphere, tropical cyclones may develop. The highest wind speeds can be used to locate the jet stream.

Surface weather analysis maps are weather maps that only show conditions on the ground**.** However, maps showing conditions at various altitudes in the atmosphere are also created to help pilots and general weather forecasting.

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1.7: Oceans and Coastal Environments

Learning Objectives

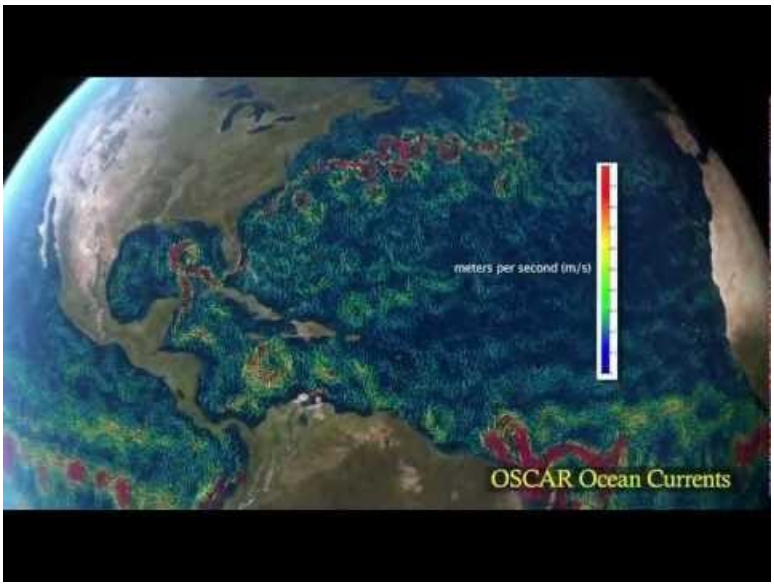
- Describe the significance of the ocean and how it influences weather and climate.
- Explain the different layers of the ocean.
- Understand the basic physics of ocean waves.
- Compare and contrast the differences between surface and deep ocean currents.

Environmental Questions

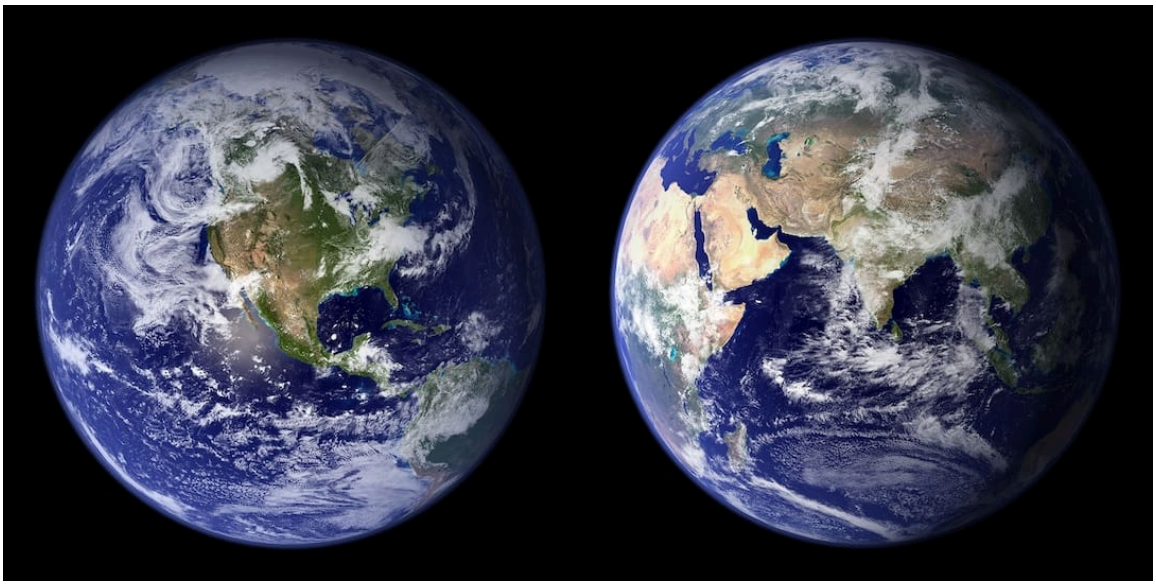
Based on scientific data, some scientists have hypothesized that if enough ice from Greenland melts, the Gulf Stream might be shut down. The logic is that too much fresh water could flow into the ocean, changing the salt water it would disrupt the salt and fresh water distribution. Why might this happen and how could it influence places like Europe?

SIGNIFICANCE OF THE OCEANS

The oceans make up 70 percent of the planet and contains 97 percent of all the water on Earth. It also makes up the vast majority of water stores the majority of the planet's moisture, terrestrial energy, and heat from the Sun. This energy is transferred between the equator and the two poles by larger surface currents by winds and deep ocean currents driven by differences in ocean density. It also provides the moisture and energy for storm systems and ultimately global climates. **Phytoplankton**, microscopic plants and animals in the oceans provide the foundation of the global **food web** of species. The earth's oceans are so vital for life that over 40 percent of the world's population live near coastal areas.



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The Blue Marble, captured by NASA in 2001.

MODERATE CLIMATES

As terrestrial creatures, humans think of the importance of the planet's land surfaces, yet Earth is a planet consisting of 70 percent water. From space, the dominance of water is obvious because most of it is stored in Earth's oceans. Earth would not be the same planet without its oceans. The oceans, along with the atmosphere, keep Earth's surface temperatures fairly constant worldwide. Some places on Earth reach as cold as -7 °Celsius, whereas other places reach as hot as 55 °Celsius. Yet on other planets like Mercury, temperatures range from -180 °Celsius to 430 °Celsius. The oceans, along with the atmosphere, distribute heat around the planet. The oceans absorb heat near the equator and then transport that solar energy to polar regions. The oceans also moderate climate within a region. At the same latitude, the temperature range is smaller along coastal areas compared to areas farther inland. Along coastal areas, summer temperatures are not as hot, and winter temperatures are not as cold, because water takes a long time to heat up or cool down.

BIOLOGICALLY RICH

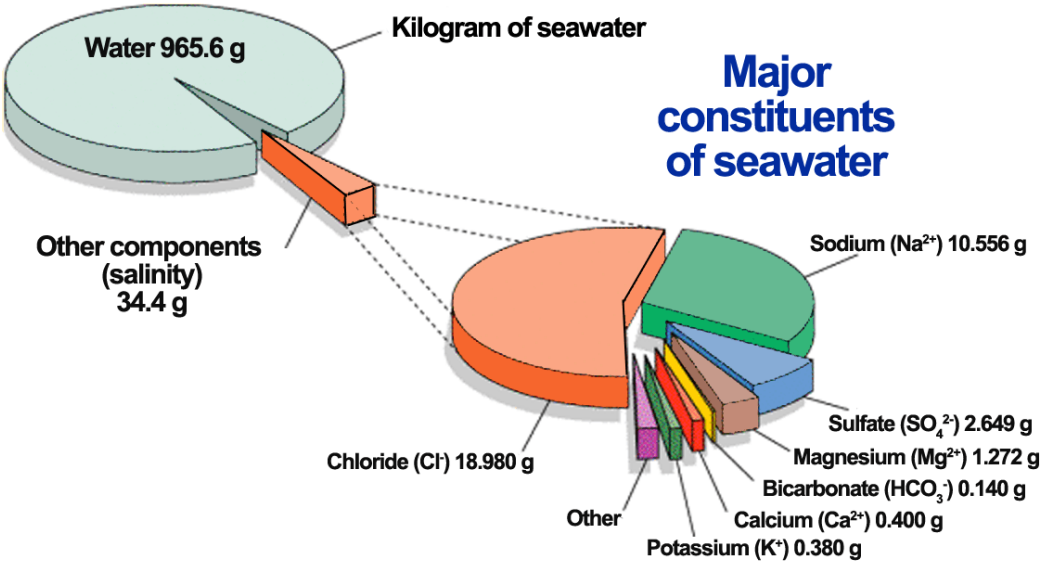


Krill are a key food source.

The oceans are an essential part of Earth's water cycle. Since they cover so much of the planet, most evaporation comes from the

ocean and most precipitation falls on the oceans. The oceans are also home to an enormous amount of life. That is, they have tremendous biodiversity. Tiny ocean plants create the base of a food web that supports all sorts of life forms. Marine life makes up the majority of all biomass on Earth. (**Biomass** is the total mass of living organisms in a given area.) These organisms supply us with food and even the oxygen created by marine plants.

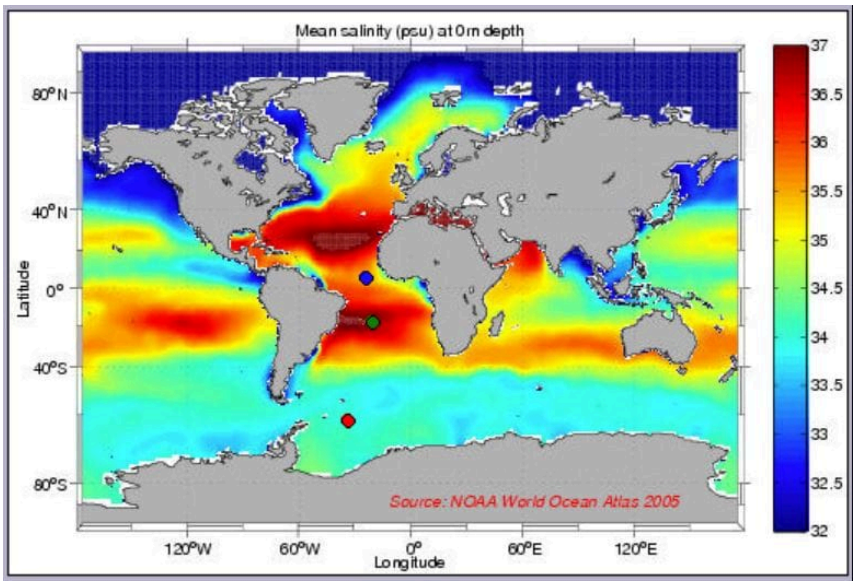
COMPOSITION OF OCEAN WATER



Chemical Composition of Seawater

Water is a polar molecule so it can dissolve many substances such as salts, sugars, acids, bases, and organic molecules. Where does the salt in seawater come from? As water moves through rock and soil on land it picks up ions. This is the flip side of weathering. Salts comprise about 3.5 percent of the mass of ocean water, but the salt content or **salinity** is different in different locations. In places like estuaries, seawater mixes with fresh water, causing salinity to be much lower than average. Where there is lots of evaporation but little circulation of water, salinity can be much higher. The Dead Sea has 30 percent salinity – nearly nine times the average salinity of ocean water. It is called the Dead Sea because nearly nothing can survive within it because of its salinity. Earthquide has an interactive ocean maps, which can show salinity, temperature, nutrients, and other characteristics. Differences in water density are responsible for deep ocean currents. With so many dissolved substances mixed in seawater, what is the density (mass per volume) of seawater relative to fresh water? Water density increases as: salinity increases; temperature decreases; pressure increases.

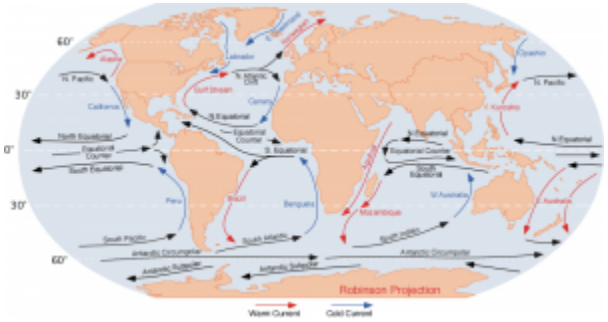
The salinity of ocean water depending on the location. In general, salinity increases as you move away from continents and into the center of subtropical high pressure zones.



Variability of Seawater Salinity at the Ocean Surface

OCEAN CURRENTS

Ocean currents are described as either surface currents or as deep ocean currents. The two types of currents are influenced by different forces.



Surface Ocean Currents

SURFACE OCEAN CURRENTS

Surface ocean currents are currents in the upper few hundred meters of the ocean. Recall the average depth of the ocean is 12,000 m so these surface waters are a small part of the overall volume, but the surface of the ocean is where there's interaction with the atmosphere thus leading to weather and climate interaction. Surface water moves in predictable ways for thousands of kilometers. These surface currents do not depend on weather; they remain unchanged even in large storms because they depend on factors that do not change. Surface currents are created by three things: *global wind patterns*, the *rotation of the Earth*, and the *shape of the ocean basins*.

Surface currents are extremely important because they distribute heat around the planet and are a major factor influencing climate around the globe.

Surface currents play an enormous role in Earth's climate. Even though the equator and poles have very different climates, these regions would have more extremely different climates if ocean currents did not transfer heat from the equatorial regions to the higher latitudes.

The Gulf Stream is a river of warm water in the Atlantic Ocean, about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream was heated as it traveled along the equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe. The energy the Gulf Stream transfers is enormous: more than 100 times the

world's human energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea, which raises the air temperatures over land between 3 to 6 °C (5 to 11°F). London, U.K., for example, is at the same latitude as Quebec, Canada. However, London's average January temperature is 3.8 °C (38 °F), while Quebec's is only -12 °C (10 °F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. In contrast, Quebec is much drier and receives its precipitation as snow.

GLOBAL WIND CURRENTS

Winds on Earth are either global or local. **Global winds** blow in the same directions all the time and are related to the unequal heating of Earth by the Sun, that is that more solar radiation strikes the equator than the polar regions, and the rotation of the Earth called the **Coriolis effect**. The causes of the global wind patterns are described in detail the section about atmosphere. Water in the surface currents is pushed in the direction of the major wind belts:

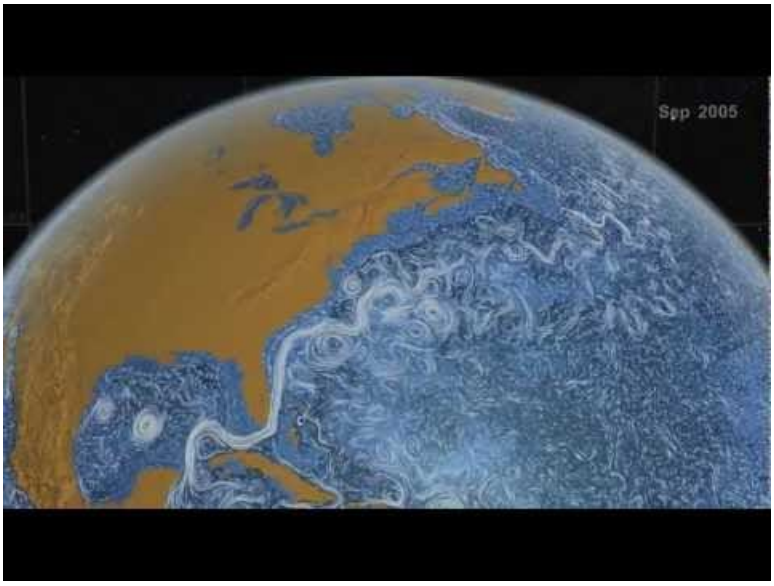
- **trade winds**: east to west between the equator and 30° North and 30° South
- **westerlies**: west to east in the middle latitudes
- **polar easterlies**: east to west between 50° and 60° north and south of the equator and the north and south pole

ROTATION OF THE EARTH

Wind is not the only factor that affects ocean currents. The Coriolis effect describes how Earth's rotation steers winds and surface ocean currents. The Coriolis effect causes freely moving objects to appear to move to the 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. So to reach his intended destination, the pilot must also veer right while flying north. Surface ocean currents in the northern hemisphere tend to rotate clockwise and in the southern hemisphere will rotate counterclockwise around the subtropical high pressure center.

As wind or an ocean current moves, the Earth spins underneath it. As a result, an object moving north or south along the Earth will appear to move in an arc. Winds and currents moving away from the equator, towards the poles, will move faster than the ground below since they departed from a region that was rotating faster than the destination region.



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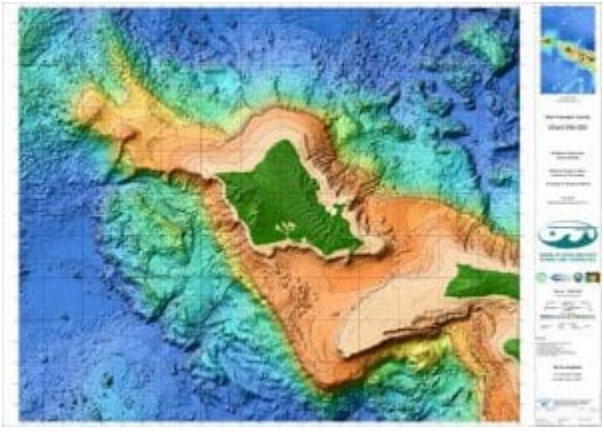
SHAPE OF THE OCEAN BASIN



General Location of the Five Major Surface Ocean Currents.

When a surface current collides with land, the current must change direction. In the figure below, the Atlantic South Equatorial Current travels westward along the equator until it reaches South America. Near Brazil, some of it goes north and some goes south. Because of Coriolis effect, the water goes right in the Northern Hemisphere and left in the Southern Hemisphere. You can see on the map below the major surface ocean currents that the surface ocean currents create loops called **gyres**. The Antarctic Circumpolar Current is unique because it travels uninhibited around the globe. Why is it the only current to go all the way around?

CONTINENTAL MARGIN



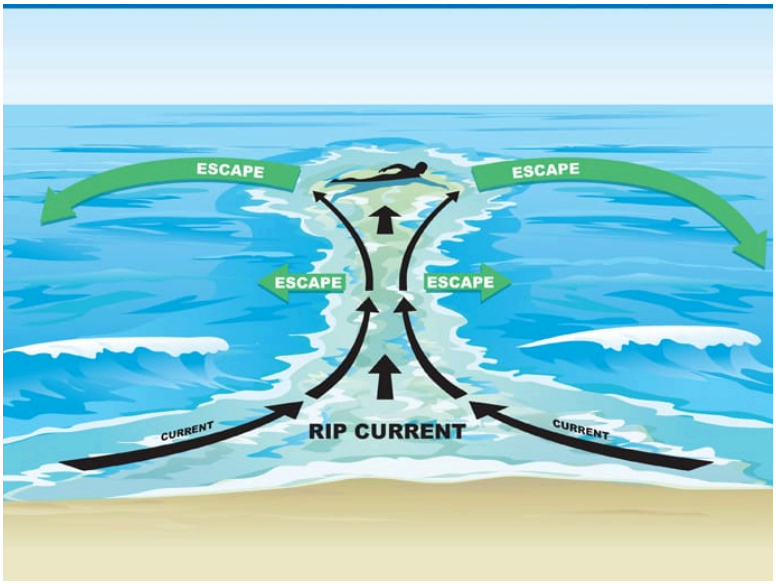
Ocean Floor Near Ohau, HI

Recall from the chapter on Plate Tectonics that the ocean floor is not flat. Mid-ocean ridges, deep sea trenches, and other features all rise sharply above or plunge deeply below the abyssal plains. In fact, Earth's tallest mountain is Mauna Kea volcano, which rises 10,203 m (33,476 ft.) from the Pacific Ocean floor to become one of the volcanic mountains of Hawaii. The deepest canyon is also on the ocean floor, the Challenger Deep in the Marianas Trench, 10,916 m (35,814 ft). The mapping of the ocean floor and coastal margins is called **bathymetry**. The **continental margin** is the transition from the land to the deep sea or, geologically speaking, from continental crust to oceanic crust. More than one-quarter of the ocean basin is continental margin.



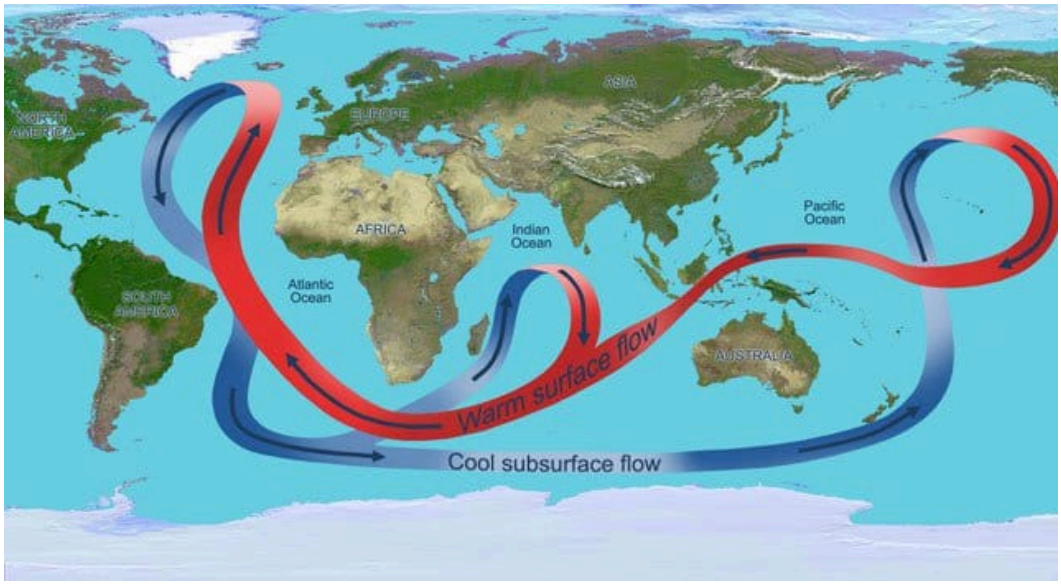
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LOCAL CURRENTS



The surface currents described above are all large and unchanging. Local surface currents are also found along shorelines. Two are *long shore currents* and *rip currents*. **Rip currents** are potentially dangerous currents that carry large amounts of water offshore quickly. Look at the rip-current animation to determine what to do if you are caught in a rip current. Each summer in the United States at least a few people die when they are caught in rip currents.

DEEP CURRENTS



The Ocean Conveyor Belt Showing surface and deep currents.

Thermohaline circulation drives deep ocean circulation. Thermo means heat and haline refers to salinity. Differences in temperature and in salinity change the density of seawater. So thermohaline circulation is the result of density differences in water masses because of their different temperature and salinity. What is the temperature and salinity of very dense water? Lower temperature and higher salinity yield the densest water. When a volume of water is cooled, the molecules move less vigorously so same number of molecules takes up less space and the water is denser. If salt is added to a volume of water, there are more molecules in the same volume so the water is denser.

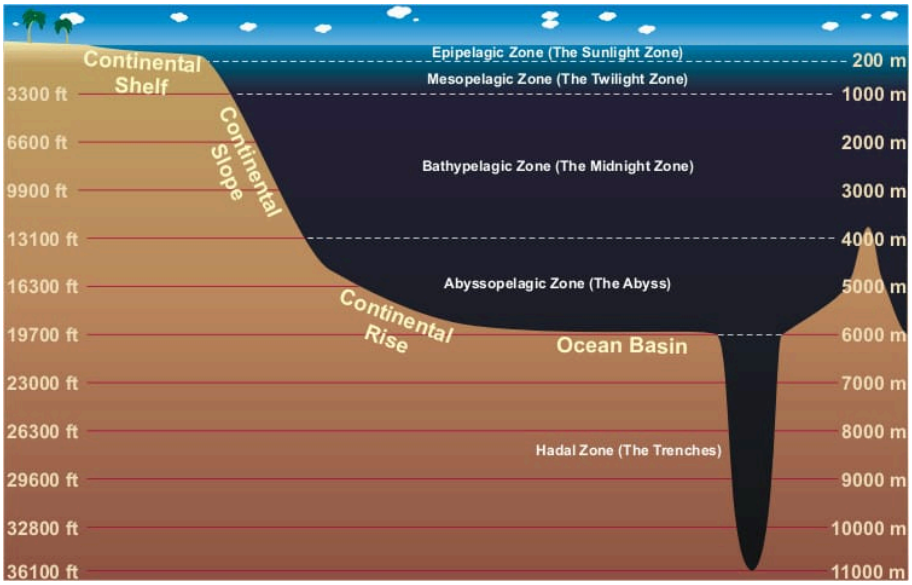
Changes in temperature and salinity of seawater take place at the surface. Water becomes dense near the poles. Cold polar air cools the water and lowers its temperature, increasing its salinity. Fresh water freezes out of seawater to become sea ice, which also increases the salinity of the remaining water. This very cold, very saline water is very dense and sinks. This sinking is called **downwelling**. A significant amount of downwelling occurs north of Scandinavia. The North Atlantic Drift moves through the large gap between Greenland and Scandinavia. This gap allows more water to move into the Arctic Ocean from the Atlantic Ocean, then c. There is a much smaller gap in the Bering Strait so relatively little water moves from the north Pacific Ocean into the Arctic Ocean.

Two things then happen. The dense water pushes deeper water out of its way and that water moves along the bottom of the ocean. This deep water mixes with less dense water as it flows. Surface currents move water into the space vacated at the surface where the dense water sank. Water also sinks into the deep ocean off of Antarctica. Since unlimited amounts of water cannot sink to the bottom of the ocean, water must rise from the deep ocean to the surface somewhere. This process is called **upwelling**.

Generally, upwelling occurs along the coast when wind blows water strongly away from the shore. This leaves a void that is filled by deep water that rises to the surface. Upwelling is extremely important where it occurs. During its time on the bottom, the cold deep water has collected nutrients that have fallen down through the water column. Upwelling brings those nutrients to the surface. Those nutrient support the growth of plankton and form the base of a rich ecosystem. California, South America, South Africa, and the Arabian Sea all benefit from offshore upwelling.

Upwelling also takes place along the equator between the North and South Equatorial Currents. Winds blow the surface water north and south of the equator so deep water undergoes upwelling. The nutrients rise to the surface and support a great deal of life in the equatorial oceans.

LAYERS OF THE OCEAN



Depths and Regions of Oceans.

In 1960, two men in a specially designed submarine called the **Trieste** descended into a submarine trench called the Challenger Deep (10,910 meters). The average depth of the ocean is 3,790 m, a lot more shallow than the deep trenches but still an incredible depth for sea creatures to live in. There are three major factors that make the deep ocean hard to inhabit: *the absence of light*, *low temperature*, and *extremely high pressure*.

VERTICAL DIVISIONS

To better understand regions of the ocean, scientists define the **water column** by depth. They divide the entire ocean into two zones vertically, based on light level. Large lakes are divided into similar regions. Sunlight only penetrates the sea surface to a depth of about 200 m, creating the **photic zone** (consisting of the Sunlight Zone and Twilight Zone). Organisms that photosynthesize depend on sunlight for food and so are restricted to the photic zone. Since tiny photosynthetic organisms, known as **phytoplankton**, supply nearly all of the energy and nutrients to the rest of the marine food web, most other marine organisms live in or at least visit the photic zone. In the **aphotic zone** (consisting of the Midnight Zone and the Abyss) there is not enough light for photosynthesis. The aphotic zone makes up the majority of the ocean, but has a relatively small amount of its life, both in diversity of type and in numbers.

HORIZONTAL DIVISIONS

The seabed is also divided into the zones described above, but the ocean itself is also divided horizontally by distance from the shore. Nearest to the shore lies the **intertidal zone**, the region between the high and low tidal marks. This hallmark of the intertidal is change, where water is in constant motions from ocean waves, tides, and currents. The land is sometimes under water and sometimes is exposed. The **neritic zone** is from low tide mark and slopes gradually downward to the edge of the seaward side of the continental shelf. Some sunlight penetrates to the seabed here. The **oceanic zone** is the entire rest of the ocean from the bottom edge of the neritic zone, where sunlight does not reach the bottom.

WAVES



Ocean water is constantly in motion: north-south, east-west, alongshore, and vertically. Seawater motion**s** are the result of waves, tides, and currents. Ocean movements are the consequence of many separate factors: *wind*, *tides*, *Coriolis effect*, *water density differences*, and the *shape of the ocean basins*. **Waves** have been discussed in previous chapters in several contexts: seismic waves traveling through the planet, sound waves traveling through seawater, and ocean waves eroding beaches. Waves transfer energy and the size of a wave and the distance it travels depends on the amount of energy that it carries.

WIND WAVES

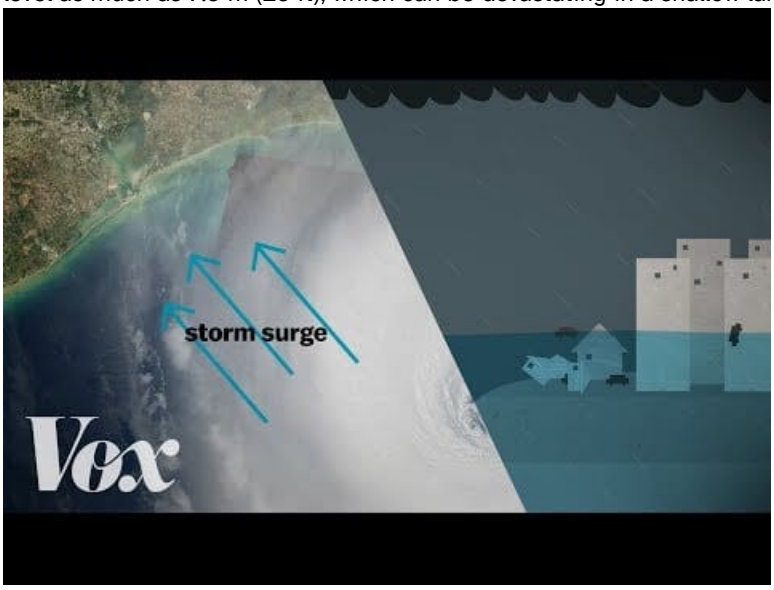
Ocean waves originate from steady winds or high storm winds over the water. Sometimes these winds are far from where the ocean waves are seen. The largest wind waves form when the wind is very strong, blows steadily for a long time, and blows over a long distance. The wind could be strong, but if it gusts for just a short time, large waves won't form. Wind blowing across the water transfers energy to that water. The energy first creates tiny ripples that create an uneven surface for the wind to catch so that it may create larger waves. These waves travel across the ocean out of the area where the wind is blowing.

remember that a wave is a transfer of energy. Water molecules in waves make circles or ellipses. Energy transfers between molecules but the molecules themselves mostly bob up and down in place. The Internet has a variety of animations to help explain the concept of wave action. In this animation, a water bottle bobs in place like a water molecule. An animation of motion in wind waves from the Scripps Institution of Oceanography. Here is an animation of a deep water wave is seen here. Notice the circular motion of water as wave energy transfers through it. Compare that to the wave action in shallow waters using this animation.



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Waves break when they become too tall to be supported by their base. This can happen at sea but happens predictably as a wave moves up a shore. The energy at the bottom of the wave is lost by friction with the ground so that the bottom of the wave slows down but the top of the wave continues at the same speed. The crest falls over and crashes down. Some of the damage done by storms is from **storm surges** . Water piles up at a shoreline as storm winds push waves into the coast. Storm surge may raise sea level as much as 7.5 m (25 ft), which can be devastating in a shallow land area when winds, waves, and rain are intense.



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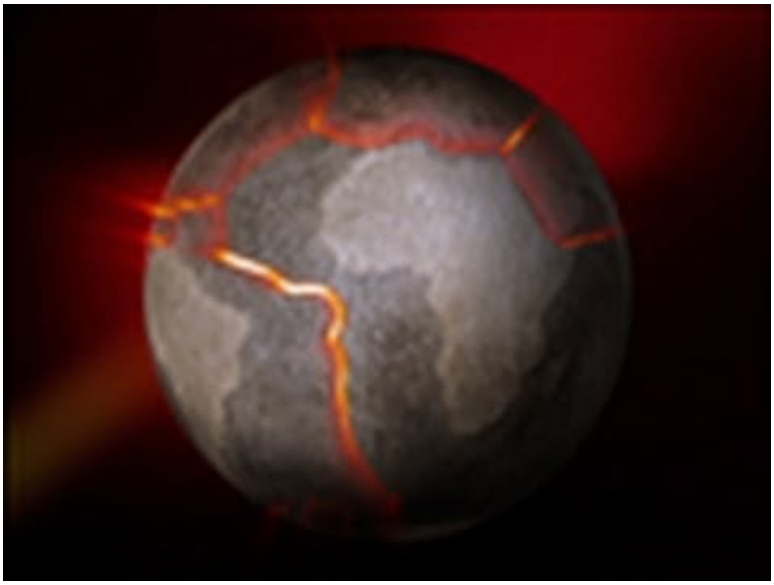


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TSUNAMIS

Tsunami are described in the Tectonic Forces chapter as damaging waves that result from the sharp jolt to the water from a powerful geologic event such as undersea earthquakes or volcanic eruptions. Landslides, meteorite impacts, or any other jolt to ocean water may form a tsunami. Tsunami can travel at speeds of 800 kilometers per hour (500 miles per hour). Tsunami have small wave heights and long wavelengths so they are usually unnoticed at sea. As the wave rides up the continental shelf the wave height increases.

The wave speed of a tsunami is also slowed by friction with the shallower ocean floor, which causes the wavelength to decrease, creating a much taller wave called a **run-up**. Many people caught in a tsunami have no warning of its approach. Since the wavelength is long, a long time can pass between crests or troughs onshore. In 1755 in Lisbon, an offshore earthquake caused a great deal of damage on land. People rushed to the open space of the shore and discovered that the water was flowing seaward fast. The trough of the tsunami wave reached shore first. People who went out onto the open beach were drowned when the crest of the wave reached shore.



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TIDAL WAVES

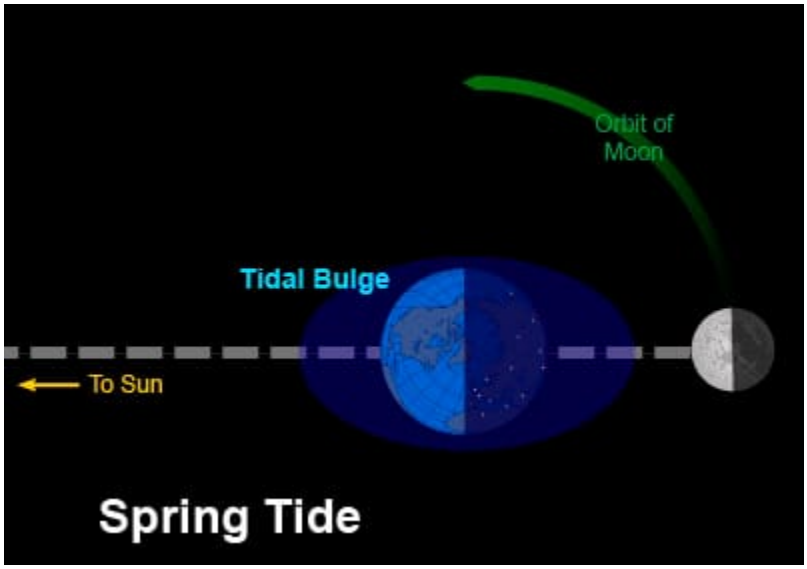


Exposed Shore during low Tide

Tides are the daily rise and fall of sea level at any given place. The pull of the Moon's gravity on Earth is the primarily cause of tides and the pull of the Sun's gravity on Earth is the secondary cause. The Moon has a greater effect because, although it is much smaller than the Sun, it is much closer. The Moon's pull is about twice that of the Sun's.

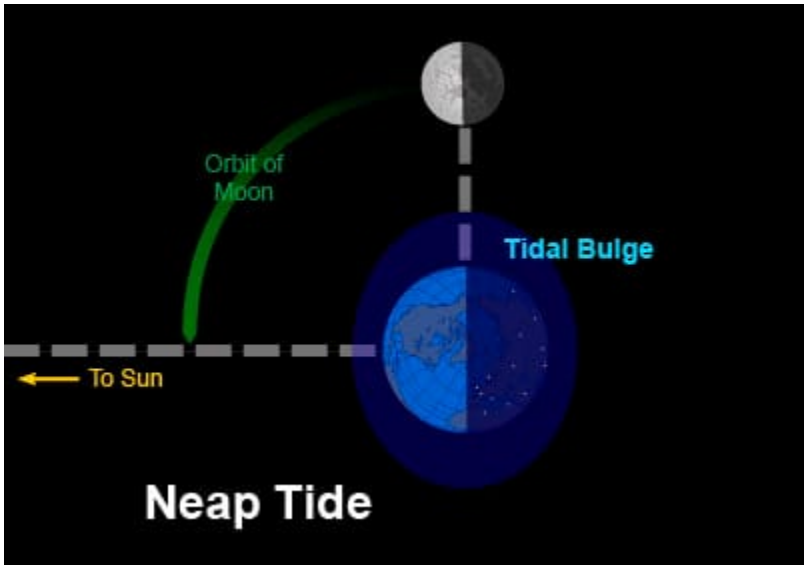
Daily Tide Patterns

To understand the tides it is easiest to start with the effect of the Moon on Earth. As the Moon revolves around our planet, its gravity pulls Earth toward it. The lithosphere is unable to move much but the water above it is pulled by the gravity and a bulge is created. This bulge is the high tide beneath the Moon. The Moon's gravity then pulls the Earth toward it, leaving the water on the opposite side of the planet behind. This creates a second high tide bulge on the opposite side of Earth from the Moon. These two water bulges on opposite sides of the Earth aligned with the Moon are the **high tides**. Click here to learn more. Since so much water is pulled into the two high tides, **low tides** form between the two high tides. As the Earth rotates beneath the Moon, a single spot will experience two high tides and two low tides every day. The **tidal range** is the difference between the ocean level at high tide and the ocean at low tide. The tidal range in a location depends on a number of factors, including the slope of the seafloor. Water appears to move a greater distance on a gentle slope than on a steep slope.



Spring tide Monthly Tide Patterns

Waves are additive so when the gravitational pull of the Sun and Moon are in the same direction, the high tides add and the low tides add. Highs are higher and lows are lower than at other times through the month. These more extreme tides, with a greater tidal range, are called **spring tides**. Spring tides don't just occur in the spring; they occur whenever the Moon is in a new-moon or full-moon phase, about every 14 days. The National Oceanic and Atmospheric Administration (NOAA) has a simple diagram of this process.

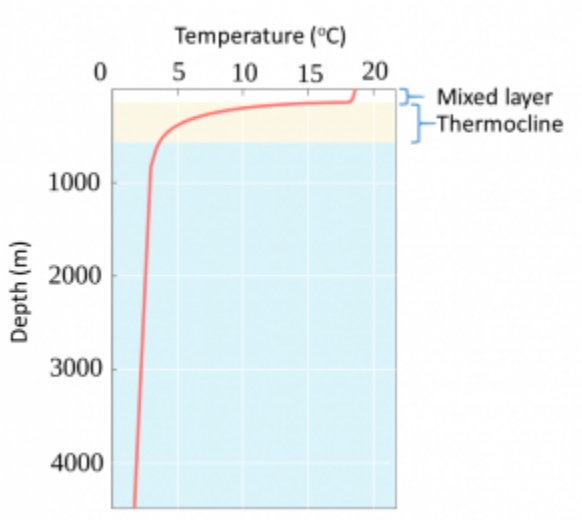


Neap tide

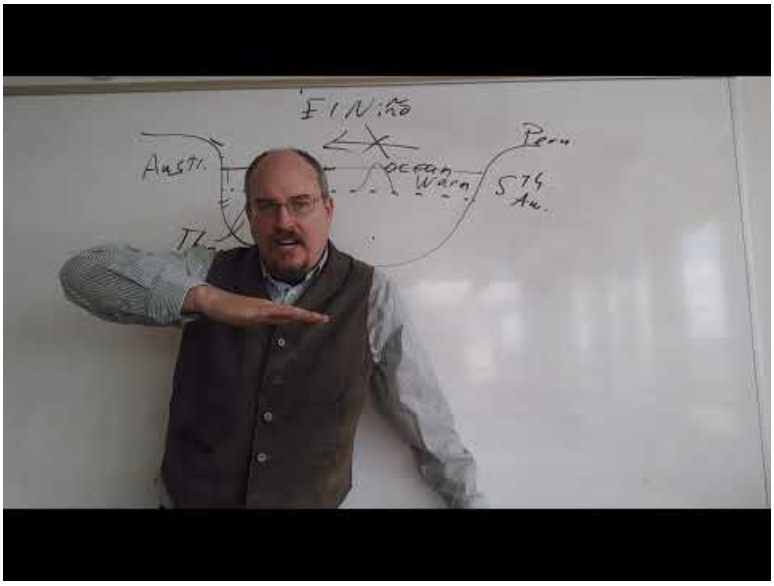
Neap tides are tides that have the smallest tidal range, and they occur when the Earth, the Moon, and the Sun form a 90 degree angle. They occur exactly halfway between the spring tides, when the Moon is at first or last quarter. How do the tides add up to create neap tides? The Moon's high tide occurs in the same place as the Sun's low tide and the Moon's low tide in the same place as the Sun's high tide. At neap tides, the tidal range relatively small. Here is another simple animation of spring and neap tides from NOAA. High tides occur about twice a day, about every 12 hours and 25 minutes. The reason is that the Moon takes 24 hours and 50 minutes to rotate once around the Earth so the Moon is over the same location 24 hours and 50 minutes later. Since high tides occur twice a day, one arrives each 12 hours and 25 minutes. What is the time between a high tide and the next low tide? This animation shows the effect of the Moon and Sun on the tides.

Some coastal areas do not follow this pattern at all. These coastal areas may have one high and one low tide per day or a different amount of time between two high tides. These differences are often because of local conditions, such as the shape of the coastline that the tide is entering.

ENSO (El Niño Southern Oscillation)



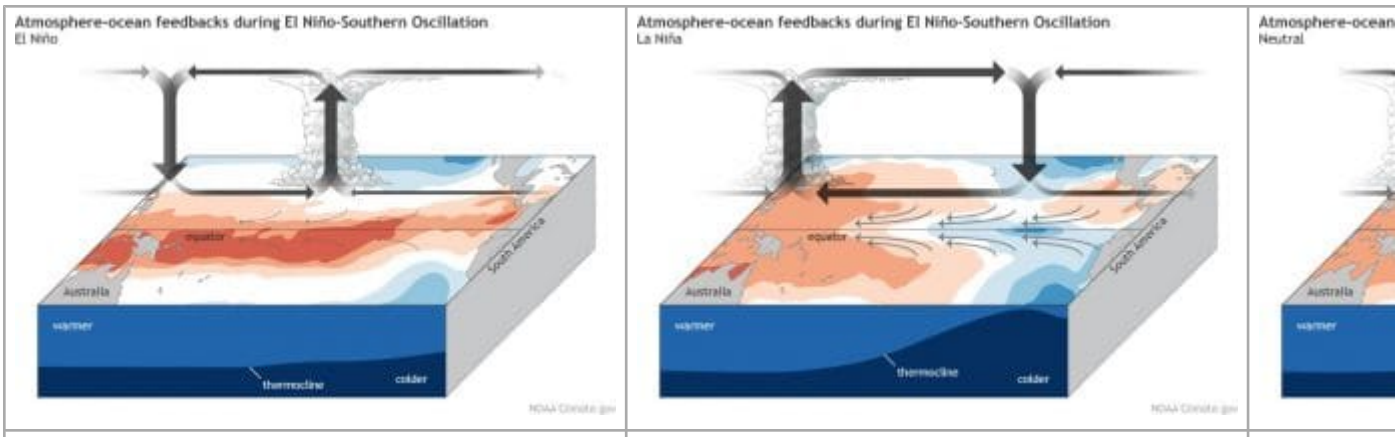
Thermocline: Large Temperature Change over a short depth.



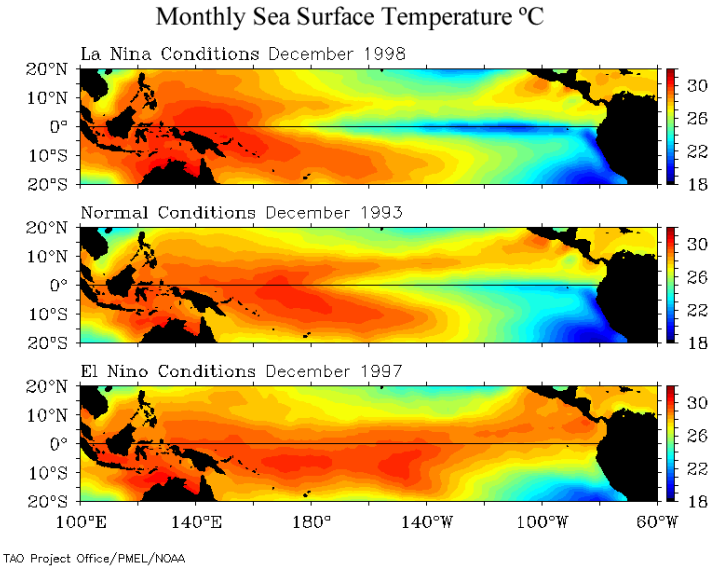
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To a great extent, warm, buoyant water stays near the upper 200m of the ocean. Winds and the Coriolis effect drive surface ocean currents, but thermohaline circulation drives deep ocean circulation. Where the warm surface water meet the cooler deep water, there is a rapid change in temperature over a short change in depth. This is a thermocline.

In the Pacific Ocean, Equatorial Easterly winds blow consistently from east to wind from Peru toward Australia. This pushes the warm surface water towards Australia and allows the cooler, deeper waters to rise to the surface near Peru. A wedge of warm water gets progressively deeper as you near Australia. This is the normal, expected situation that happens most of the time. This is called La Nada. However, once in a while, perhaps every 7-12 years, the easterly winds slow down and the warm water extends all the way to the Peruvian coast. This event leads to more rain in Peru and the water warm forces cool-water fish to move away. This happens around Christmas and is called an El Niño. In contrast, if the easterly winds are stronger than usual, the warm water wedge extend a shorter distance from Australia and the cool water extends farther from Peru. This is a La Niña.

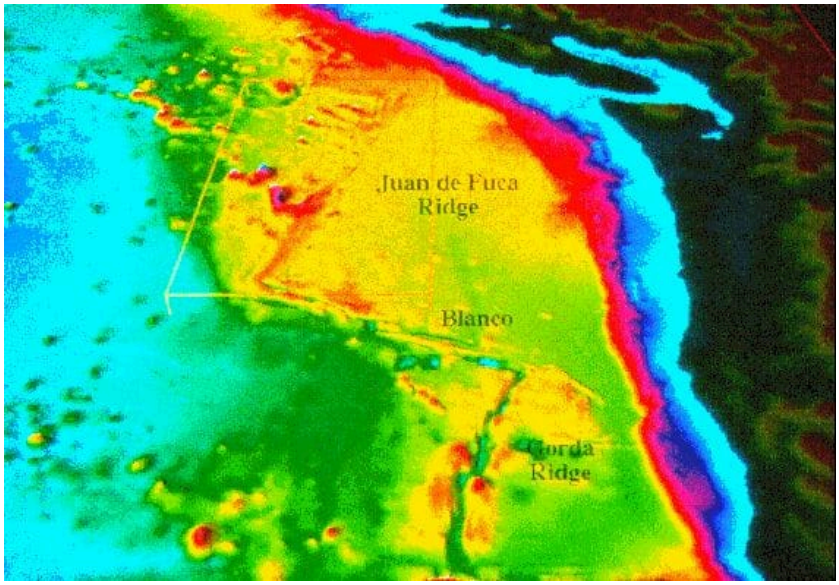


ENSO situation: El Nino, La Nina, Neutral. Note the thermocline, surface temperatures, and cloud locations.



Since these events are constantly shifting between the extremes of El Niño and La Niña in the southern Pacific, the phenomenon is called the El Niño Southern Oscillation, or ENSO. It is not well understood what creates the shift from one extreme to the other, but we are able to predict a few months in advance what situation to expect. This prediction is based on monitoring sea surface temperatures and comparing existing conditions with the long term average temperatures.

STUDYING THE SEA FLOOR



Bathymetric map of the Juan de Fuca Plate.

Oceanographers like to say that we know more about the dark side of the Moon than we do about the oceans. That statement is doubly true of the seafloor. Although modern technology has allowed us to learn more about the seafloor, vast regions remain unexplored. Scuba divers can only dive to about 40 meters and they cannot stay down there for very long. Although this is good for researching the organisms and ecosystems very near a coast, most oceanic research requires accessing greater depths.

MAPPING

In the Plate Tectonics chapter, you learned that echo sounders designed to locate enemy submarines allowed scientists to create bathymetric maps of the seafloor. Prior to this advance, explorers mapped a small amount of the seafloor by painstakingly dropping a line over the side of a ship to measure the depth at one tiny spot at a time.

SAMPLING REMOTELY

Samples of seawater from different depths in the water column are needed to understand ocean chemistry. To do this bottles are placed along a cable at regular depths and closed as a weight is dropped down the cable. The water trapped in the bottle can be analyzed later in a laboratory. Scientists are also interested in collecting rock and sediment samples from the seafloor. A dredge is a giant rectangular bucket that is dragged along behind a ship to collect loose rocks. Gravity corers are metal tubes that fall to the seafloor and slice into the sediments to collect a sample. The research vessel, the Joides Resolution, drills deep into the seafloor to collect samples of the sediment and ocean crust. Scientists analyze the samples for chemistry and paleomagnetism.

OCEAN RESOURCES

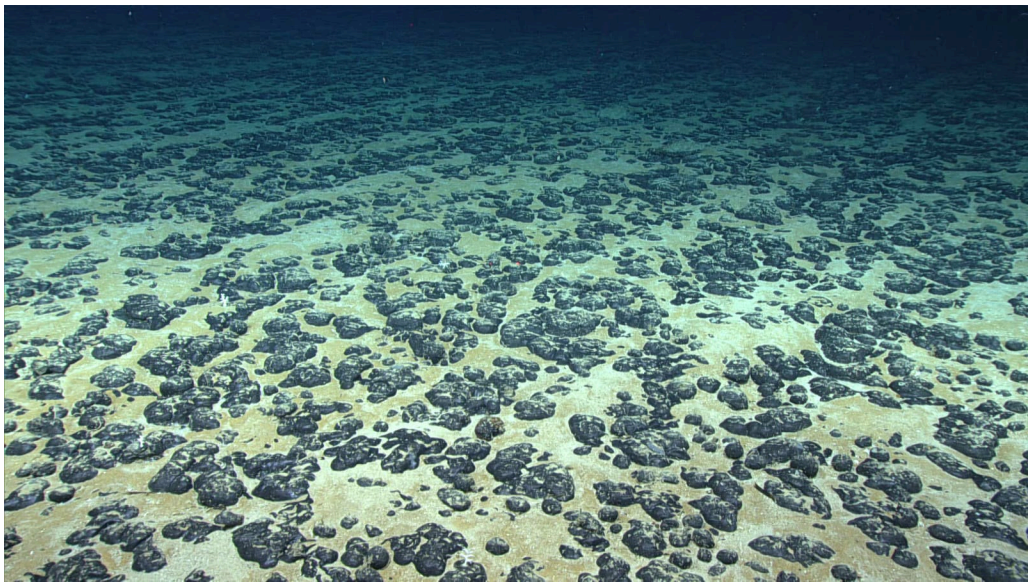
LIVING RESOURCES



Commercial Salmon Fishing

The ocean provides important living and nonliving resources. To be maintained for future use, these resources must be managed sustainably. Most fish are caught by lines or nets as they swim in the open waters of the ocean. Some species of fish are being over-harvested, which means their rate of reproduction cannot keep up with the rate at which people consume them. **Bottom trawling** is a method of fishing that involves towing a weighted net across the seafloor to harvest fish. In many areas where bottom trawling is done, ecosystems are severely disturbed by the large nets. For this reason, in a few areas in the world, laws limit bottom trawling to waters not more than 1,000 m deep or waters far from protected and sensitive areas. Still these actions protect some of the seafloor. Besides food, ocean organisms have other uses. Some provide us with medications.

NONLIVING RESOURCES



Manganese Nodules on Ocean Floor

Oil and natural gas are the most valuable non-living resources taken from the ocean. Extracting these resources requires drilling into the seafloor. Oil platforms have dozens of oil wells that are drilled in places where the ocean is sometimes 2,000 m deep.

A description of the Deepwater Horizon oil spill affecting the Gulf of Mexico is located in the Human Actions and Earth's Waters chapter. The seafloor has some valuable minerals. **Manganese nodules** containing manganese, iron, copper, nickel, phosphate, and cobalt may be as small as a pea or as large as a basketball. Estimates are that there may be as much as 500 billion tons of nodules on the seafloor. The minerals in manganese nodules have many uses in the industrial world, but currently they are not being mined. Think back to the discussion of ore deposits in the Earth's Minerals chapter. Why do you think these seafloor resources are not being mined?

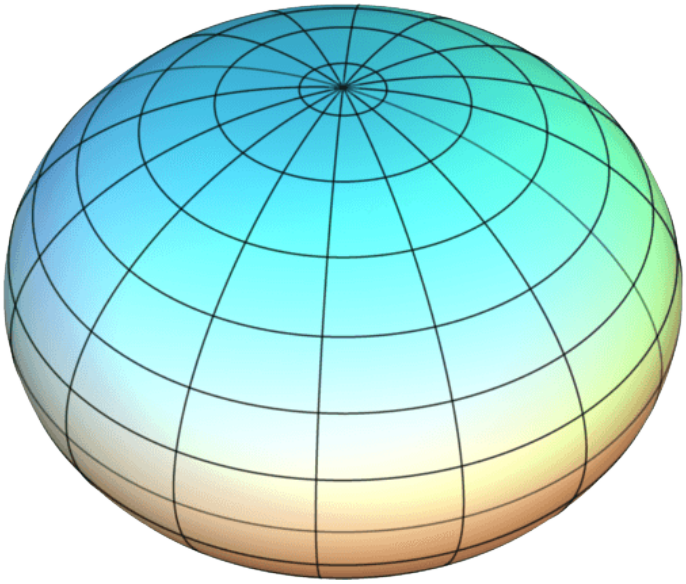
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1.8: Planet Earth

Learning Objectives

- Describe Earth as a planetary body.
- Explain the various motions of Earth and the results of those motions.
- Compare continental and oceanic features on the surface of the Earth.
- Describe the three major types of rock features and how the rock cycle describes their creation.

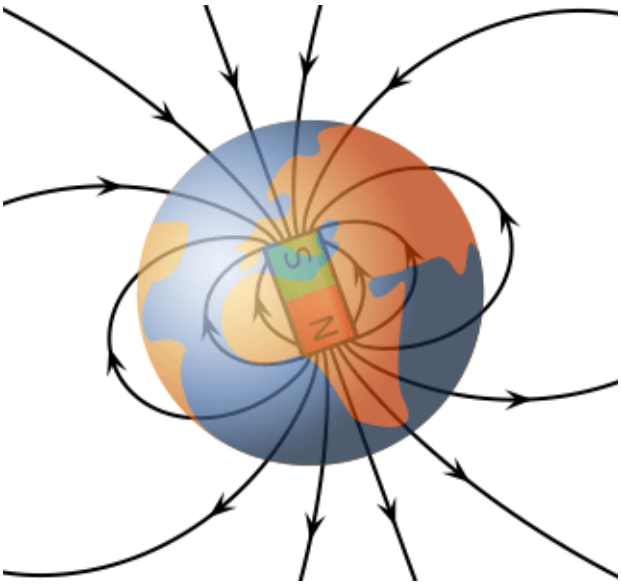
Earth as a Planetary Body



Earth is an Oblate Spheroid.

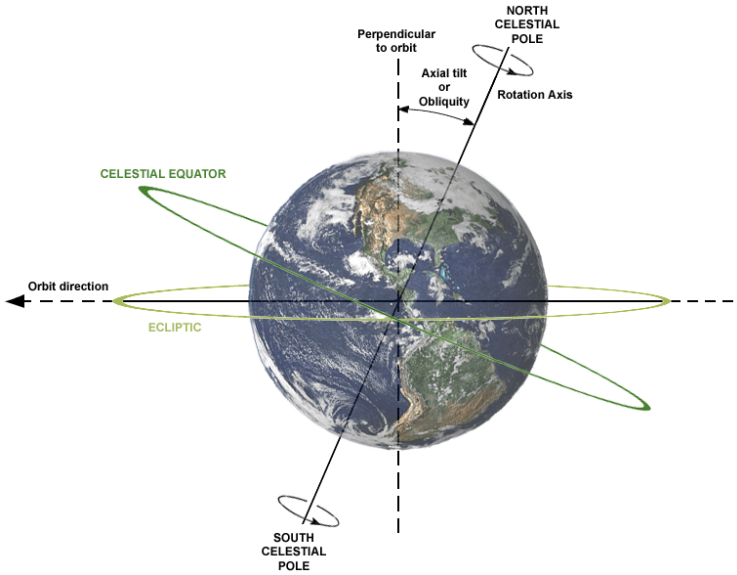
EARTH'S SHAPE

Earth is an inner planet in the solar system and it is very much like the other inner planets, at least in its size, shape, and composition. But many features make Earth very different from the planets and any other planet that we know of so far. Earth is a sphere or, more correctly, an **oblate spheroid**, which is a sphere that is a bit squished down at the poles and bulges a bit at the equator. Or to be more technical, the minor axis (the diameter through the poles) is smaller than the major axis (the diameter through the equator). When the earth is cut in equal halves, each half is called a **hemisphere**. North of the equator is the northern hemisphere and south of the equator is the southern hemisphere. Eastern and western hemispheres are also designated. What evidence is there that Earth is spherical? What evidence was there before spaceships and satellites? Try to design an experiment involving a ship and the ocean to show Earth is round. If you are standing on the shore and a ship is going out to sea, the ship gets smaller as it moves further away from you but the ship's bottom also starts to disappear as the vessel goes around the arc of the planet. There are many other ways that early scientists and mariners knew that Earth was not flat.Even the ancient Greeks knew that Earth was round by observing the arc shape of the shadow on the Moon during a lunar eclipse. The Sun and the other planets of the solar system are also spherical. Larger satellites, those that have enough mass for their gravitational attraction to have made them round, are as well.



Earth has a **magnetic field** that behaves as if the planet had a gigantic bar magnet inside of it. Earth's magnetic field also has a north and south pole and a magnetic field that surrounds it. The magnetic field arises from the convection of molten iron and nickel metal in Earth's outer liquid iron core. Earth's magnetic field extends several thousand kilometers into space. The magnetic field shields the planet from harmful radiation from the Sun. Some animals use the magnetic field for long distance migration navigation.

Earth's Motions



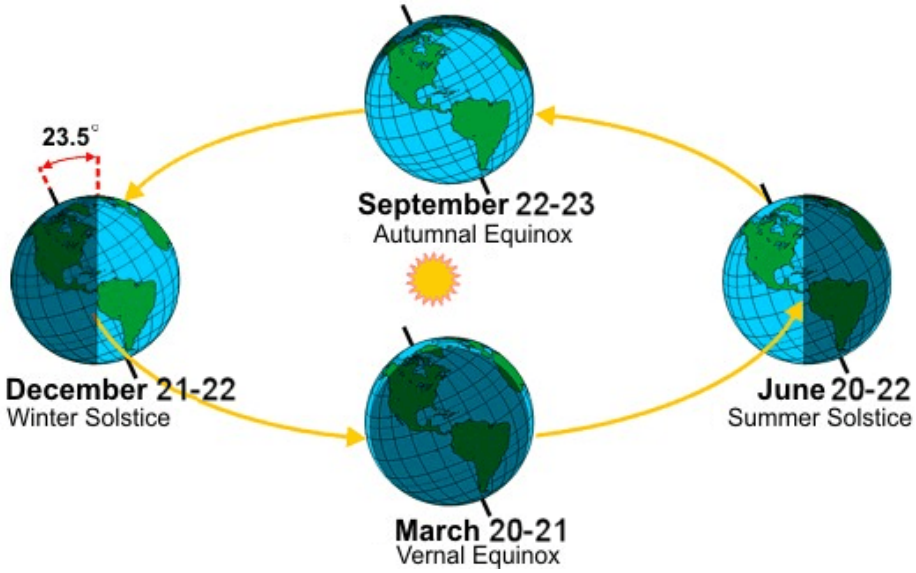
At the equator, the earth rotates about 1700 km/hr (1050mi/hr) while at the poles the speed of rotation is 0.

EARTH'S ROTATION

Imagine a line passing through the center of Earth that goes through both the North Pole and the South Pole. This imaginary line is called an **axis**. Earth spins around its axis, just as a top spins around its spindle. This spinning movement is called Earth's **rotation**. At the same time that the Earth spins on its axis, it also orbits, or revolves around the Sun. This movement is called **revolution**. A pendulum set in motion will not change its motion, and so the direction of its swinging should not change. However, Foucault observed that his pendulum did seem to change direction. Since he knew that the pendulum could not change its motion, he concluded that the Earth, underneath the pendulum was moving. An observer in space will see that Earth requires 23 hours, 56 minutes, and 4 seconds to make one complete rotation on its axis. But because Earth moves around the Sun at the same time

that it is rotating, the planet must turn just a little bit more to reach the same place relative to the Sun. Hence the length of a day on Earth is actually 24 hours.

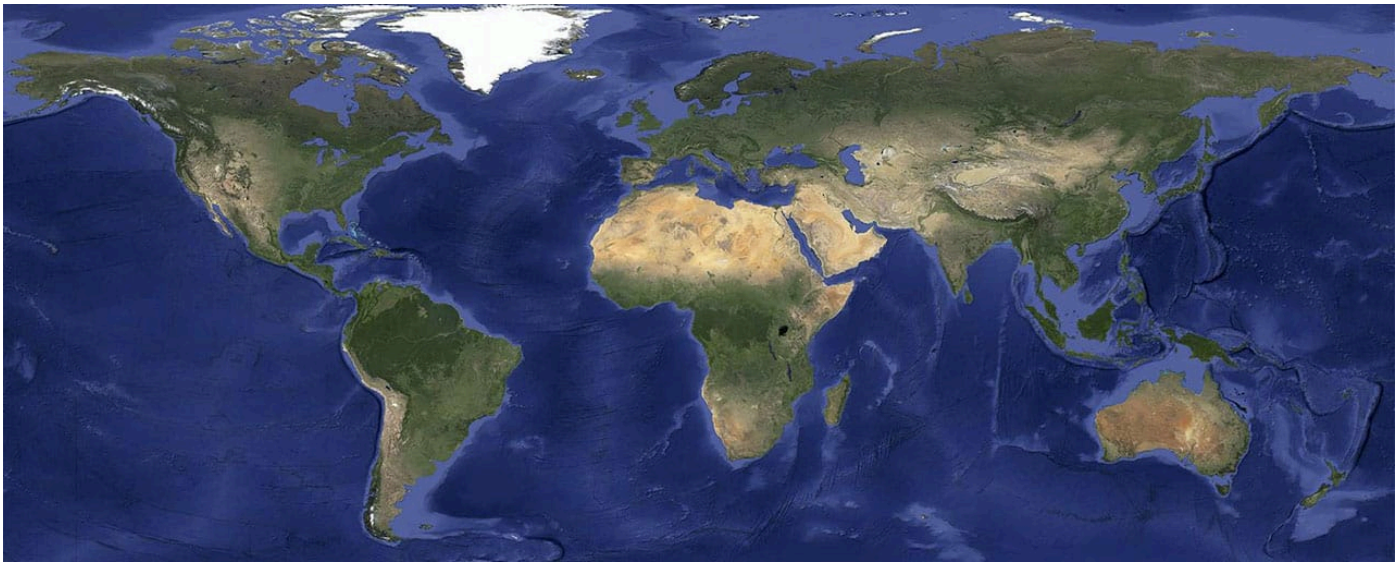
EARTH'S REVOLUTION



The tilt of the axis relative to incoming solar energy creates the earth's seasons.

For Earth to make one complete revolution around the Sun takes 365.24 days. This amount of time is the definition of one year. The gravitational pull of the Sun keeps Earth and the other planets in orbit around the star. Like the other planets, Earth's orbital path is an ellipse so the planet is sometimes farther away from the Sun than at other times. The closest Earth gets to the Sun each year is at perihelion (147 million km) on about January 3rd and the furthest is at aphelion (152 million km) on July 4th. Earth's elliptical orbit has nothing to do with Earth's seasons. During one revolution around the Sun, Earth travels at an average distance of about 150 million km. Earth revolves around the Sun at an average speed of about 27 km (17 mi) per second, but the speed is not constant. The planet moves slower when it is at aphelion and faster when it is at perihelion. The reason the Earth (or any planet) has seasons is that Earth is tilted 23 1/2° on its axis. During the Northern Hemisphere summer the North Pole points toward the Sun, and in the Northern Hemisphere winter the North Pole is tilted away from the Sun.

Earth's Surface Features



Earth's surface features are the result of constructive and destructive forces. Constructive forces cause landforms to grow. The

eruption of a new volcano creates a new landform. Destructive forces wear landforms down. The slow processes of mechanical and chemical weathering and erosion work over time to change once high mountains into smooth flat plateaus.

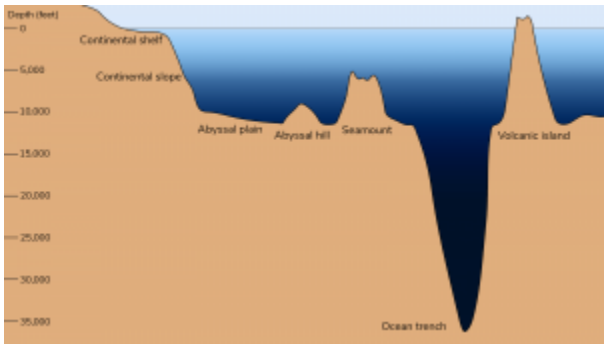
- The continents are large land areas extending from high mountaintops to sea level.
- The ocean basins extend from the edges of the continents down steep slopes to the ocean floor and into deep trenches.

CONTINENTS

The oldest continental rocks are billions of years old, so the continents have had a lot of time for things to happen to them. Constructive forces cause physical features on Earth's surface known as landforms to grow. Crustal deformation – when crust compresses, pulls apart, or slides past other crust – results in hills, valleys, and other landforms. Mountains rise when continents collide, when one slab of ocean crust plunges beneath another or a slab of continental crust to create a chain of volcanoes. Sediments are deposited to form landforms, such as deltas.

Volcanic eruptions can also be destructive forces that blow landforms apart. The destructive forces of weathering and erosion modify landforms. Water, wind, ice, and gravity are important forces of erosion. This scene is within the East African Rift where the crust is being pulled apart to form a large valley.

- Which features result from constructive forces? Volcanoes have been constructed within the valley by rising magma.
- Which features result from destructive forces? Volcanic explosions or collapses have destroyed volcanic mountains to form craters. Fractures caused by the rifting in the valley are signs that the valley is breaking apart. Streams are eroding downward into the slopes of the volcanoes. Landslides erode the steep volcanoes. A landslide scar is seen on left side of the small, very steep volcanic cone near the center of the image, and landslide deposits have traveled outward from the scar.



Ocean Floor Features

OCEAN BASINS

The ocean basins are all younger than 180 million years. Although the ocean basins begin where the ocean meets the land, the continent extends downward to the seafloor, so the continental margin is made of continental crust. The ocean floor itself is not totally flat. The most distinctive feature is the mountain range that runs through much of the ocean basin, known as the mid-ocean ridge. The deepest places of the ocean are the ocean trenches, many of which are located around the edge of the Pacific Ocean. Chains of volcanoes are also found in the center of the oceans, such as in the area of Hawaii. Flat plains are found on the ocean floor with their features covered by mud.

CHANGING EARTH

Earth's surface changes over short and long periods of time. Constructive forces cause new features to form by volcanic activity or uplift of the crust. Existing landforms are modified by destructive forces, perhaps even eroded away by water, wind, ice, and gravity. Beneath the oceans, volcanic activity forms new seafloor while old seafloor is destroyed at the trenches.

Defining Rock Types

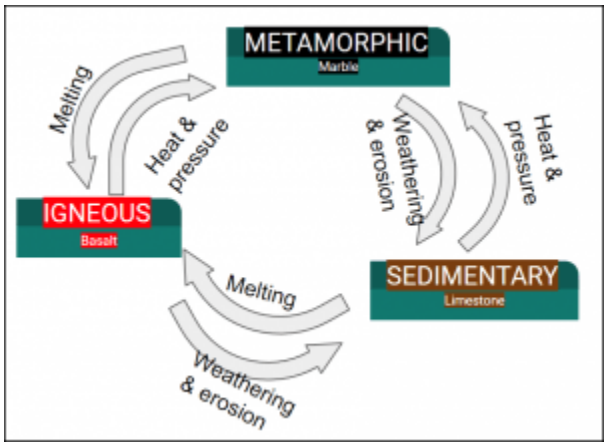
There are three types of rocks: *igneous*, *sedimentary* and *metamorphic*. Each of these types is part of the rock cycle. Through changes in conditions one rock type can become another rock type. Or it can become a different rock of the same type. A **rock** is

a naturally formed, non-living earth material. Rocks are made of collections of mineral grains that are held together in a firm, solid mass. How is a rock different from a mineral? Rocks are made of minerals. The mineral grains in a rock may be so tiny that you can only see them with a microscope, or they may be as big as your fingernail or even your finger. Rocks are identified primarily by the minerals they contain and by their texture. Each type of rock has a distinctive set of minerals. A rock may be made of grains of all one mineral type, such as quartzite. Much more commonly, rocks are made of a mixture of different minerals. Texture is a description of the size, shape, and arrangement of mineral grains.

Rocks are classified into three major groups according to how they form. Rocks can be studied in hand samples that can be moved from their original location. Rocks can also be studied in outcrop, exposed rock formations that are attached to the ground, at the location where they are found.

Igneous rocks form from cooling magma. Magma that erupts onto Earth's surface is lava. The chemical composition of the magma and the rate at which it cools determine what rock forms as the minerals cool and crystallize. Sedimentary rocks form by the compaction and cementing together of sediments, broken pieces of rock-like gravel, sand, silt, or clay. Those sediments can be formed from the weathering and erosion of preexisting rocks. Sedimentary rocks also include chemical precipitates, the solid materials left behind after a liquid evaporates. Metamorphic rocks form when the minerals in an existing rock are changed by heat or pressure within the Earth.

The Rock Cycle



Simple Rock Cycle

Rocks change as a result of natural processes that are taking place all the time. Most changes happen very slowly; many take place below the Earth's surface, so we may not even notice the changes. Although we may not see the changes, the physical and chemical properties of rocks are constantly changing in a natural, never-ending cycle called the rock cycle. The concept of the rock cycle was first developed by James Hutton, an eighteenth century scientist often called the "Father of Geology." Hutton recognized that geologic processes have "no [sign] of a beginning, and no prospect of an end." The processes involved in the rock cycle often take place over millions of years. So on the scale of a human lifetime, rocks appear to be "rock solid" and unchanging, but in the longer term, change is always taking place. In the rock cycle the three main rock types are igneous, sedimentary, and metamorphic. Arrows connecting the three rock types show the processes that change one rock type into another. The cycle has no beginning and no end. Rocks deep within the Earth are right now becoming other types of rocks. Rocks at the surface are lying in place before they are next exposed to a process that will change them.

Several processes can turn one type of rock into another type of rock. The key processes of the rock cycle are crystallization, erosion and sedimentation, and metamorphism.

CRYSTALLIZATION

Magma cools either underground or on the surface and hardens into an igneous rock. As the magma cools, different crystals form at different temperatures, undergoing crystallization. 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 larger crystals.

EROSION AND SEDIMENTATION

Weathering wears rocks at the Earth's surface down into smaller pieces. The small fragments are called sediments. Running water, ice, and gravity all transport these sediments from one place to another by erosion. During sedimentation, the sediments are laid down or deposited. In order to form a sedimentary rock, the accumulated sediment must become compacted and cemented together.

When a rock is exposed to extreme heat and pressure within the Earth but does not melt, the rock becomes metamorphosed. Metamorphism may change the mineral composition and the texture of the rock. For that reason, a metamorphic rock may have a new mineral composition and/or texture.

Igneous Rock



Igneous rocks form from the cooling and hardening of molten magma in many different environments. These rocks are identified by their composition and texture. More than 700 different types of igneous rocks are known.

MAGMA COMPOSITION

The rock beneath the Earth's surface is sometimes heated to high enough temperatures that it melts to create magma. Different magmas have different composition and contain whatever elements were in the rock that melted. Magmas also contain gases. The main elements are the same as the elements found in the crust. Whether rock melts to create magma depends on:

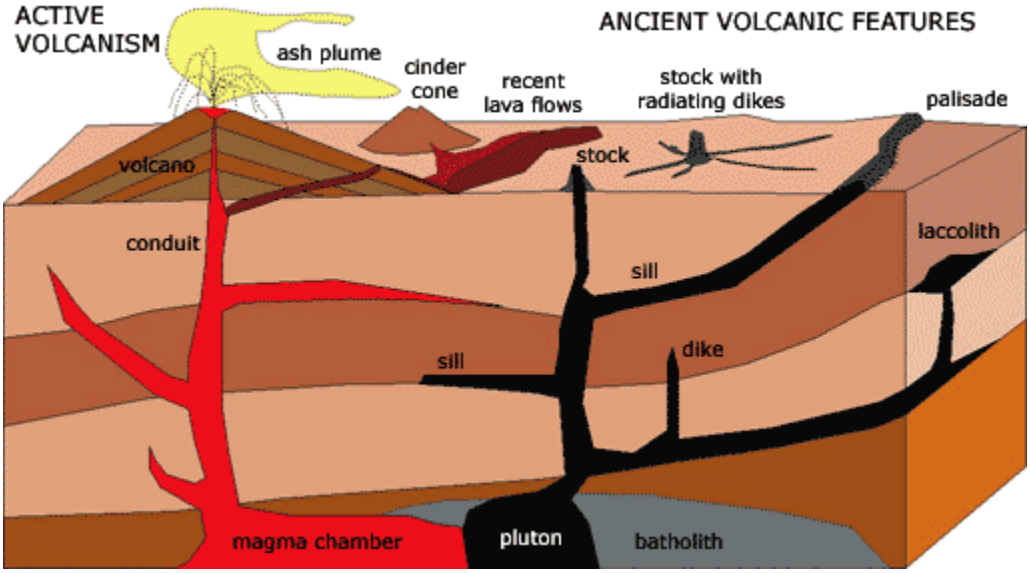
- **Temperature**: Temperature increases with depth, so melting is more likely to occur at greater depths.
- **Pressure**: Pressure increases with depth, but increased pressure raises the melting temperature, so melting is less likely to occur at higher pressures.
- **Water**: The addition of water changes the melting point of rock. As the amount of water increases, the melting point decreases.
- **Rock composition**: Minerals melt at different temperatures, so the temperature must be high enough to melt at least some minerals in the rock. The first mineral to melt from a rock will be quartz (if present) and the last will be olivine (if present).

The different geologic settings that produce varying conditions under which rocks melt will be discussed in the "Plate Tectonics" chapter. As a rock heats up, the minerals that melt at the lowest temperatures will melt first. Partial melting occurs when the temperature on a rock is high enough to melt only some of the minerals in the rock. The minerals that will melt will be those that melt at lower temperatures. Fractional crystallization is the opposite of partial melting. This process describes the crystallization of different minerals as magma cools.

Bowen's Reaction Series indicates the temperatures at which minerals melt or crystallize. An understanding of the way atoms join together to form minerals leads to an understanding of how different igneous rocks form. Bowen's Reaction Series also explains

why some minerals are always found together and some are never found together.

If the liquid separates from the solids at any time in partial melting or fractional crystallization, the chemical composition of the liquid and solid will be different. When that liquid crystallizes, the resulting igneous rock will have a different composition from the parent rock.



INTRUSIVE IGNEOUS ROCK



El Capitan in mostly Intrusive Igneous Granite

Igneous rocks are called intrusive when they cool and solidify beneath the surface. Intrusive rocks form plutons and so are also called plutonic. A **pluton** is an igneous intrusive rock body that has cooled in the crust. When magma cools within the Earth, the cooling proceeds slowly. Slow cooling allows time for large crystals to form, so intrusive igneous rocks have visible crystals. Granite is the most common intrusive igneous rock. Igneous rocks make up most of the rocks on Earth. Most igneous rocks are buried below the surface and covered with sedimentary rock, or are buried beneath the ocean water. In some places, geological processes have brought igneous rocks to the surface. Yosemite is a classic example of intrusive igneous rock. The molten magma never reached Earth's surface, so the molten material had millions of years to cool down slowly to form granite. Later, geologic forces and erosion have caused those granite plutons to surface as they are today.

EXTRUSIVE IGNEOUS ROCK



Basalt Columns are Extrusive Igneous Rock

Igneous rocks are called extrusive when they cool and solidify above the surface. These rocks usually form from a volcano, so they are also called volcanic rocks. Extrusive igneous rocks cool much more rapidly than intrusive rocks. There is little time for crystals to form, so extrusive igneous rocks have tiny crystals. Cooling rate and gas content create a variety of rock textures. Lavas that cool extremely rapidly may have a glassy texture. Those with many holes from gas bubbles have a vesicular texture.

HUMAN USE OF IGNEOUS ROCK

Igneous rocks have a wide variety of uses. One important use is as stone for buildings and statues. **Granite** is used for both of these purposes and is popular for kitchen countertops. **Pumice** is commonly used as an abrasive. Pumice is used to smooth skin or scrape up grime around the house. When pumice is placed into giant washing machines with newly manufactured jeans and tumbled, the result is “stone-washed” jeans. Ground up pumice stone is sometimes added to toothpaste to act as an abrasive material to scrub teeth. **Peridotite** is sometimes mined for peridot, a type of olivine that is used in jewelry. Diorite was used extensively by ancient civilizations for vases and other decorative artwork and is still used for art today.

Sedimentary Rocks



Sedimentary Rock often has Visible Layers

Sandstone is one of the common types of sedimentary rocks that form from sediments. There are many other types. Sediments may include:

- fragments of other rocks that often have been worn down into small pieces, such as sand, silt, or clay.
- organic materials, or the remains of once-living organisms.
- chemical precipitates, which are materials that get left behind after the water evaporates from a solution.

Rocks at the surface undergo mechanical and chemical weathering. These physical and chemical processes break rock into smaller pieces. **Physical weathering** simply breaks the rocks apart. **Chemical weathering** dissolves the less stable minerals. These original elements of the minerals end up in solution and new minerals may form. Sediments are removed and transported by water, wind, ice, or gravity in a process called erosion.

Streams carry huge amounts of sediment. The more energy the water has, the larger the particle it can carry. A rushing river on a steep slope might be able to carry boulders. As this stream slows down, it no longer has the energy to carry large sediments and will drop them. A slower moving stream will only carry smaller particles.

Sediments are deposited on beaches and deserts, at the bottom of oceans, and in lakes, ponds, rivers, marshes, and swamps. Avalanches 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. Different colors of sedimentary rock are determined by the environment where they are deposited. Red rocks form where oxygen is present. Darker sediments form when the environment is oxygen poor.



SEDIMENTARY ROCK FORMATION

Accumulated sediments harden into rock by a process called **lithification**. Two important steps are needed for sediments to lithify.

1. Sediments are squeezed together by the weight of overlying sediments on top of them. This is called compaction. Cemented, non-organic sediments become clastic rocks. If organic material is included, they are bioclastic rocks.

1. Fluids fill in the spaces between the loose particles of sediment and crystallize to create a rock by cementation.

When sediments settle out of calmer water, they form horizontal layers. One layer is deposited first, and another layer is deposited on top of it. So each layer is younger than the layer beneath it. When the sediments harden, the layers are preserved. Sedimentary rocks formed by the crystallization of chemical precipitates are called chemical sedimentary rocks.

Biochemical sedimentary rocks form in the ocean or a salt lake. Living creatures remove ions, such as calcium, magnesium, and potassium, from the water to make shells or soft tissue. When the organism dies, it sinks to the ocean floor to become a biochemical sediment, which may then become compacted and cemented into solid rock.

HUMAN USE OF SEDIMENTARY ROCK

Sedimentary rocks are used as building stones, although they are not as hard as igneous or metamorphic rocks. Sedimentary rocks are used in construction. Sand and gravel are used to make concrete; they are also used in asphalt. Many economically valuable resources come from sedimentary rocks. Iron ore and aluminum are two examples.

Metamorphic Rock



Metamorphic Rock near Diablo Lake

Metamorphism is the addition of heat and/or pressure to existing rocks, which causes them to change physically and/or chemically so that they become a new rock. Metamorphic rocks may change so much that they may not resemble the original rock. Any type of rock—igneous, sedimentary, or metamorphic—can become a metamorphic rock. All that is needed is enough heat and/or pressure to alter the existing rock's physical or chemical makeup without melting the rock entirely. Rocks change during metamorphism because the minerals need to be stable under the new temperature and pressure conditions. The need for stability may cause the structure of minerals to rearrange and form new minerals. Ions may move between minerals to create minerals of different chemical composition. Hornfels, with its alternating bands of dark and light crystals, is a good example of how minerals rearrange themselves during metamorphism. Extreme pressure may also lead to foliation, the flat layers that form in rocks as the rocks are squeezed by pressure. Foliation normally forms when pressure is exerted in only one direction. Metamorphic rocks may also be non-foliated. Quartzite and limestone are nonfoliated. The two main types of metamorphism are both related to heat within Earth:

- **Regional metamorphism**: Changes in enormous quantities of rock over a wide area caused by the extreme pressure from overlying rock or from compression caused by geologic processes. Deep burial exposes the rock to high temperatures.
- **Contact metamorphism**: Changes in a rock that is in contact with magma because of the magma's extreme heat.

Quartzite is very hard and is often crushed and used in building railroad tracks. Schist and slate are sometimes used as building and landscape materials. Graphite, the "lead" in pencils, is a mineral commonly found in metamorphic rocks.

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1.9: Earth- Plate Tectonics

Learning Objectives

- Compare and describe each of these Earth layers: lithosphere, oceanic crust, and continental crust.
- Describe how convection takes place in the mantle and compare the two parts of the core and describe why they are different from each other.
- Explain the concepts of the following hypothesis: continental drift hypothesis, seafloor spreading hypothesis, and the theory of plate tectonics.
- Describe the three types of tectonic plate and how the processes lead to changes in Earth's surface features.

Essential Questions

- What is the driving force of plate tectonics and how does this impact earthquakes and volcanoes around the world?
- How does the theory of plate tectonics help explain the different types of earthquakes and volcanoes around the planet?



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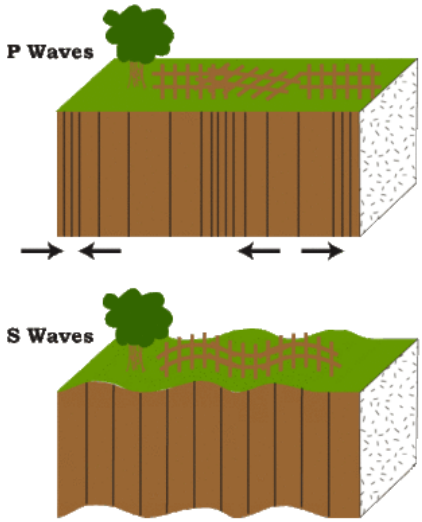
UNDERSTANDING EARTH'S INTERIOR

Before you can learn about plate tectonics, you need to know something about the layers that are found inside Earth. These layers are divided by composition into core, mantle, and crust or by mechanical properties into lithosphere and asthenosphere. Scientists use information from earthquakes and computer modeling to learn about Earth's interior. Humans have never drilled past Earth's crust, and yet we know a lot about the composition of the earth's interior. Rocks yield some clues, but they only reveal information about the outer crust. In rare instances, a mineral, such as a diamond, comes to the surface from deeper down in the crust or the mantle. To learn about Earth's interior, scientists use energy, recorded by seismographs, to "see" the different layers of the Earth, just like doctors can use an MRI, CT scan, or x-ray to see inside our bodies.

SEISMIC WAVES

One ingenious way scientists learn about Earth's interior is by looking at how energy travels from the point of an earthquake, called

seismic waves. Seismic waves travel outward in all directions from where the ground breaks at an earthquake. Seismograph stations measure the energy released by these earthquakes, but there are two that scientists are most interested with in regards to understanding the interior of the earth.



P and S waves have differing movement.

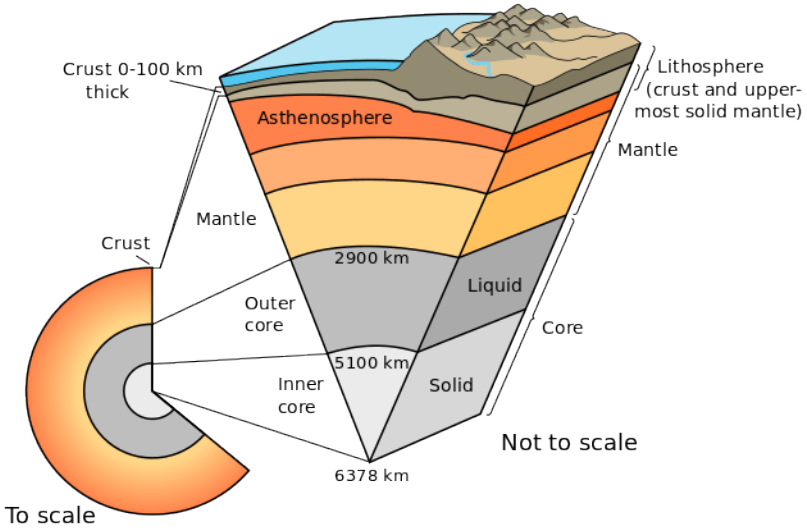
Primary waves (also called **P-waves**) are fastest, traveling at about 6 to 7 kilometers (about 4 miles) per second, so they arrive first at the seismometer. P-waves move in a compression/expansion type motion, squeezing and unsqueezing earth materials as they travel. P-waves bend slightly when they travel from one layer into another. Seismic waves move faster through denser or more rigid material. As P-waves encounter the liquid outer core, which is less rigid than the mantle, they slow down. This makes the P-waves arrive later and further away than would be expected. The result is a P-wave shadow zone. No P-waves are picked up at seismographs 104° to 140° from the earthquakes focus.

Secondary waves (also called **S-waves**) are about half as fast as P-waves, traveling at about 3.5 km (2 miles) per second, and arrive second at seismographs. S-waves move in an up and down motion perpendicular to the direction of wave travel. This produces a change in shape for the earth materials they move through. Only solids resist a change in shape, so S-waves are only able to propagate through solids. S-waves cannot travel through liquid. By tracking seismic waves, scientists have learned what makes up the planet's interior. P-waves slow down at the mantle core boundary, so we know the outer core is less rigid than the mantle. S-waves disappear at the mantle core boundary, so the outer core is liquid.

Other clues to Earth's interior includes the fact that we know that Earth's overall density is higher than the density of crustal rocks, so the core must be made of something dense, like metal. Also, since Earth has a magnetic field, there must be metal within the planet. Iron and nickel are both magnetic. Finally, meteorites are the remains of the material that formed the early solar system and are thought to be similar to material in Earth's interior.

COMPOSITION AND STRUCTURE OF EARTH

Core, mantle, and crust are divisions based on composition. The crust makes up less than 1 percent of Earth by mass, consisting of oceanic crust and continental crust is often more felsic rock. The mantle is hot and represents about 68 percent of Earth's mass. Finally, the core is mostly iron metal. The core makes up about 31% of the Earth. The lithosphere and asthenosphere are divisions based on mechanical properties. The **lithosphere** is composed of both the crust and the portion of the upper mantle that behaves as a brittle, rigid solid. The **asthenosphere** is partially molten upper mantle material that behaves plastically and can flow.



CRUST AND LITHOSPHERE

Earth's outer surface is its crust; a cold, thin, brittle outer shell made of rock. The crust is very thin, relative to the radius of the planet. There are two very different types of crust, each with its own distinctive physical and chemical properties.

Oceanic crust is composed of magma that erupts on the seafloor to create basalt lava flows or cools deeper down to create the intrusive igneous rock gabbro. Sediments, primarily muds and the shells of tiny sea creatures, coat the seafloor. Sediment is thickest near the shore where it comes off the continents in rivers and on wind currents. Ocean plates are rich in iron.

Continental crust is made up of many different types of igneous, metamorphic, and sedimentary rocks. The average composition is granite, which is much less dense than the mafic igneous rocks of the oceanic crust. Because it is thick and has relatively low density, continental crust rises higher on the mantle than oceanic crust, which sinks into the mantle to form basins. When filled with water, these basins form the planet's oceans. Continental plates are rich in silicates and have relatively less iron than ocean plates.

The lithosphere is the outermost mechanical layer, which behaves as a brittle, rigid solid. The lithosphere is about 100 kilometers thick. The definition of the lithosphere is based on how earth materials behave, so it includes the crust and the uppermost mantle, which are both brittle. Since it is rigid and brittle, when stresses act on the lithosphere, it breaks. This is what we experience as an earthquake.

MANTLE

The two most important things about the mantle are: (1) it is made of solid rock, and (2) it is hot. Scientists know that the mantle is made of rock based on evidence from seismic waves, heat flow, and meteorites. The properties fit the ultramafic rock peridotite, which is made of the iron- and magnesium-rich silicate minerals. Peridotite is rarely found at Earth's surface.

Scientists know that the mantle is extremely hot because of the heat flowing outward from it and because of its physical properties. Heat flows in two different ways within the Earth: conduction and convection. Conduction is defined as the heat transfer that occurs through rapid collisions of atoms, which can only happen if the material is solid. Heat flows from warmer to cooler places until all are the same temperature. The mantle is hot mostly because of heat conducted from the core. Convection is the process of a material that can move and flow may develop convection currents.

Convection in the mantle is the same as convection in a pot of water on a stove. Convection currents within Earth's mantle form as material near the core heats up. As the core heats the bottom layer of mantle material, particles move more rapidly, decreasing its density and causing it to rise. The rising material begins the convection current. When the warm material reaches the surface, it spreads horizontally. The material cools because it is no longer near the core. It eventually becomes cool and dense enough to sink back down into the mantle. At the bottom of the mantle, the material travels horizontally and is heated by the core. It reaches

the location where warm mantle material rises, and the mantle convection cell is complete.

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CORE

At the planet's center lies a dense metallic **core**. Scientists know that the core is metal for a few reasons. The density of Earth's surface layers is much less than the overall density of the planet, as calculated from the planet's rotation. If the surface layers are less dense than average, then the interior must be denser than average. Calculations indicate that the core is about 85 percent iron metal with nickel metal making up much of the remaining 15 percent. Also, metallic meteorites are thought to be representative of the core.

If Earth's core were not metal, the planet would not have a magnetic field. Metals such as iron are magnetic, but rock, which makes up the mantle and crust, is not. Scientists know that the outer core is liquid and the inner core is solid because S-waves stop at the inner core. The strong magnetic field is caused by convection in the liquid outer core. Convection currents in the outer core are due to heat from the even hotter inner core. The heat that keeps the outer core from solidifying is produced by the breakdown of radioactive elements in the inner core.

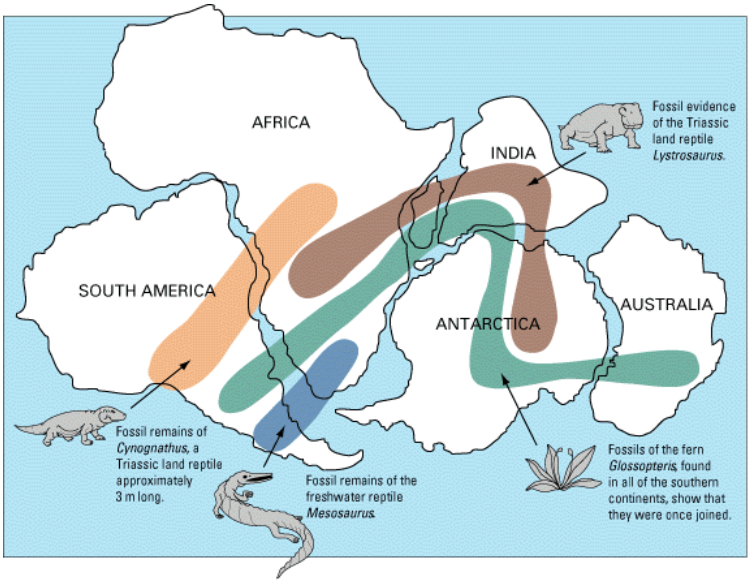
CONTINENTAL DRIFT

The continental drift hypothesis was developed in the early part of the 20th century, mostly by Alfred Wegener. Wegener said that continents move around on Earth's surface and that they were once joined together as a single supercontinent. While Wegener was alive, scientists did not believe that the continents could move.

Find a map of the continents and cut each one out. Better yet, use a map where the edges of the continents show the continental shelf. That's the true size and shape of a continent and many can be pieced together like a puzzle. The easiest link is between the eastern Americas and western Africa and Europe, but the rest can fit together too.

Alfred Wegener proposed that the continents were once united into a single supercontinent named Pangaea, meaning all earth in

ancient Greek. He suggested that Pangaea broke up long ago and that the continents then moved to their current positions. He called his hypothesis continental drift.



EVIDENCE FOR CONTINENTAL DRIFT

Besides the way the continents fit together, Wegener and his supporters collected a great deal of evidence for the continental drift hypothesis. For one, identical rocks of the same type and age are found on both sides of the Atlantic Ocean. Wegener said the rocks had formed side-by-side and that the land had since moved apart.

Mountain ranges with the same rock types, structures, and ages are now on opposite sides of the Atlantic Ocean. The Appalachians of the eastern United States and Canada, for example, are just like mountain ranges in eastern Greenland, Ireland, Great Britain, and Norway. Wegener concluded that they formed as a single mountain range that was separated as the continents drifted.

Ancient fossils of the same species of extinct plants and animals are found in rocks of the same age but are on continents that are now widely separated. Wegener proposed that the organisms had lived side by side, but that the lands had moved apart after they were dead and fossilized. He suggested that the organisms would not have been able to travel across the oceans. For example, the fossils of the seed fern *Glossopteris* were too heavy to be carried so far by wind. The reptile Mesosaurus could only swim in fresh water. was a swimming reptile but could only swim in fresh water. *Cynognathus* and *Lystrosaurus* were land reptiles and were unable to swim.

Grooves and rock deposits left by ancient glaciers are found today on different continents very close to the equator. This would indicate that the glaciers either formed in the middle of the ocean and/or covered most of the Earth. Today glaciers only form on land and nearer the poles. Wegener thought that the glaciers were centered over the southern land mass close to the South Pole and the continents moved to their present positions later on.

Coral reefs and coal-forming swamps are found in tropical and subtropical environments, but ancient coal seams and coral reefs are found in locations where it is much too cold today. Wegener suggested that these creatures were alive in warm climate zones and that the fossils and coal later had drifted to new locations on the continents.

Although Wegener's evidence was sound, most geologists at the time rejected his hypothesis of continental drift. Scientists argued that there was no way to explain how solid continents could plow through solid oceanic crust. There was no mechanism explaining how the continents moved. Wegener's idea was nearly forgotten until technological advances presented even more evidence that the continents moved and gave scientists the tools to develop a mechanism for Wegener's drifting continents.

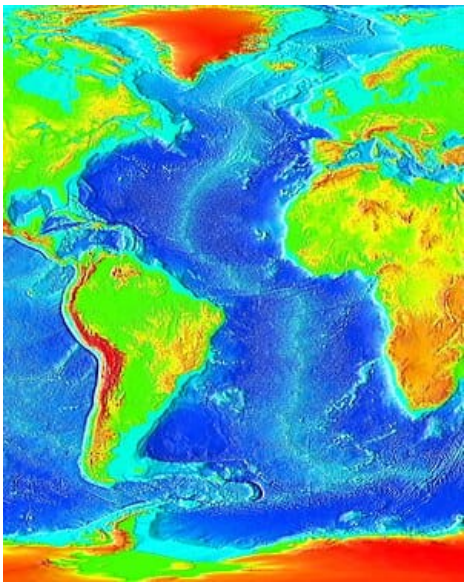
THE SEAFLOOR

Wegener first proposed his concept of Continental Drift in 1915. There weren't effective tools available for investigating the ocean floor. But that changed during and after WWII. World War II gave scientists the tools to find the mechanism for continental drift that had eluded Wegener. Maps and other data gathered during the war allowed scientists to develop the **seafloor spreading**

hypothesis. This hypothesis traces oceanic crust from its origin at a mid-ocean ridge to its destruction at a deep sea trench and is the mechanism for continental drift.

Mapping the Ocean Floors: Physical geography

During World War II, battleships and submarines carried echo sounders to locate enemy submarines. Echo sounders produce sound waves that travel outward in all directions, bounce off the nearest object, and then return to the ship. By knowing the speed of sound in seawater, scientists calculate the distance to the object based on the time it takes for the wave to make a round-trip. During the war, most of the sound waves ricocheted off the ocean bottom.



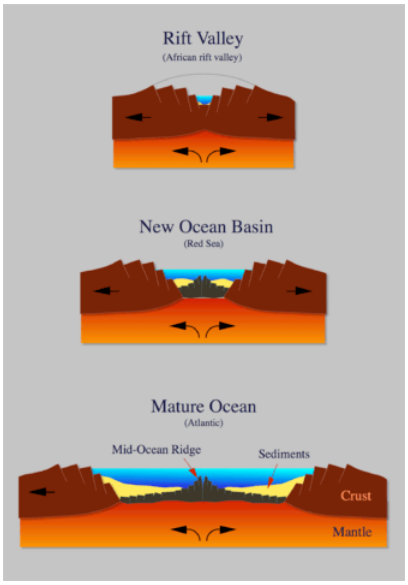
After the war, using sonar information, Bruce Heezen and Marie Tharp created the first detailed map of the ocean floor to reveal the Mid-Atlantic Ridge, a basaltic mountain range that spanned the length of the Atlantic Ocean, with dimensions unlike the mountains found on the continents. The world now had a new understanding of the shape and landforms of the seafloor.

The next step is to explain those landforms. Initially scientists thought the ridge was part of a mechanism that explained the expanding Earth or ocean-basin growth hypotheses. In 1959, Harry Hess proposed the hypothesis of seafloor spreading – that the mid-ocean ridges represented tectonic plate factories, where new oceanic plate was issuing from these long volcanic ridges. Scientists later included transform faults perpendicular to the ridges to better account for varying rates of movement between the newly formed plates. When earthquake epicenters were discovered along the ridges, the idea that earthquakes were linked to plate movement took hold.



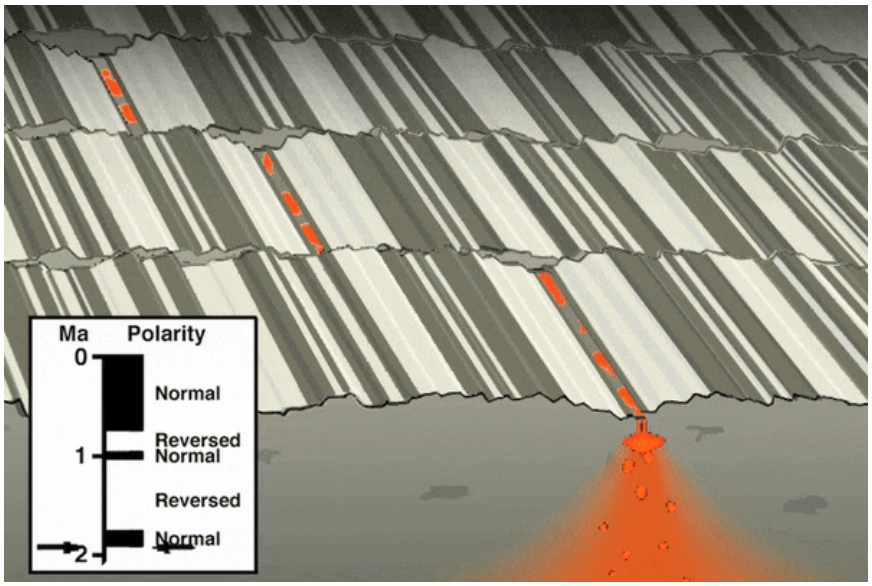
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Seafloor sediment , measured by dredging and drilling, provided another clue. Scientists once believed sediment accumulated on the ocean floors over a very long time in a static environment. When some studies showed less sediment than expected, these results were initially used to argue against continental movement. With more time, researchers discovered these thinner sediment layers were located close to mid-ocean ridges , indicating the ridges were younger than the surrounding ocean floor . This finding supported the idea that the sea floor was not fixed in one place.



Spreading Seafloor pushes some Continents Apart

Explaining the landforms: Chemistry and Magnetism



The Orange areas are Divergent Boundaries showing Polarity Reversal. There are also several Transform Boundary lines running left to right.

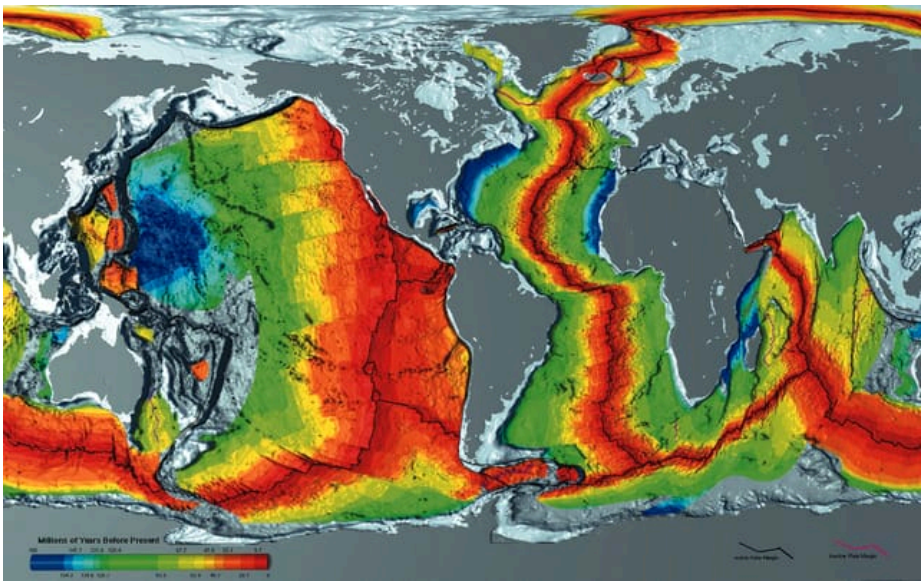
During WWII, magnetometers devices capable of measuring the magnetic field intensity, were also attached to ships to search for submarines. They found an astonishing feature. The magnetic polarity of seafloor basalts reverses, and creates a pattern. Stripes of normal polarity and reversed polarity alternate across the ocean bottom. These stripes also forms a mirror image of itself on either side of the mid-ocean ridges. But the stripes end abruptly at the edges of continents, sometimes at a deep sea trench.

Although the magnetite crystals were pointing to the magnetic north pole, the location of the pole seemed to wander. Scientists were amazed to find that the north magnetic pole changed location through time. There are three possible explanations for this: 1) The continents remained fixed and the north magnetic pole moved. 2) The north magnetic pole stood still and the continents moved, or 3) both the continents and the north pole moved.

Geologists noted that for rocks of the same age but on different continents, the little magnets pointed to different magnetic north poles. For example, 400-million-year-old magnetite in Europe pointed to a different north magnetic pole than the same-aged magnetite in North America. Around 250 million years ago, the north poles were also different for the two continents.

The scientists looked again at the three possible explanations. Only one can be correct. If the continents had remained fixed while the north magnetic pole moved, there must have been two separate north poles. Since there is only one north pole today, the only reasonable explanation is that the north magnetic pole has remained fixed but that the continents have moved.

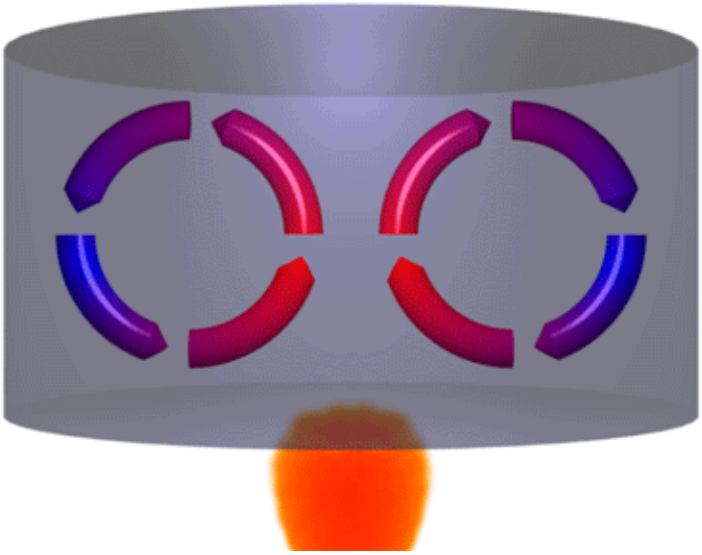
To test this, geologists fitted the continents together as Wegener had done and behold, it worked. There has only been one magnetic north pole and the continents have drifted. They named the phenomenon of the magnetic pole that seemed to move but actually did not apparent polar wander. This evidence for continental drift gave geologists renewed interest in understanding how continents could move about on the planet's surface.



Seafloor Crust Age

The oldest seafloor is near the edges of continents or deep sea trenches and is less than 180 million years old. Since the oldest ocean crust is so much younger than the oldest continental crust, scientists realized that seafloor was being destroyed in a relatively short time.

SEAFLOOR SPREADING HYPOTHESIS, How Plates Move



Convection Cells in the Mantle Operate like Convection Cells in the Atmosphere.

Scientists brought these observations together in the early 1960s to create the **seafloor spreading hypothesis**. In this hypothesis, hot buoyant mantle rises up a mid-ocean ridge, causing the ridge to rise upward. The hot magma at the ridge erupts as lava that forms new seafloor. When the lava cools, the magnetite crystals take on the current magnetic polarity and as more lava erupts, it pushes the seafloor horizontally away from ridge axis.

The magnetic stripes continue across the seafloor. As oceanic crust forms and spreads, moving away from the ridge crest, it pushes the continent away from the ridge axis. If the oceanic crust reaches a deep sea trench, it sinks into the trench and is lost into the mantle. Scientists now know that the oldest crust is coldest and lies deepest in the ocean because it is less buoyant than the hot new crust.

Seafloor spreading is the mechanism for Wegener's drifting continents. Convection currents within the mantle take the continents

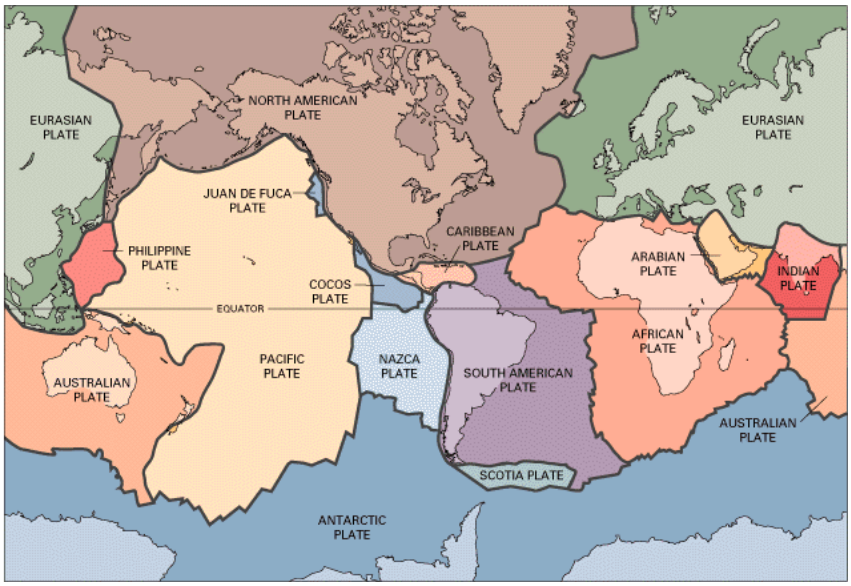
on a conveyor-belt ride of oceanic crust that over millions of years takes them around the planet's surface.

TECTONIC THEORY

Plate tectonics is the unifying theory of geology. Plate tectonics theory explains why:

- Earth's geography has changed through time and continues to change today.
- some places are prone to earthquakes while others are not.
- certain regions may have deadly, mild, or no volcanic eruptions.
- mountain ranges are located where they are.

Plate tectonic motions affect Earth's rock cycle, climate, and the evolution of life.



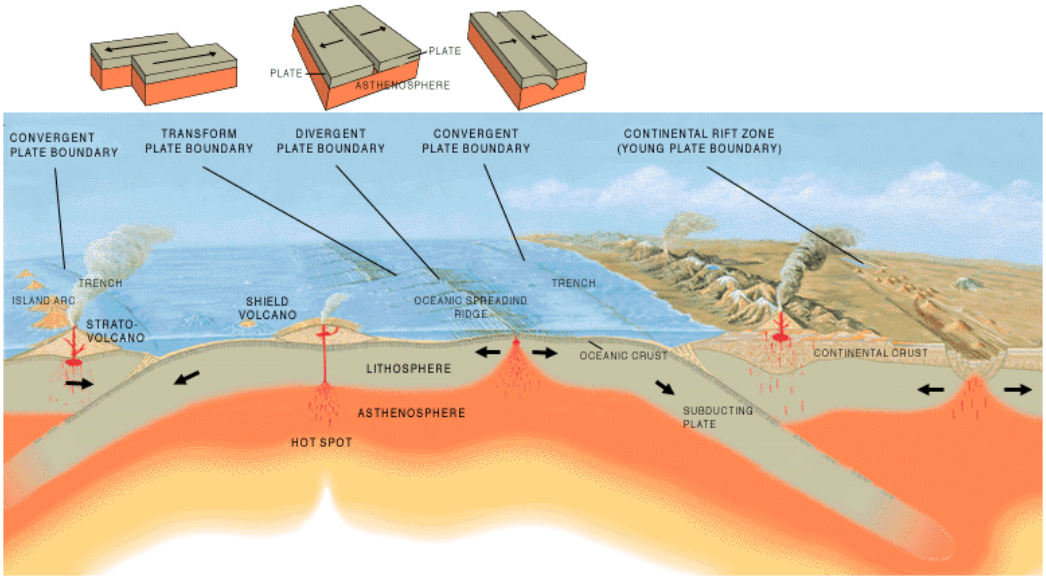
Location of Major Tectonic Plates and Relative Motion

PLATE BOUNDARIES

We've now looked at the interior of the Earth, the major landforms of the surface, and how plates move. Now let's see what happens at the surface because of the movement and interaction of different plates.

Plate boundaries are the edges where two plates meet. Most geologic activities, including volcanoes, earthquakes, and mountain building, take place at plate boundaries. How can two plates move relative to each other?

- Divergent plate boundaries: the two plates move away from each other.
- Convergent plate boundaries: the two plates move towards each other.
- Transform plate boundaries: the two plates slip past each other.



Schematic of plate boundary types.

The type of plate boundary and the type of crust found on each side of th e boundary determines what sort of geologic activity will be found there.

Plate Boundary Landforms by the Numbers

1 Earth

2 Types of Plates: Oceanic and Continental

3 Types of Relative Movement: Divergent, Convergent, Transform

2×3= 6 Unique Landforms: Non-Volcanic Mountains, Volcanoes, Trenches, Ocean Ridges, Continental Rifts, Narrow Valleys



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DIVERGENT PLATE BOUNDARIES



Afar Triangle: A Divergent Boundary runs through the Red Sea, Gulf of Aden and into the East African Rift.

Plates move apart at mid-ocean ridges where new seafloor forms. Between the two plates is a rift valley. Lava flows at the surface cool rapidly to become basalt, but deeper in the crust, magma cools more slowly to form gabbro. So the entire ridge system is made up of igneous rock that is either extrusive or intrusive. Earthquakes are common at mid-ocean ridges since the movement of magma and oceanic crust results in crustal shaking. The vast majority of mid-ocean ridges are located deep below the sea. Here is an animation from the United States Geologic Survey (USGS) of divergent plate boundary at mid-ocean ridge and another animation by IRIS.As divergence occurs, shallow earthquakes can occur along with volcanoes along the rift areas. When the process begins, a valley will develop such as the Great Rift Valley in Africa. Over time that valley can fill up with water creating **linear lakes**. If divergence continues, a sea can form like the Red Sea and finally an ocean like the Atlantic Ocean. Check out the eastern half of Africa and notice the lakes that look linear. Eastern Africa is tearing apart from these linear lakes, to the Great Rift Valley, and up to the Red Sea. The ultimate divergent boundary is the Atlantic Ocean, which began when Pangea broke apart.

CONVERGENT PLATE BOUNDARIES



Long narrow lakes along the East African Rift. Lake Victoria, while large and nearby, is not on a rift.

When two plates converge, the result depends on the type of lithosphere the plates are made of. No matter what, smashing two enormous slabs of lithosphere together results in the creation of magma and earthquakes.



Convergent Boundary along Western South America

Ocean-to-continent convergence occurs when oceanic crust converges with continental crust, forcing the denser oceanic plate to plunge beneath the continental plate. This process called **subduction**, occurs along oceanic trenches called **subduction zones** where lots of intense earthquakes and volcanic eruptions can occur. The denser, subducting plate begins to heat up under extreme pressure near the mantle and melts to create causes melting in the volcanoes. These coastal volcanic mountains are found in a line above the subducting plate. The volcanoes are known as a continental arc. The movement of crust and magma causes earthquakes. Click here for a map of earthquake epicenters at subduction zones.

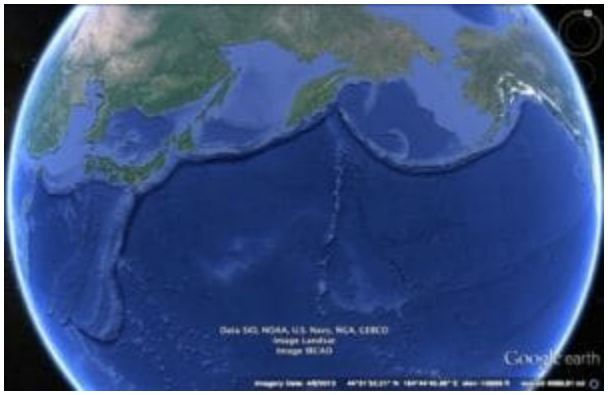
Video

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View this Video online

The volcanoes of northeastern California—Lassen Peak, Mount Shasta, and Medicine Lake volcano—along with the rest of the Cascade Mountains of the Pacific Northwest are the result of subduction of the Juan de Fuca plate beneath the North American plate. The Juan de Fuca plate is created by seafloor spreading just offshore at the Juan de Fuca ridge.

If the magma at a continental arc is felsic, it may be too viscous (thick) to rise through the crust. The magma will cool slowly to form granite or granodiorite. These large bodies of intrusive igneous rocks are called batholiths, which may someday be uplifted to form a mountain range.



Ocean-Ocean Convergence creates Trenches

An **oceanic-to-oceanic plate boundary** occurs when two oceanic plates converge, causing the older, denser plate will subduct into the mantle. An ocean trench marks the location where the plate is pushed down into the mantle. The line of volcanoes that grows on the upper oceanic plate is an island arc.

The Ring of Fire is a ring around the Pacific Ocean of subduction zones, which most are oceanic-to-oceanic convergence. Here is an animation of an ocean continent plate boundary. Along these subduction zones, volcanic islands (also called volcanic arcs) form. Examples of these regions include Japan, Indonesia, and the Aleutian Islands.



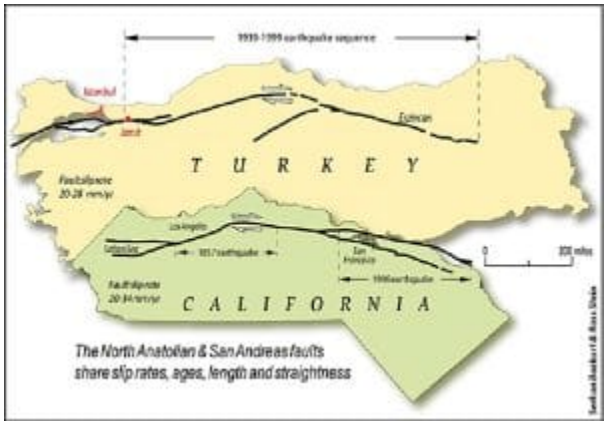
Continent-Continent Convergence

When two continental plates converge, instead of subduction, the two similar tectonic plates will buckle up to create large mountain ranges like a massive car pile-up. This is called **continental-to-continental convergence**, and geologically creates intense folding and faulting rather than volcanic activity.

Examples of mountain ranges created by this process are the Himalayan mountains as India is colliding with Asia, the Alps in Europe, and the Appalachian mountains in the United States as the North American plate collided with the African plate when Pangea was forming. The Kashmir India earthquake of 2005 that killed over 80,000 people occurred because of this process. And most recently, the 2008 earthquake in China which killed nearly 85,000 people before the Summer Olympics was because of this tectonic force. The Appalachian Mountains are the remnants of a large mountain range that was created when North America rammed into Eurasia about 250 million years ago.

TRANSFORM PLATE BOUNDARIES

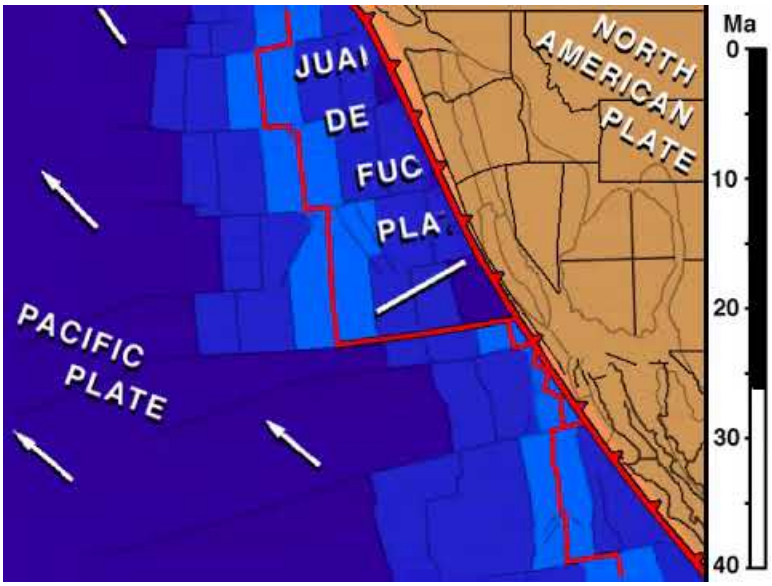
Transform plate boundaries occur when two tectonic plates slide (or grind) past parallel to each other. The most famous **transform boundary** is the **San Andreas Fault** where the Pacific plate that Los Angeles and Hawaii are on is grinding past the North American plate that San Francisco and the rest of the United States is on at the rate of 3 inches a year. Recently, geologists have stated that San Francisco should expect another disastrous earthquake in the next 30 years. Another important transform boundary is the **North Anatolian Fault** in Turkey. This powerful fault last ruptured in 1999 in Izmit, Turkey which killed 17,000 people in 48 seconds.



Two Transform Faults



Creek bed location shifting due to San Andreas fault movement.



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INTRAPLATE BOUNDARIES

A small amount of geologic activity, known as **intraplate activity**, does not take place at plate boundaries but within a plate instead. Mantle plumes are pipes of hot rock that rise through the mantle. The release of pressure causes melting near the surface to form a **hotspot**. Eruptions at the hotspot create a volcano. Hotspot volcanoes are found in a line. Can you figure out why? Hint: The youngest volcano sits above the hotspot and volcanoes become older with distance from the hotspot. Geologists use some hotspot chains to tell the direction and the speed a plate is moving. Hotspot magmas rarely penetrate through thick continental crust. One exception is the Yellowstone hotspot.

A CHANGING SURFACE

Geologists know that Wegener was right because the movements of continents explain so much about the geology we see. Most of the geologic activity that we see on the planet today is because of the interactions of the moving plates.

In the map of North America, where are the mountain ranges located? Using what you have learned about plate tectonics, try to answer the following questions:

1. What is the geologic origin of the Cascades Range? The Cascades are a chain of volcanoes in the Pacific Northwest. They are not labelled on the diagram but they lie between the Sierra Nevada and the Coastal Range.
2. What is the geologic origin of the Sierra Nevada? (Hint: These mountains are made of granitic intrusions.)
3. What is the geologic origin of the Appalachian Mountains along the Eastern US?

Remember that Wegener used the similarity of the mountains on the west and east sides of the Atlantic as evidence for his continental drift hypothesis. The Appalachian mountains formed at a convergent plate boundary as Pangaea came together.

Before Pangaea came together, the continents were separated by an ocean where the Atlantic is now. The proto-Atlantic ocean shrank as the Pacific ocean grew. Currently, the Pacific is shrinking as the Atlantic is growing. This supercontinent cycle is responsible for most of the geologic features that we see and many more that are long gone.

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1.10: Tectonic Forces- Quakes and Volcanoes

Learning Objectives

- Describe the causes of tectonic stress and how they influence earthquakes and volcanoes.
- Understand where earthquakes and volcanoes are located around the world and why.
- Explain geologic structures that lead to folding and faulting of the physical landscape.
- Determine how the composition of magma determines the explosiveness of the volcanic eruption.
- Describe the various types of fault lines and volcanoes and the landforms they form.

Essential Questions

- Could humans live in places along the Wasatch Front without the Wasatch fault and the earthquakes it causes?
- How does plate tectonics explain where and why earthquakes and volcanoes occur where they do?
- What role do earthquakes and volcanoes have on civilization? What benefits do they bring us?
- How could understanding Earth's tectonic forces help save lives?
- What beneficial roles do tectonic forces have ecologically and for humanity?

TECTONIC STRESS



Three stresses work to deform the lithosphereand create a landscape of diverse landforms. Tectonic forces have the ability to lift rock and increase the elevation of the land surface, or ocean floor. In a later chapter we'll discuss weathering and erosion which counteract tectonic forces. For now we'll begin by considering what can happen to rocks when they are exposed to stress. **Stress** is the force applied to an object. In geosciences, stress is the force per unit area that is placed on a rock.

- **Compression** squeezes rocks together, causing rocks to fold or fracture. Compression is the most common stress at convergent plate boundaries.
- Rocks that are pulled apart are under **tension**. Rocks under tension lengthen or break apart. Tension is the major type of stress at divergent plate boundaries.
- When forces are parallel but moving in opposite directions, the stress is called shear. **Shear** stress is the most common stress at transform plate boundaries.

A rock's response to stress depends on the rock type, the surrounding temperature, and pressure conditions the rock is under, the length of time the rock is under stress, and the type of stress. The rocks then have three possible responses to increasing stress: elastic deformation, plastic deformation, or fracturing. **Elastic deformation** occurs when the rock returns to its original shape when the stress is removed. When rocks under stress do not return to its original shape when the stress is removed, it is called **plastic deformation**. Finally, when a rock under stress breaks, it's called a **fracture**.

Under what conditions do you think a rock is more likely to fracture? Is it more likely to break deep within Earth's crust or at the surface? What if the stress applied is sharp rather than gradual? At the Earth's surface, rocks usually break quite quickly, but deeper in the crust, where temperatures and pressures are higher, rocks are more likely to deform plastically. Sudden stress, such as a hit with a hammer, is more likely to make a rock break. Stress applied over time often leads to plastic deformation.

Geologic Structures

Sedimentary rocks are important for deciphering the geologic history of a region because they follow certain rules. First, sedimentary rocks are formed with the oldest layers on the bottom and the youngest on top. Second, sediments are deposited horizontally, so sedimentary rock layers are originally horizontal, as are some volcanic rocks, such as ash falls. Finally, sedimentary rock layers that are not horizontal are deformed in some manner. Often times looking like they are tiling into the earth.

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 that are caused by stresses.

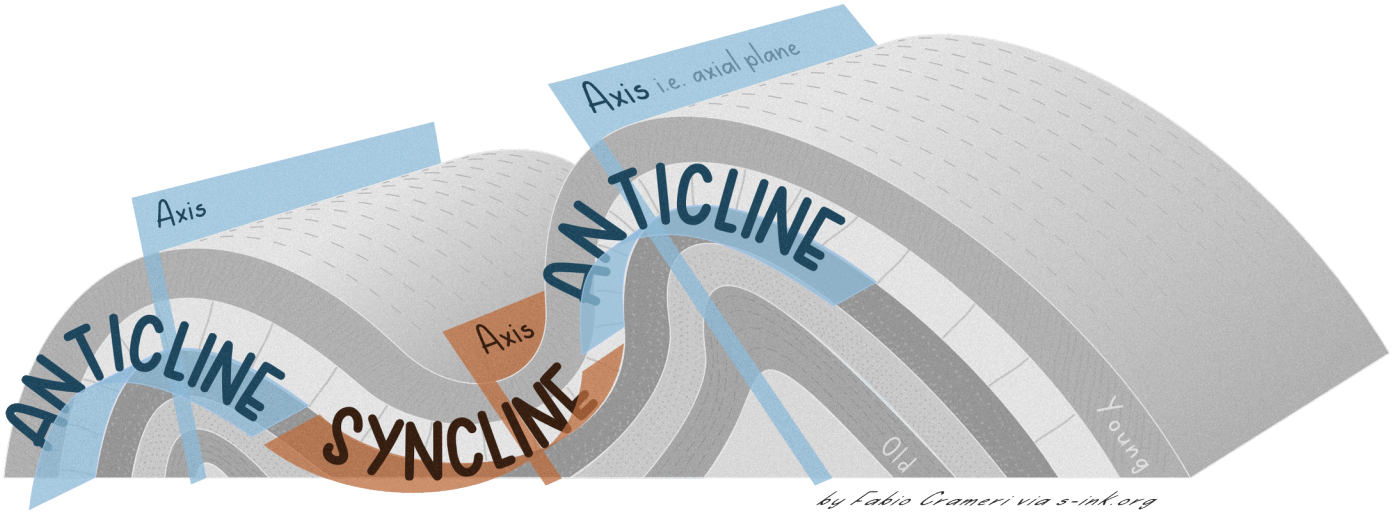


FOLDS

Rocks deforming plastically under compressive stresses crumple into folds. They do not return to their original shape. If the rocks experience more stress, they may undergo more folding or even fracture. There are three major types of rock folding: monoclines, synclines, and anticlines. A **monocline** is a simple bend in the rock layers so that they are no longer horizontal. **Anticlines** are folded rocks that arch upward and dip away from the center of the fold. The oldest rocks are at the center of an anticline and the youngest are draped over them. When rocks arch upward to form a circular structure, that structure is called a **dome**. A **syncline** is a fold that bends downward, causing the youngest rocks are to be at the center and the oldest are on the outside. When rocks bend downward in a circular structure, that structure is called a **basin**. If the rocks are exposed at the surface, where are the oldest rocks located?

Picture

Monocline diagram



A Anticline has layers that bend and are similar to an Arch. A Syncline looks like a Smile.

FAULTS



Tectonic Faults, like electrical faults, disrupt a continuous line of rock or electricity.

A rock under enough stress will eventually fracture. If there is no movement on either side of a fracture, the fracture is called a **joint**. But if the blocks of rock on one or both sides of a fracture move, the fracture is called a fault. Sudden motions along faults cause rocks to break and move suddenly, releasing the stored up stress energy to create an earthquake.

A **slip** is the distance rocks move along a fault and can be up or down the fault plane. Slip is relative, because there is usually no way to know whether both sides moved or only one. Faults lie at an angle to the horizontal surface of the Earth. That angle is called the fault's **dip**. The dip defines which of two basic types a fault is. If the fault's dip is inclined relative to the horizontal, the fault is a dip-slip fault. There are two types of **dip-slip faults**. In **normal faults**, the hanging wall drops down relative to the footwall. Normal faults can be huge and are often times responsible for uplifting mountain ranges in regions experiencing tensional stress.

With **reverse faults**, the footwall drops down relative to the hanging wall. A type of reverse fault is a thrust fault, in which the fault plane angle is nearly horizontal. Rocks can slip many miles along thrust faults.

A **strike-slip fault** is a dip-slip fault in which the dip of the fault plane is vertical and result from shear stresses. California's San Andreas Fault is the world's most famous strike-slip fault. It is a right-lateral strike slip fault.

STRESS AND MOUNTAIN BUILDING

It is the shear power and strength of two or more converging continental plates smash upwards that create mountain ranges. Stresses from this uplift cause folds, reverse faults, and thrust faults, which allow the crust to rise upwards. Subduction of oceanic lithosphere at convergent plate boundaries also builds mountain ranges.

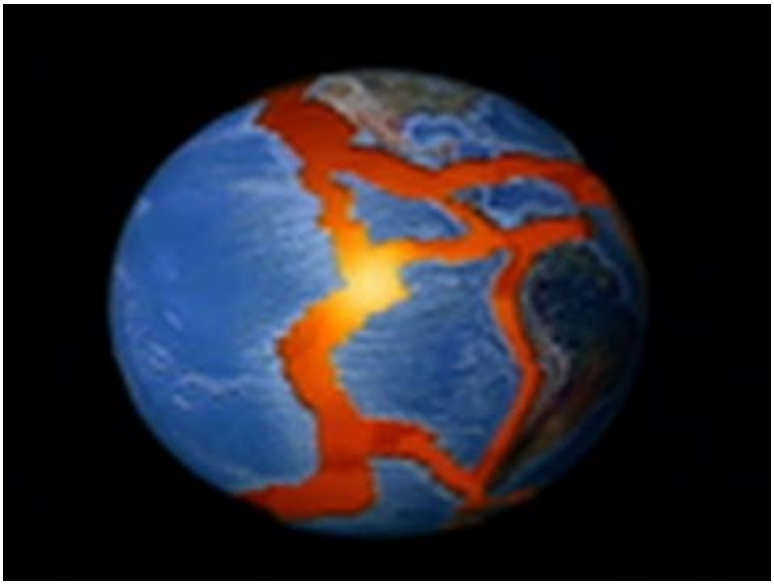
When tensional stresses pull crust apart, it breaks into blocks that slide up and drop down along normal faults. The result is alternating mountains and valleys, known as a basin-and-range.

EARTHQUAKES

CAUSES OF QUAKES

An **earthquake** is sudden ground movement caused by the sudden release of energy stored in rocks, called the **elastic rebound theory**. Earthquakes happen when so much stress builds up in the rocks that the rocks rupture. The energy is transmitted by seismic waves. Each year there are more than 150,000 earthquakes strong enough to be felt by people and 900,000 recorded by seismometers!

In an earthquake, the initial point where the rocks rupture in the crust is called the **focus** (sometimes called the **hypocenter**). The **epicenter** is the point on the land surface that is directly above the focus. In about 75% of earthquakes, the focus is in the top 10 to 15 kilometers (6 to 9 miles) of the crust. **Shallow earthquakes** cause the most damage because the focus is near where people live. However, it is the epicenter of an earthquake that is reported by scientists and the media.



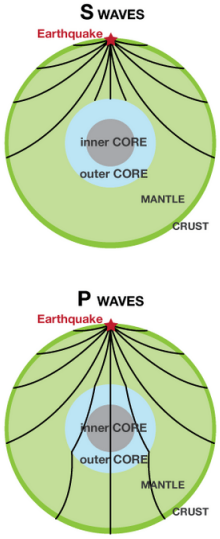
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SEISMIC WAVES

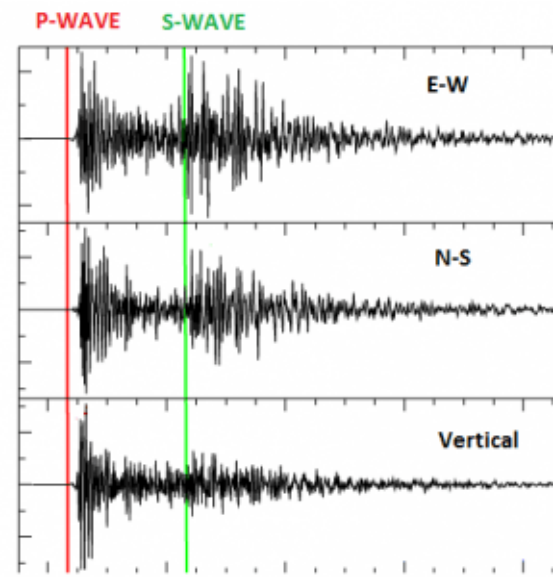
Physics shows us that energy is always transmitted in waves. Every wave has a high point called a **crest** and a low point called a **trough**. The height of a wave from the center line to its crest is its **amplitude**. The distance between waves from crest to crest (or trough to trough) is its **wavelength**.



S waves can't transmit through fluids. P waves do, but will bend.

The energy from earthquakes travels in seismic waves. The study of seismic waves is known as **seismology**. Seismologists use seismic waves to learn about earthquakes and also to learn about the Earth's interior. The two types of seismic waves described in "Plate Tectonics," P-waves and S-waves, are known as **body waves** because they move through the solid body of the Earth. P-waves travel through solids, liquids, and gases. S-waves only move through solids. **Surface waves** travel along the ground, outward from an earthquake's epicenter. Surface waves are the slowest of all seismic waves, traveling at 2.5 km (1.5 miles) per second. In an earthquake, body waves produce sharp jolts, while rolling motions of surface waves do most of the damage in an earthquake.

LOCATING A QUAKE



At one location, there are 3 seismometers. Each records the arrival time of P and S waves.

In order to locate an earthquake epicenter, scientists must first determine the epicenter distance from three different seismographs. P waves travel faster than S waves, so a seismogram will record P waves first, then S waves later. The longer the time between the arrival of the P-wave and S-wave, the farther away is the epicenter. So the difference in the P and S wave arrival times determines the distance between the epicenter and a seismometer. After analyzing thousands, perhaps millions of quakes, we now have a reliable estimate of the average speed of P and S ways.

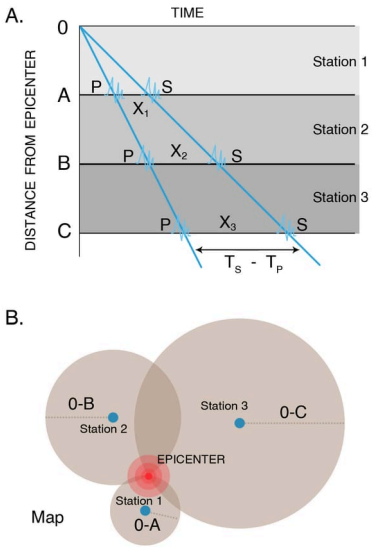
Triangulating the location of a quake. Three circles intersect near Mt. Rainier.

The scientist then draws a circle with a radius equal to the distance from the epicenter for that seismograph. The epicenter is somewhere along that circle. This is done for three locations. Using data from two seismographs, the two circles will intercept at two points. A third circle will intercept the other two circles at a single point. This point is the earthquake epicenter. Although useful for decades, this technique has been replaced by digital calculations. IRIS has an app here for practicing triangulation.

Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this Video online



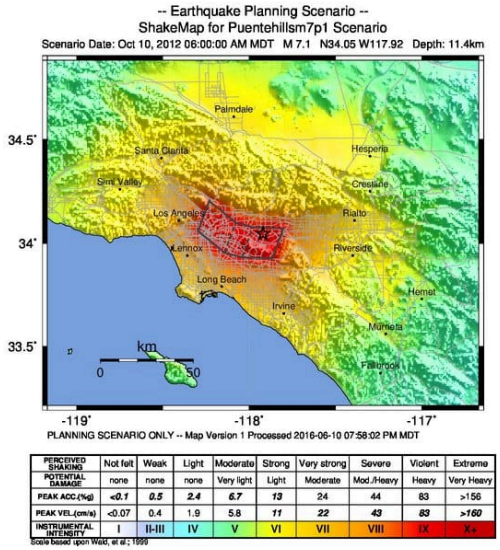
Two views of (a) P waves and (b) S waves, all moving from left to right. P waves move by alternately compressing and extending the material through which it passes, somewhat analogous to stop-and-go traffic on the freeway during rush hour. S waves move by shearing the material from side to side, analogous to flipping a rope tied to a tree. Note the illustration of wavelength for P and S waves and amplitude for S waves. The number of complete wavelengths to pass a point in a second is the frequency.

MEASURING MAGNITUDE

People have always tried to quantify the size of and damage done by earthquakes. With the invention of the seismograph station, the **Richter magnitude scale** was created. Developed in 1935 by Charles Richter, this scale uses a seismometer to measure the magnitude of the largest jolt of energy released by an earthquake. Today, the moment magnitude scale has replaced the Richter scale. The **moment magnitude scale** measures the total energy released by an earthquake. Moment magnitude is calculated from the area of the fault that is ruptured and the distance the ground moved along the fault. The Richter scale and the moment magnitude scale are logarithmic. The amplitude of the largest wave increases ten times from one integer to the next. An increase in one integer means that thirty times more energy was released. These two scales often give very similar measurements. How does the amplitude of the largest seismic wave of a magnitude 5 earthquake compare with the largest wave of a magnitude 4 earthquake? How does it compare with a magnitude 3 quake? The amplitude of the largest seismic wave of a magnitude 5 quake is 10 times that of a magnitude 4 quake and 100 times that of a magnitude 3 quake.

A **seismograph** produces a graph-like representation of the seismic waves it receives and records them onto a **seismogram**. Seismograms contain information that can be used to determine how strong an earthquake was, how long it lasted, and how far away it was. Modern **seismometers** record ground motions using electronic motion detectors. The data are then kept digitally on a computer.

The third and oldest of the scale for quantifying quakes is the **Mercalli Intensity scale**. Earthquakes are described in terms of what nearby residents felt and the damage that was done to nearby structures. This scale is more qualitative in information because it's based on visual damage and not the actual energy released by the earthquake. Today these maps are still important and various seismological stations will create **shake maps** of the surface damage.



A Shake Map depicting the Mercalli Scale.

Each scale has their benefits. As mentioned above, the Mercalli Intensity scale is based on how much damage someone would see. This is relative though because some places have strong building codes, and the rock material underneath will impact ground shaking without changing the energy released at the focus. With the Richter scale, a single sharp jolt measures higher than a very long intense earthquake that releases more energy. The moment magnitude scale more accurately reflects the energy released and the damage caused. Today, most seismologists now use the moment magnitude scale.

If a seismogram records P-waves and surface waves but not S-waves, the seismograph was on the other side of the Earth from the earthquake because those waves cannot travel through the liquid core of the earth. The amplitude of the waves can be used to determine the magnitude of the earthquake, which will be discussed in a later section.

In a single year, on average, more than 900,000 earthquakes are recorded and 150,000 of them are strong enough to be felt. Each year about 18 earthquakes are major with a Richter magnitude of 7.0 to 7.9, and on average one earthquake has a magnitude of 8 to 8.9.Magnitude 9 earthquakes are rare. The United States Geological Survey lists five since 1900. All but the Great Indian Ocean Earthquake of 2004 occurred somewhere around the Pacific Ocean basin.

LIVING WITH QUAKES

Scientists are a long way from being able to predict earthquakes. A good prediction must be accurate as to where an earthquake will occur, when it will occur, and at what magnitude it will be so that people can evacuate. An unnecessary evacuation is expensive and causes people not to believe authorities the next time an evacuation is ordered.

Where an earthquake will occur is the easiest feature to predict. Scientists know that earthquakes take place at plate boundaries and tend to happen where they've occurred before. Earthquake-prone communities should always be prepared for an earthquake. These communities can implement building codes to make structures earthquake safe.

When an earthquake will occur is much more difficult to predict. Since stress on a fault builds up at the same rate over time, earthquakes should occur at regular intervals. But so far scientists cannot predict when quakes will occur even to within a few

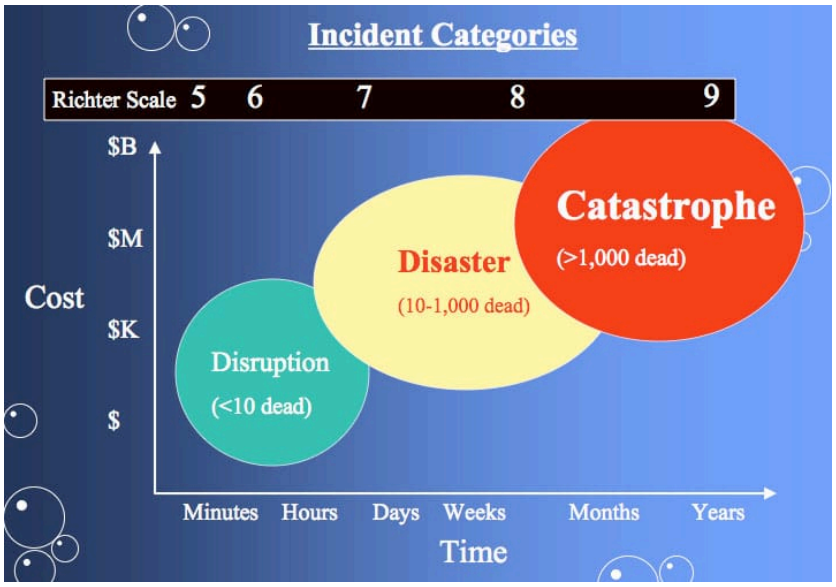
years. Signs sometimes come before a large earthquake. Small quakes, called **foreshocks**, sometimes occur a few seconds to a few weeks before a major quake. However, many earthquakes do not have foreshocks and small earthquakes are not necessarily followed by a large earthquake. Often, the rocks around a fault will dilate as **microfractures** form.

Ground tilting, caused by the buildup of stress in the rocks, may precede a large earthquake, but not always. Water levels in wells fluctuate as water moves into or out of fractures before an earthquake. This is also an uncertain predictor of large earthquakes. The relative arrival times of P-waves and S-waves also decreases just before an earthquake occurs.

Folklore tells of animals behaving erratically just before an earthquake. Mostly these anecdotes are told after the earthquake. If indeed animals sense danger from earthquakes or tsunami, scientists do not know what it is they could be sensing, but they would like to find out.

The geology of California underlies the state's wealth of natural resources as well as its natural hazards. This video explores the enormous diversity of California's geology, (57:50).

DAMAGE FROM EARTHQUAKES



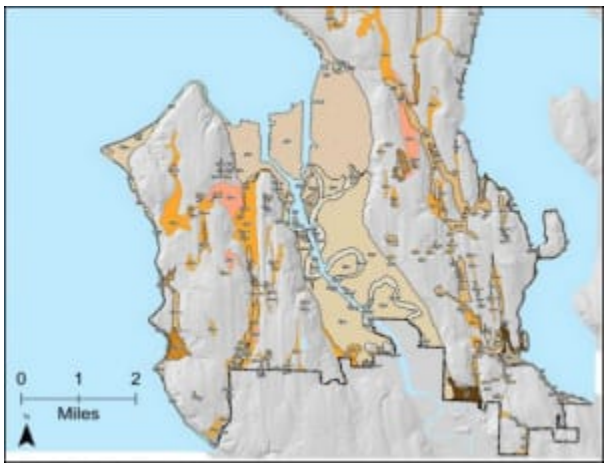
Recovery Time from a Quake can take minutes to years.



Earthquakes are natural disasters that cause enormous amounts of damage, second only to hurricanes. Earthquake-safe construction techniques, securing heavy objects, and preparing an emergency kit are among the precautions people can take to minimize damage.

Earthquakes kill people and cause property damage. However, the ground shaking almost never kills people, and the ground does not swallow someone up. The damage depends somewhat on the earthquake size but mostly on the quality of structures. Structures falling on people injure and kill them. More damage is done and more people are killed by the fires that follow an earthquake than the earthquake itself.

There are a variety of ways earthquakes become deadly. Probably the greatest influence is **population density**. The magnitude 9.2 Great Alaska Earthquake, near Anchorage, of 1964 resulted in only 131 deaths. At the time few people lived in the area. Oddly enough, size doesn't matter. Only about 2,000 people died in the 1960 Great Chilean earthquake, the largest earthquake ever recorded. The Indian Ocean earthquake of 2004 was one of the largest ever, but most of the 230,000 fatalities were caused by the tsunami, not the earthquake itself.



Liquefaction Risk Zones in Seattle.

Ground type is an important factor in earthquake damage. Solid bedrock vibrates less than soft sediments so there is less damage on bedrock. Sediments that are saturated with water under go **liquefaction** and become like quicksand. This will have dangerous implications for Salt Lake City and the Wasatch Front in Utah. Much of the Wasatch Front is loose soil, left over from the remnants of Lake Bonneville. Along the middle of the two mountain ranges, between the Wasatch Mountains and the Oquirrh Mountains, is the Jordan River which flows from Utah Lake northward to the Great Salt Lake. Near the river and surrounding floodplain, the water table is near the surface. When the ground shakes, the water near the surface shifts upward and over-saturates the soil making it extremely unstable.

EARTHQUAKE-SAFE STRUCTURES


Exterior cross bracing for quake resistance.

Construction is a large factor in what happens during an earthquake. For example, many more people died in the 1988 Armenia earthquake where people live in mud houses than in the 1989 earthquake in Loma Prieta. Most buildings in California's earthquake country are designed to be earthquake safe.

The key to earthquake safety are the structures we live in. It is often said that earthquakes don't kill people, it's the buildings that

kill people. But the reason why not all buildings are not built to withstand earthquakes is cost. More sturdy structures are much more expensive to build, so communities must weigh how great the hazard is, what different building strategies cost, and make an informed decision. But this is the crucial factor in earthquake safety. Let's compare Salt Lake City, UT and Port-au-Prince, Haiti. When Salt Lake City has it's expected 7.0 magnitude earthquake, worst case scenario is that 3,000-4,000 will die. But on January 12, 2010, Haiti experienced a 7.0 magnitude earthquake that killed nearly 300,000 people. The difference – building codes.

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. 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 also be placed on rollers so that they move with the ground.

Earthquake prone areas should have building codes that require the use of correct building materials. Houses should also be built with wood and steel rather than brick and stone because they need to be able to bend and sway. New buildings should be built on layers of steel and rubber to absorb the shock of the waves. Connections, such as where the walls meet the foundation, must be made strong to withstand the shaking. In a multi-story building, the first story must be well supported.

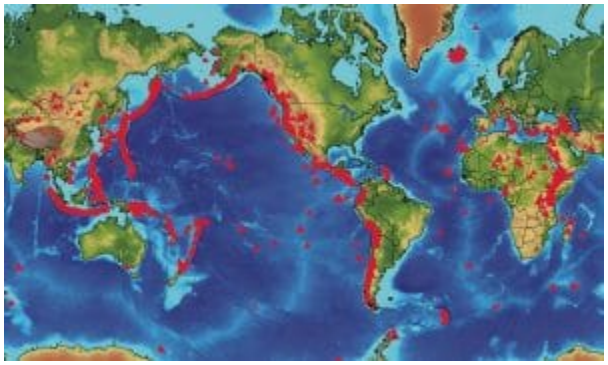
To make older buildings more earthquake safe, retrofitting with steel or wood can reinforce a building's structure and its connections. Elevated freeways and bridges can also be retrofitted so that they do not collapse.

Fires often cause more damage than the earthquake. Fires start because seismic waves rupture gas and electrical lines, and 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.

HUMAN-INDUCED EARTHQUAKES

Can humans create earthquakes? Maybe not intentionally, but the answer is yes and here is why. If a water reservoir is built on top of an active fault line, the water may actually lubricate the fault and weaken the stress built up within it. This may either create a series of small earthquakes or potentially create a large earthquake. Also the shear weight of the reservoir's water can weaken the bedrock causing it to fracture. Then the obvious concern is if the dam fails. Earthquakes can also be generated if humans inject other fluids into a fault such as sewage or chemical waste. Finally, nuclear explosions can trigger earthquakes. In fact, one way to determine if a nation has tested a nuclear bomb is by monitoring the earthquakes and energy released by the explosion.

VOLCANOES: LOCATIONS



Global Volcano Locations

VOLCANOES ALONG CONVERGENT PLATE BOUNDARIES

Volcanoes are a vibrant manifestation of plate tectonics processes. Volcanoes are common along convergent and divergent plate boundaries, but are also found within lithospheric plates away from plate boundaries. Wherever mantle is able to melt, volcanoes may be the result.

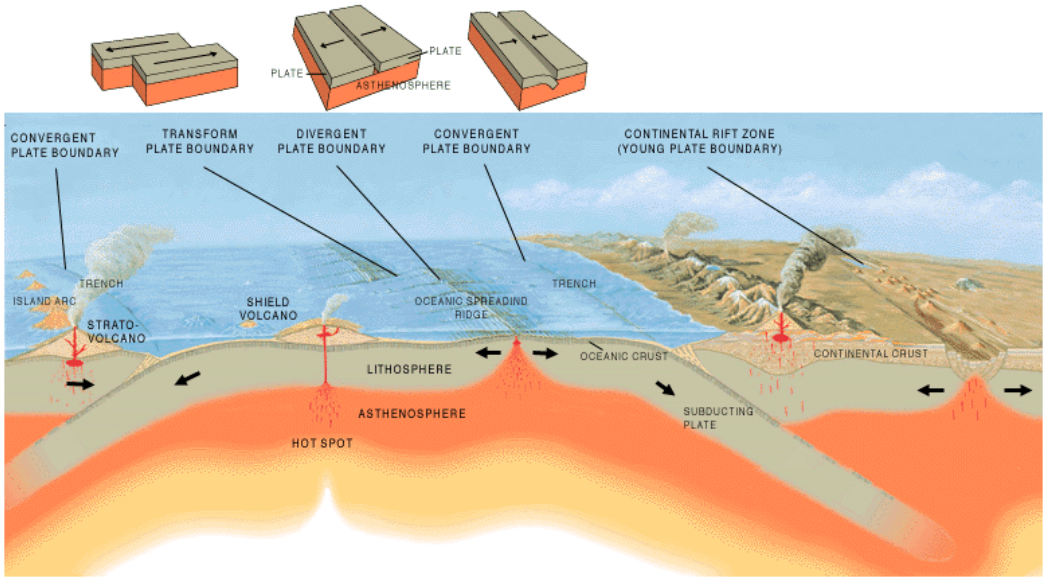
Volcanoes erupt because mantle rock melts. The first stage in creating a volcano is when mantle rock begins to melt because of extremely high temperatures, lithospheric pressure lowers, or water is added. Along subducting plate boundaries, the crust heats up as it sinks into the mantle. Also, ocean water is mixed in with the sediments lying on top of the subducting plate. This water lowers the melting point of the mantle material, which increases melting. Volcanoes at convergent plate boundaries are found all

along the Pacific Ocean basin, primarily at the edges of the Pacific, Cocos, and Nazca plates.

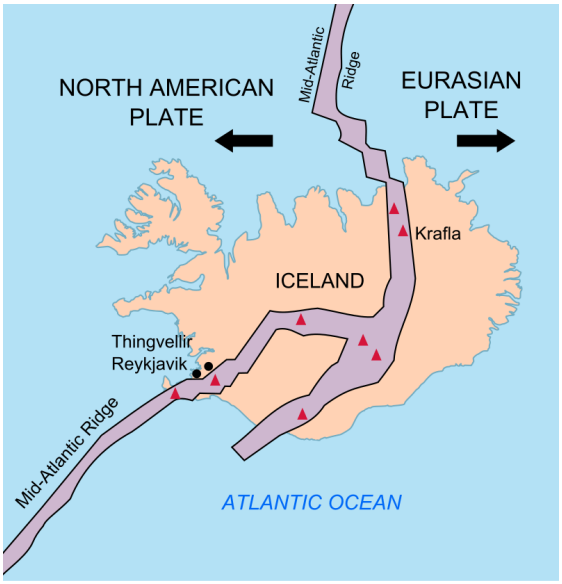
Large earthquakes are extremely common along convergent plate boundaries. Since the Pacific Ocean is rimmed by convergent and transform boundaries, about 80% of all earthquakes strike around the Pacific Ocean basin and is why the region is called the Ring of Fire. A description of the Pacific Ring of Fire along western North America is below:

- Subduction at the Middle American Trench creates volcanoes in Central America.
- The San Andreas Fault is a transform boundary.
- Subduction of the Juan de Fuca plate beneath the North American plate creates the Cascade volcanoes like Mount St. Helens, Mount Rainer, Mount Hood and more.
- Subduction of the Pacific plate beneath the North American plate in the north creates the long chain of the Aleutian Islands volcanoes near Alaska.

This incredible explosive eruption of Mount Vesuvius in Italy in A.D. 79 is an example of a composite volcano that forms as the result of a convergent plate boundary.



VOLCANOES ALONG DIVERGENT PLATE BOUNDARIES



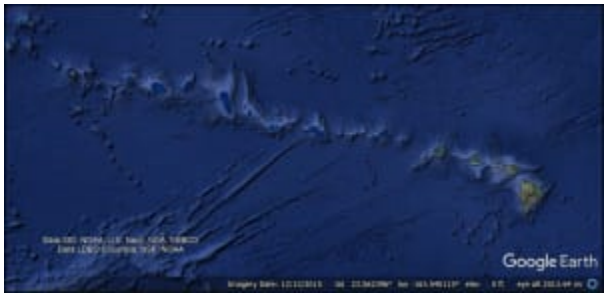
Iceland is a Volcanic Island along a Divergent Boundary

Why does melting occur at divergent plate boundaries? Hot mantle rock rises where the plates are moving apart. This releases pressure on the mantle, which lowers its melting temperature allowing lava to erupt through long cracks or fissures. Scientists have captured incredible footage of “Deepest Ocean Eruption Ever Filmed” and other undersea volcanoes. Volcanoes erupt at mid-ocean ridges, such as the Mid-Atlantic ridge, where seafloor spreading creates new seafloor in the rift valleys. Where a hotspot is located along the ridge, such as at Iceland, volcanoes grow high enough to create islands. Eruptions are found at divergent plate boundaries as continents break apart such as the East African Rift between the African and Arabian plates and the Great Basin and Range in the western United States. But those volcanoes of the ladder are now extinct.

VOLCANIC HOTSPOTS

Although most volcanoes are found at convergent or divergent plate boundaries, intraplate volcanoes are found in the middle of a tectonic plate. The Hawaiian Islands are the exposed peaks of a great chain of volcanoes that lie on the Pacific plate. These islands are in the middle of the Pacific plate. The youngest island sits directly above a column of hot rock called a mantle plume. As the plume rises through the mantle, pressure is released and mantle melts to create a **hotspot**.

Earth is home to about 50 known hot spots. Most of these are in the oceans because they are better able to penetrate oceanic lithosphere to create volcanoes. The hotspots that are known beneath continents are extremely large, such as Yellowstone. The video on the right is of the hot spot beneath Hawaii, the origin of the voluminous lava produced by the shield volcano Kilauea. There are several key indicators to determine a hot spot from island arc volcanoes. At island arcs, the volcanoes are all about the same age. By contrast, at hotspots the volcanoes are youngest at one end of the chain and oldest at the other.



Hawaiian Islands follow a Hotspot

LOCATION AND MAGMA COMPOSITION

Picture

It should first be noted that **magma** is molten material inside the earth, whereas **lava** is molten material on the surface of the earth. The reason for the distinction is because lava can cool quickly from the air and solidify into rock rapidly, whereas magma may never reach the earth’s surface. Volcanoes do not always erupt in the same way. Each volcanic **eruption** is unique, differing in size, style, and composition of erupted material. One key to what makes the eruption unique is the chemical composition of the magma that feeds a volcano, which determines (1) the eruption style, (2) the type of volcanic cone that forms, and (3) the composition of rocks that are found at the volcano.

Different minerals within a rocks melt at different temperatures and the amount of partial melting and the composition of the original rock determine the composition of the magma. Magma collects in **magma chambers** in the crust at 160 kilometers (100 miles) beneath the surface of a volcano.

The words that describe composition of igneous rocks also describe magma composition. **Mafic magmas** are low in silica and contain more dark, magnesium and iron rich mafic minerals, such as olivine and pyroxene. **Felsic magmas** are higher in silica and contain lighter colored minerals such as quartz and orthoclase feldspar. The higher the amount of silica in the magma, the higher is its **viscosity**. Viscosity is a liquid’s resistance to flow.

Viscosity determines what the magma will do. Mafic magma is not viscous and will flow easily to the surface. Felsic magma is viscous and does not flow easily. Most felsic magma will stay deeper in the crust and will cool to form igneous intrusive rocks such as granite and granodiorite. If felsic magma rises into a magma chamber, it may be too viscous to move and so it gets stuck. Dissolved gases become trapped by thick magma and the magma chamber begins to build pressure.

EXPLOSIVE ERUPTIONS



Mt. Pinatubo in the Philippines was a massive explosive eruption

The type of magma in the chamber determines the type of volcanic eruption. A **large explosive eruption** creates even more devastation than the force of the atom bomb dropped on Nagasaki at the end of World War II in which more than 40,000 people died. A large explosive volcanic eruption is 10,000 times as powerful. Felsic magmas erupt explosively because of hot, gas-rich magma churning within its chamber. The pressure becomes so great that the magma eventually breaks the seal and explodes, just like when a cork is released from a bottle of champagne. Magma, rock, and ash burst upward in an enormous explosion creating volcanic ash called **tephra**. It should be noted that when looked under a microscope, the volcanic "ash" is actual microscopic shards of glass. That is why it is so dangerous to inhale the air following an eruption.

Scorching hot tephra, ash, and gas may speed down the volcano's slopes at 700 km/h (450 mph) as a **pyroclastic flow**. Pyroclastic flows knock down everything in their path. The temperature inside a pyroclastic flow may be as high as 1,000°C (1,800° F).

Prior to the Mount St. Helens eruption in 1980, the Lassen Peak eruption on May 22, 1915, was the most recent Cascades eruption. A column of ash and gas shot 30,000 feet into the air. This triggered a high-speed pyroclastic flow, which melted snow and created a volcanic mudflow known as a **lahar**. Lassen Peak currently has geothermal activity and could erupt explosively again. Mt. Shasta, the other active volcano in California, erupts every 600 to 800 years. An eruption would most likely create a large pyroclastic flow, and probably a lahar. Of course, Mt. Shasta could explode and collapse like Mt. Mazama in Oregon.

Volcanic gases can form poisonous and invisible clouds in the atmosphere that could contribute to environmental problems such as acid rain and ozone destruction. Particles of dust and ash may stay in the atmosphere for years, disrupting weather patterns and blocking sunlight.

EFFUSIVE ERUPTIONS



Mafic magma creates gentler **effusive eruptions**. Although the pressure builds enough for the magma to erupt, it does not erupt with the same explosive force as felsic magma. People can usually be evacuated before an effusive eruption, so they are much less deadly. Magma pushes toward the surface through fissures and reaches the surface through volcanic vents. Click here to view a lava stream within the vent of a Hawaiian volcano using a thermal camera. Low-viscosity lava flows down mountainsides. Differences in composition and where the lavas erupt result in lava types like a ropy form **pahoehoe** and a chunky form called **aa**. Although effusive eruptions rarely kill anyone, they can be destructive. Even when people know that a lava flow is approaching, there is not much anyone can do to stop it from destroying a building, road, or infrastructure.

Pahoehoe lava



Aa lava

PREDICTING ERUPTIONS

Volcanologists attempt to forecast volcanic eruptions, but this has proven to be nearly as difficult as predicting an earthquake. Many pieces of evidence can mean that a volcano is about to erupt, but the time and magnitude of the eruption are difficult to pin down. This evidence includes the history of previous volcanic activity, earthquakes, slope deformation, and gas emissions.

HISTORY OF VOLCANIC ACTIVITY



A volcano's history, how long since its last eruption and the recurrence interval between its previous eruptions, is a good first step to predicting eruptions. If the volcano is considered **active**, it is currently erupting or shows signs of erupting soon. A **dormant** volcano means there is no current activity, but it has erupted recently. Finally, an **extinct** volcano means their is no activity and will probably not erupt again. Active and dormant volcanoes are heavily monitored, especially in populated areas.

EARTHQUAKES

Moving magma shakes the ground, so the number and size of earthquakes increases before an eruption. A volcano that is about to erupt may produce a sequence of earthquakes. Scientists use seismographs that record the length and strength of each earthquake to try to determine if an eruption is imminent.

Magma and gas can push the volcano's slope upward. Most **ground deformation** is subtle and can only be detected by tiltmeters, which are instruments that measure the angle of the slope of a volcano. But ground swelling may sometimes create huge changes in the shape of a volcano. Mount St. Helens grew a bulge on its north side before its 1980 eruption. Ground swelling may also increase rockfalls and landslides.

GAS EMISSIONS

Gases may be able to escape a volcano before magma reaches the surface. Scientists measure gas emissions in vents on or around the volcano. Gases, such as sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrochloric acid (HCl), and even water vapor can be measured at the site or, in some cases, from a distance using satellites. The amounts of gases and their ratios are calculated to help predict eruptions.

REMOTE MONITORING and DEFORMATION

Some gases can be monitored using satellite technology. Satellites also monitor temperature readings and deformation. As technology improves, scientists are better able to detect changes in a volcano accurately and safely.

Since volcanologists are usually uncertain about an eruption, officials may not know whether to require an evacuation. If people are evacuated and the eruption doesn't happen, the people will be displeased and less likely to evacuate the next time there is a threat of an eruption. The costs of disrupting business are great. However, scientists continue to work to improve the accuracy of their predictions.

TYPES OF VOLCANOES



Mt. Rainier is a Composite (Strato) Volcano

A volcano is a vent through which molten rock and gas escape from a magma chamber and they can differ in height, shape, and slope steepness. Some volcanoes are tall cones and others are just cracks in the ground. As you might expect, the shape of a volcano is related to the composition of its magma.

COMPOSITE (STRATO) VOLCANOES

Composite volcanoes are some of the most dangerous volcanoes on the planet. They tend to occur along oceanic-to-oceanic or oceanic-to-continental boundaries because of subduction zones. They tend to be made of felsic to intermediate rock and the viscosity of the lava means that eruptions tend to be explosive. The viscous lava cannot travel far down the sides of the volcano before it solidifies, which creates the steep slopes of a composite volcano. Viscosity also causes some eruptions to explode as ash and small rocks. The volcano is constructed layer by layer, as ash and lava solidify, one upon the other and are sometimes called stratovolcanoes or andesite volcanoes. The result is the classic cone shape of composite volcanoes. Examples of composite volcanoes include Mount St. Helens, Mount Rainer, Mount Shasta, Mount Hood, and Mount Pinatubo. Here's a great time-lapse of Mount St. Helens from NASA's Earth Observatory from 1979 to 2013.Sometimes composite volcanoes and other violent volcanoes can erupt so violently that they sometimes collapse in on themselves or actually blow themselves up to produce calderas. One of the most powerful volcanoes in the world – Yellowstone – is a massive caldera that has collapsed several times. Sometimes these calderas can fill up with water to produce beautiful lakes such as Mount Mazama (Crater Lake), in Oregon.

SHIELD VOLCANOES



Shield volcanoes get their name from their shape. Although shield volcanoes are not steep, they may be very large. In fact, Mauna

Loa, Hawaii is the tallest mountain in the world. From sea level, Mount Everest is the tallest, but when you consider from the ocean floor to the top of the island, Mauna Loa wins. Shield volcanoes are common at spreading centers or intraplate hot spots.

The lava that creates shield volcanoes is fluid and flows easily and creates the shield shape. Shield volcanoes are built by many layers over time and the layers are usually of very similar composition. The low viscosity also means that shield eruptions are non-explosive. Eruptions tend to be mild in comparison to other volcanoes, but lava flows can destroy property and vegetation. The low viscosity magma can flow not only on the surface as lava, but also underground in lava tubes. The most well known shield volcano is Hawaii. There are two types of lava flows, pahoehoe which is a ropy type of lava that flows easily (low viscosity). The other type is called aa and is a blocky type of lava and has a higher viscosity and does not like to flow well.

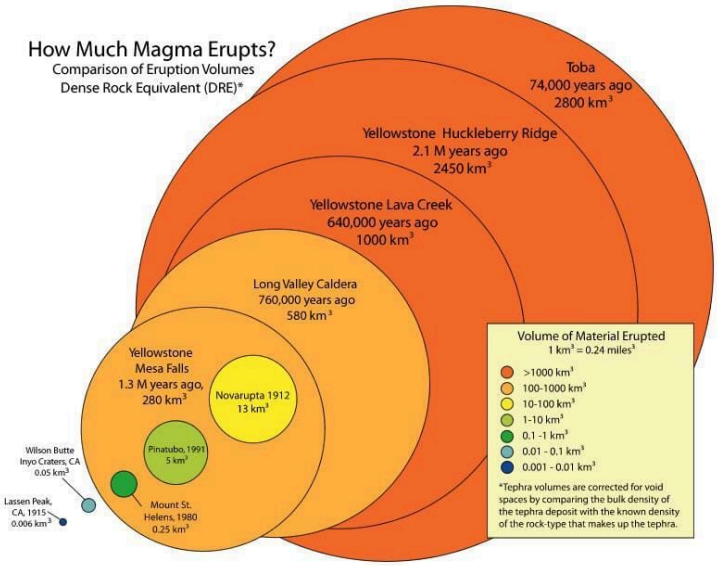


Lava Butte, a Cinder Cone south of Bend, OR.

CINDER CONES

Cinder cones are the most common type of volcano. A cinder cone has a cone shape, but is much smaller than a composite volcano. Cinder cones rarely reach 300 meters in height but they have steep sides. Cinder cones grow rapidly, usually from a single eruption cycle. Cinder cones are composed of small fragments of rock, such as pumice, piled on top of one another. The rock shoots up in the air and doesn't fall far from the vent. The exact composition of a cinder cone depends on the composition of the lava ejected from the volcano. Cinder cones usually have a crater at the summit. Cinder cones are often found near larger volcanoes.

SUPERVOLCANOES



Supervolcano Eruptions may eject 1000 time more material than Mt. St. Helens.

Supervolcano eruptions are extremely rare in Earth history. It's a good thing because they are unimaginably large. A supervolcano must erupt more than 1,000 cubic km (240 cubic miles) of material, compared with 1.2 km^3 for Mount St. Helens or 25 km^3 for Mount Pinatubo, a large eruption in the Philippines in 1991. Not surprisingly, supervolcanoes are the most dangerous type of volcano. Supervolcanoes are a fairly new idea in volcanology. The exact cause of supervolcano eruptions is still debated, however, scientists think that a very large magma chamber erupts entirely in one catastrophic explosion. This creates a huge hole or **caldera** into which the surface collapses.

The largest supervolcano in North America is beneath Yellowstone National Park in Wyoming. Yellowstone sits above a hotspot that has erupted catastrophically three times: 2.1 million, 1.3 million, and 640,000 years ago. Yellowstone has produced many smaller (but still enormous) eruptions more recently. Fortunately, current activity at Yellowstone is limited to the region's famous geysers.

Long Valley Caldera, south of Mono Lake in California, is the second largest supervolcano in North America. Long Valley had an extremely hot and explosive rhyolite explosion about 700,000 years ago. An earthquake swarm in 1980 alerted geologists to the possibility of a future eruption, but the quakes have since calmed down.

A supervolcano could change life on Earth as we know it. Ash could block sunlight so much that photosynthesis would be reduced and global temperatures would plummet. Volcanic eruptions could have contributed to some of the mass extinctions in our planet's history. No one knows when the next super eruption will be.

VOLCANIC LANDFORMS AND GEOTHERMAL ACTIVITY

VOLCANIC LANDFORMS AND VENTS



Ship Rock, NM is what remains from weathering after an eruption.

Volcanoes are associated with many types of landforms. The landforms vary with the composition of the magma that created them. Hot springs and geysers are also examples of surface features related to volcanic activity.

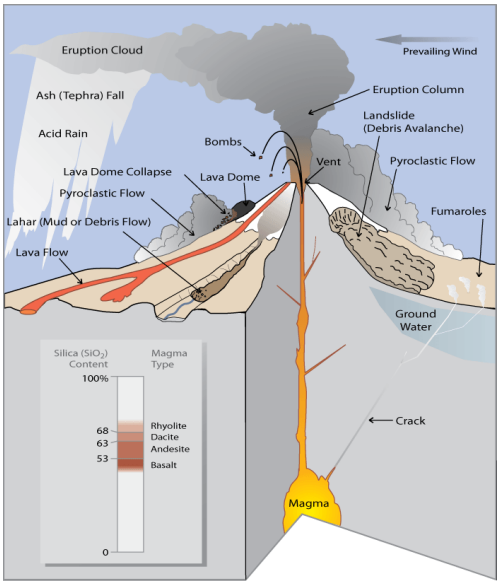
The most obvious landforms created by lava are volcanoes, most commonly as cinder cones, composite volcanoes, and shield volcanoes or eruptions that take place through fissures. The eruptions that created the entire ocean floor are essentially fissure eruptions. Magma intrusions ALSO can create landforms. The image on the right is of Shiprock in New Mexico, which is the neck of an old volcano that has eroded away.

A **lava plateau** forms when large amounts of fluid lava flows over an extensive area. When the lava solidifies, it creates a large, flat surface of igneous rock. Lava creates new land as it solidifies on the coast or emerges from beneath the water. Over time the eruptions can create whole islands. The Hawaiian Islands are formed from shield volcano eruptions that have grown over the last 5 million years.

HOT SPRINGS AND GEYSERS

Water sometimes comes into contact with hot rock. The water may emerge at the surface as either a hot spring or a geyser. Water heated below ground that rises through a crack to the surface creates a **hot spring**. The water in hot springs may reach temperatures in the hundreds of degrees Celsius beneath the surface, although most hot springs are much cooler.

VOLCANOES: HAZARDS AND BENEFITS



There are several hazards that volcanic activity can produce.

- Eruption clouds occur when massive quantities of ash is ejected into the atmosphere where it can reach heights of 50,000 feet. Eruption clouds have proven to be very dangerous for aviation jets because the ash can shut down the engines. The ash cloud can also be very hazardous in terms of air pollution.
- Lahars are volcanic mudflows. Lahars are very dangerous because they do not require a volcanic eruption yet can travel hundreds of miles. All that is required is loose pyroclastic material on the volcano that mixes with precipitation or melting snow.
- Lava flows are layers of molten rock that flow over the surface, later cooling and solidifying.
- Lava bombs are large chunks of pyroclastic material ejected from a volcano. Larger pyroclastic material is called blocks.

- Pyroclastic flows are some of the most dangerous hazards caused by composite volcanoes. Pyroclastic flows are superheated clouds of pyroclastic material (e.g. hot rock and tephra) ranging in size from small rocks to the size of houses that are over 1,000 degrees F traveling down a mountain at speeds up to 100 mph.
- Tephra (or volcanic ash) is fine particles of pyroclastic material that can be carried thousands of miles away by prevailing winds. Regions hundreds of miles away could suffer collapsed buildings is the falling ash accumulates enough. Tephra can also cool the entire planet if enough is ejected into the atmosphere.
- Poisonous gases such as carbon dioxide, carbon monoxide, and sulfur dioxide can travel down a volcano and asphyxiate (suffocating) wildlife and humans. In 1986, an invisible cloud of carbon dioxide traveled down a volcano in Africa asphyxiating 1,742 people and 3,000 cattle.

There are actually many benefits to volcanic activity. One of the major benefits is the fact that volcanic activity can create very fertile soil for agriculture. The problem is that many civilizations developed near volcanoes for this reason – with sometimes deadly effects. Volcanic activity can also create many mineral resources such as gold, sliver, nickel, copper, and lead. Volcanic rock is often used for landscaping, tile, and cement.

Some of the most amazing landscapes are near volcanoes. This is because volcanic activity builds land creating breathtaking scenery. So volcanoes are economically vital for many regions because of the recreational activity and tourism they bring.

Finally, a new but important trend is **geothermal power**. The heat generated by volcanoes can create electricity to power

civilization. Geothermal power is a completely **renewable resource** free of pollution and energy dependency on fossil fuels. Iceland – the surface manifestation of the mid-Atlantic ridge – has a goal of powering the entire nation on geothermal energy. Geothermal energy is also being used in California, Kilauea, Hawaii, and now Utah.

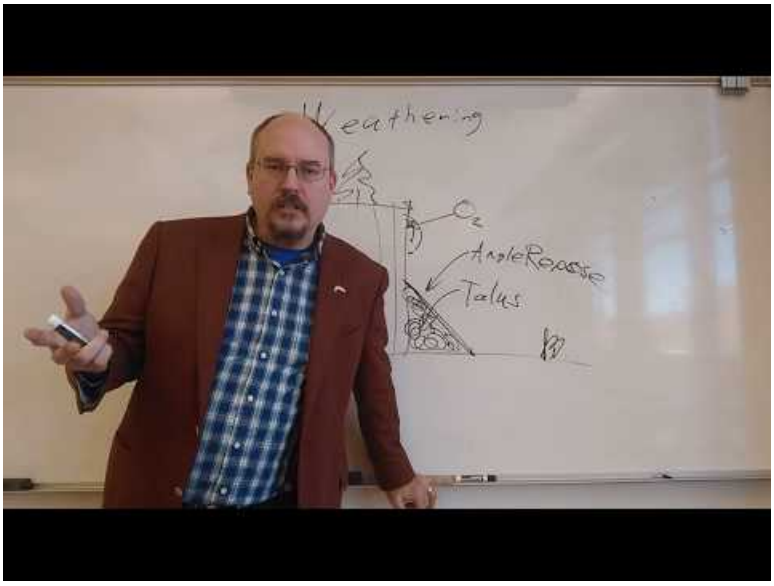
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1.11: Gradational Processes

Learning Objectives

- Describe the basic processes, functions, and influences of weathering and erosion.
- Describe the various types of mass wasting processes.
- Compare the difference between fast and slow subsidence and how it may be limited.
- Describe how streams have the ability to erode and deposit sediment.
- Explain how groundwater can erodes limestone to form caves.
- Describe how wave actions erode coastlines and create coastal landforms.
- Explain how wind erodes and transports sediment in arid regions of the world.
- Describe how glaciers erode and carve out the landscape.

WEATHERING PROCESSES



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Weathering is the process that changes solid rock into sediments. With weathering, rock is disintegrated into smaller pieces. Once these sediments are separated from the rocks, erosion is the process that moves the sediments away from it's original position. The four forces of erosion are water, wind, glaciers, and gravity. Water is responsible for most erosion. Water can move most sizes of sediments, depending on the strength of the force. Wind moves sand-sized and smaller pieces of rock through the air. Glaciers move all sizes of sediments, from extremely large boulders to the tiniest fragments. Gravity moves broken pieces of rock, large or small, down slope. These forces of erosion will be covered later.

While plate tectonics forces work to build huge mountains and other landscapes, the forces of weathering and mass wasting gradually wear those rocks and landscapes away, called **denudation**. Together with erosion, tall mountains turn into hills and even plains. The Appalachian Mountains along the east coast of North America were once as tall as the Himalayas.

No human being can watch for millions of years as mountains are built, nor can anyone watch as those same mountains gradually are worn away. But imagine a new sidewalk or road. The new road is smooth and even. Over hundreds of years, it will completely disappear, but what happens over one year? What changes would you see? What forces of weathering wear down that road, or rocks or mountains over time?

MECHANICAL WEATHERING



Steep Basalt Cliffs with weathered talus at the base

Mechanical weathering, also called **physical weathering**, breaks rock into smaller pieces. These smaller pieces are just like the bigger rock, just smaller. That means the rock has changed physically without changing its composition. The smaller pieces have the same minerals, in just the same proportions as the original rock. There are many ways that rocks can be broken apart into smaller pieces. **Ice wedging**, also called **freeze-thaw weathering**, is the main form of mechanical weathering in any climate that regularly cycles above and below the freezing point. Ice wedging works quickly, breaking apart rocks in areas with temperatures that cycle above and below freezing in the day and night, and also that cycle above and below freezing with the seasons. Ice wedging breaks apart so much rock that large piles of broken rock are seen at the base of a hillside called talus. Ice wedging is common in Earth's polar regions and mid latitudes, and also at higher elevations, such as in the mountains. In central Washington, the steep dark basalt cliffs heat up in the late afternoon as the sun is low on the horizon but perpendicular to the cliff face. Then the sun sets and the the temperature drops quickly in the dry air. The rock face expands and contracts quickly, every day, which weakens the face of the cliff. The rock eventually falls off the cliff face, to the base in a lose pile.

Abrasion is another form of mechanical weathering. In abrasion, one rock bumps against another rock.

- Gravity causes abrasion as a rock tumbles down a mountainside or cliff.
- Moving water causes abrasion as particles in the water collide and bump against one another.
- Strong winds carrying pieces of sand can sandblast surfaces.
- Ice in glaciers carries many bits and pieces of rock. Rocks embedded at the bottom of the glacier scrape against the rocks below.
- Abrasion makes rocks with sharp or jagged edges smooth and round. If you have ever collected beach glass or cobbles from a stream, you have witnessed the work of abrasion.

Now that you know what mechanical weathering is, can you think of other ways it could happen? Plants and animals can do the work of mechanical weathering. This could happen slowly as a plant's roots grow into a crack or fracture in rock and gradually grow larger, wedging open the crack. Burrowing animals can also break apart rock as they dig for food or to make living spaces for themselves.

CHEMICAL WEATHERING

Chemical weathering is the other important type of weathering. Chemical weathering is different from mechanical weathering because the rock changes, not just in size of pieces, but in composition. That is, one type of mineral changes into a different mineral. Chemical weathering works through chemical reactions that cause changes in the minerals. Most minerals form at high pressure or high temperatures deep in the crust, or sometimes in the mantle. When these rocks reach the Earth's surface, they are now at very low temperatures and pressures. This is a very different environment from the one in which they formed and the minerals are no longer stable. In chemical weathering, minerals that were stable inside the crust must change to minerals that

are stable at Earth's surface. Remember that the most common minerals in Earth's crust are the silicate minerals. Many silicate minerals form in igneous or metamorphic rocks deep within the earth. The minerals that form at the highest temperatures and pressures are the least stable at the surface. Clay is stable at the surface and chemical weathering converts many minerals to clay. There are many types of chemical weathering because there are many agents of chemical weathering. Water is the most important agent of chemical weathering. Two other important agents of chemical weathering are carbon dioxide and oxygen.

CHEMICAL WEATHERING BY WATER

A water molecule has a very simple chemical formula, H_2O, two hydrogen atoms bonded to one oxygen atom. But water is pretty remarkable in terms of all the things it can do. Water is a polar molecule; the positive side of the molecule attracts negative ions and the negative side attracts positive ions. So water molecules separate the ions from their compounds and surround them. Water can completely dissolve some minerals, such as salt. **Hydrolysis** is the name of the chemical reaction between a chemical compound and water. When this reaction takes place, water dissolves ions from the mineral and carries them away. These elements have undergone leaching. Through hydrolysis, a mineral such as potassium feldspar is leached of potassium and changed into a clay mineral. Clay minerals are more stable at the Earth's surface.

CHEMICAL WEATHERING BY CARBON DIOXIDE

Carbon dioxide (CO_2) combines with water as raindrops fall through the atmosphere. This makes a weak acid, called carbonic acid. Carbonic acid is a very common in nature where it works to dissolve rock. Pollutants, such as sulfur and nitrogen, from fossil fuel burning, create sulfuric and nitric acid. Sulfuric and nitric acids are the two main components of acid rain, which accelerate chemical weathering.

CHEMICAL WEATHERING BY OXYGEN

Oxidation is a chemical reaction that takes place when oxygen reacts with another element. Oxygen is very strongly chemically reactive. The most familiar type of oxidation is when iron reacts with oxygen to create rust. Minerals that are rich in iron break down as the iron oxidizes and forms new compounds. Iron oxide produces the red color in soils.Now that you know what chemical weathering is, can you think of some other ways chemical weathering might occur? Chemical weathering can also be contributed to by plants and animals. As plant roots take in soluble ions as nutrients, certain elements are exchanged. Plant roots and bacterial decay use carbon dioxide in the process of respiration.

Mechanical weathering increases the rate of chemical weathering. As rock breaks into smaller pieces, the surface area of the pieces increases. With more surfaces exposed, there are more surfaces on which chemical weathering can occur. Some types of chemical weathering add ions and mass to rock, other types remove material. Either way, the original material is altered and likely it's less stable so mechanical weathering acts more readily. Once the mechanical weathering removes the chemically altered material, new previously unexposed material can be chemically altered. There's a positive feedback loop between the two.

Influences on Weathering

ROCK AND MINERAL TYPE

Weathering rates depend on several factors. These include the composition of the rock and the minerals it contains as well as the climate of a region. Different rock types weather at different rates. Certain types of rock are very resistant to weathering. Igneous rocks, especially intrusive igneous rocks such as granite, weather slowly because it is hard for water to penetrate them. Other types of rock, such as limestone, are easily weathered because they dissolve in weak acids. Rocks that resist weathering remain at the surface and form ridges or hills. Devil's Tower in Wyoming is an igneous rock from beneath a volcano. As the surrounding less resistant rocks were worn away, the resistant center of the volcano remained behind. Different minerals also weather at different rates. Some minerals in a rock might completely dissolve in water, but the more resistant minerals remain. In this case, the rock's surface becomes pitted and rough. When a less resistant mineral dissolves, more resistant mineral grains are released from the rock.

CLIMATE

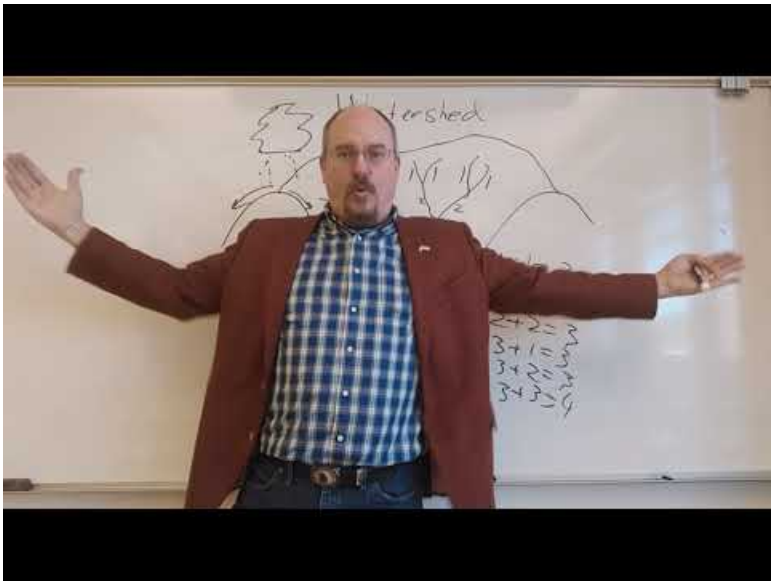
A region's climate strongly influences weathering. Climate is determined by the temperature of a region plus the amount of

precipitation it receives. Climate is weather averaged over a long period of time. Chemical weathering increases as:

- *Temperature increases*: Chemical reactions proceed more rapidly at higher temperatures. For each 10 °C increase in average temperature, the rate of chemical reactions doubles.
- *Precipitation increases*: More water allows more chemical reactions. Since water participates in both mechanical and chemical weathering, more water strongly increases weathering.

So how do different climates influence weathering? A cold, dry climate will produce the lowest rate of weathering. A warm, wet climate will produce the highest rate of weathering. The warmer a climate is, the more types of vegetation it will have and the greater the rate of biological weathering. This happens because plants and bacteria grow and multiply faster in warmer temperatures.

RIVERS



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Fresh water in streams, ponds, and lakes is an extremely important part of the water cycle if only because of its importance to living creatures. Along with wetlands, these fresh water regions contain a tremendous variety of organisms.

Streams are bodies of water that have a current; they are in constant motion. Geologists recognize many categories of streams depending on their size, depth, speed, and location. Creeks, brooks, tributaries, bayous, and rivers might all be lumped together as streams. In streams, water always flows downhill, but the form that downhill movement takes varies with rock type, topography, and many other factors. Stream erosion and deposition are extremely important creators and destroyers of landforms and were described in the Erosion and Deposition chapter.

PARTS OF A STREAM

Oddly enough, there are a variety of different types streams. A stream originates at its source (headwaters). A source is likely to be in the high mountains where snows collect in winter and melt in summer, or a source might be a spring. A stream may have more than one sources and when two streams come together it's called a confluence. The smaller of the two streams is a tributary of the larger stream. A stream may create a pool where water slows and becomes deeper. The point at which a stream comes into a large body of water, like an ocean or a lake is called the mouth. Where the stream meets the ocean or lake is an estuary. The mix of fresh and salt water where a river runs into the ocean creates a diversity of environments where many different types of organisms create unique ecosystems.

RIVERS

Rivers are the largest types of stream, moving large amounts of water from higher to lower elevations. The Amazon River, the world's river with the greatest flow, has a flow rate of nearly 220,000 cubic meters per second! People have used rivers since the beginning of civilization as a source of water, food, transportation, defense, power, recreation, and waste disposal.

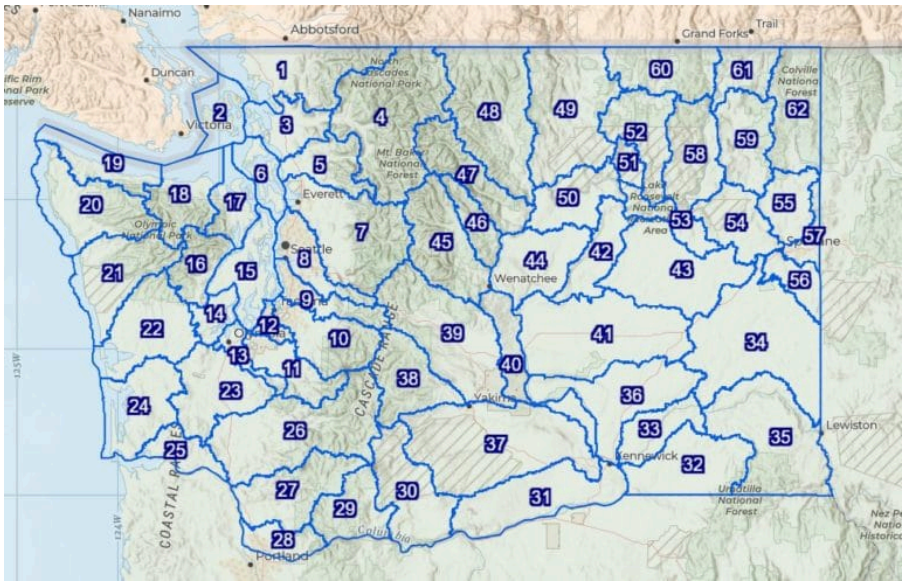


Confluence of the Blue and White Nile Rivers in Khartoum.

DIVIDES



Continental Divides of North America



Watershed Planning Units in WA

A **divide** is a topographically high area that separates a landscape into different water basins. Rain that falls on the north side of a ridge flows into the northern drainage basin and rain that falls on the south side flows into the southern drainage basin. On a much grander scale, entire continents have divides, known as continental divides.

Watersheds are the region of the landscape that drains to a single low point. The high land between watersheds is a divided, but not necessarily a continental divide. Some land use planning is based on the concepts of watersheds as a way to protect water quality and the people of the area.

Erosion and Deposition by Streams

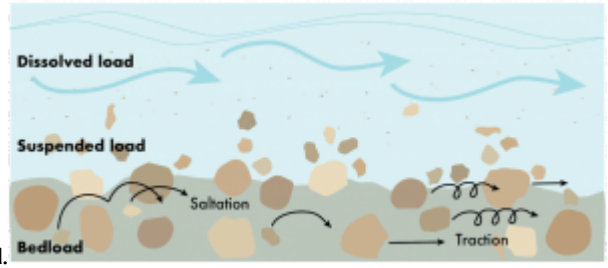
Streams, any running water from a rivulet to a raging river, are transporting material from regions of high potential energy (highlands) to regions of low potential energy (ultimately the ocean). Some of this water moves over the surface and some moves through the ground as groundwater. Flowing water does the work of both erosion and deposition.

EROSION BY STREAMS

Flowing streams pick up and transport weathered materials by eroding sediments from their banks. Streams also carry ions and ionic compounds that dissolve easily in the water. Sediments are carried as the following loads: *dissolved*, *suspended*, and *bed*. A **dissolved load** is composed of ions in solution. These ions are usually carried in the water all the way to the ocean.

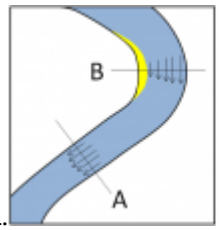
Sediments carried as solids as the stream flows are called a **suspended load**. The size of particles that can be carried within a load is determined by the stream's velocity. Faster streams can carry larger particles. Streams that carry larger particles have greater competence. Streams with a steep gradient (slope) have a faster velocity and greater competence.

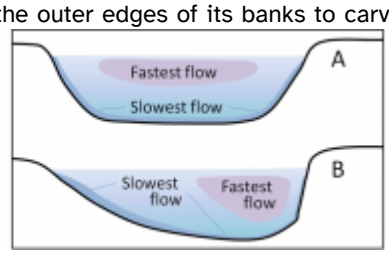
Particles that are too large to be carried as suspended loads are bumped and pushed along the stream bed, called **bed load**. Bed load sediments do not move continuously, but rather in intermittent movements, called **saltation**. Streams with high velocities and steep gradients do a great deal of down cutting into the stream bed, which is primarily accomplished by movement of particles that make up the bed load.



As a stream flows from higher elevations, like in the mountains, towards lower elevations, like the ocean, the work of the stream

changes. At a stream's headwaters, often high in the mountains, gradients are steep. The stream moves fast and does lots of work eroding the stream bed. As a stream moves into lower areas, the gradient is not as steep. Now the stream does more work eroding the edges of its banks. Many streams develop curves in their channels called **meanders**. As streams move onto flatter ground, the stream erodes the outer edges of its banks to carve a floodplain, which is a flat level area surrounding the stream channel.





Base level is where a stream meets a large body of standing water, usually the ocean, but sometimes a lake or pond. Streams work to down cut in their stream beds until they reach base level. The higher the elevation, the farther the stream is from where it will reach base level and the more cutting it has to do.



Eroding stream on Mt. Rainier. More load than the water can move. (USGS)

STREAM DEPOSITION



Meandering stream showing bright point bar deposits.

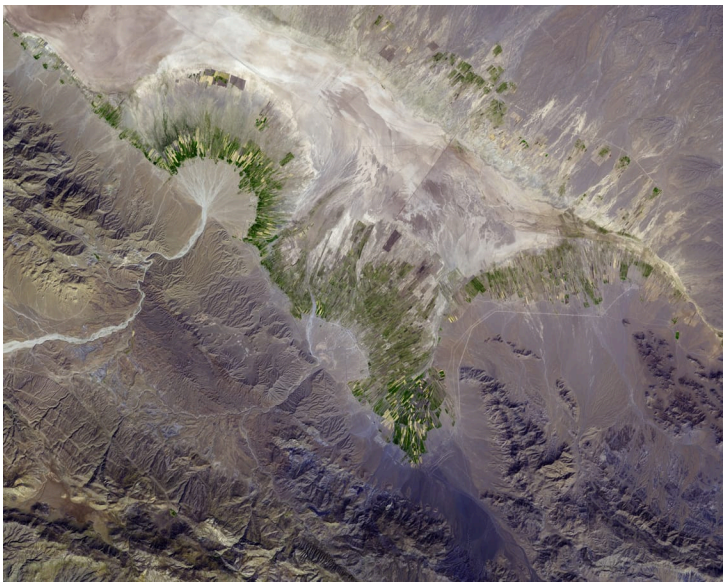


The Deposits of the Mississippi River Delta

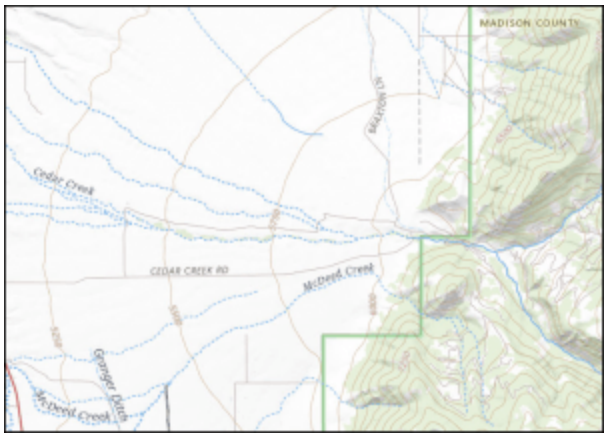
As a stream gets closer to base level, its gradient lowers and it deposits more material than it erodes. On flatter ground, streams deposit material on the inside of meanders. A stream's floodplain is much broader and shallower than the stream's channel. When a stream flows onto its floodplain, its velocity slows and it deposits much of its load. These sediments are rich in nutrients and make excellent farmland.

A stream at flood stage carries lots of sediments. When its gradient decreases, the stream overflows its banks and broadens its channel. The decrease in gradient causes the stream to deposit its sediments, the largest first. These large sediments build a higher area around the edges of the stream channel, creating natural levees.

When a river enters standing water, its velocity slows to a stop. The stream moves back and forth across the region and drops its sediments in a wide triangular-shaped deposit called a **delta**. If a stream falls down a steep slope onto a broad flat valley, an **alluvial fan** develops. Alluvial fans generally form in arid regions.



Alluvial fan, Iran



Arcing elevation contours indicate an Alluvial Fan.

Large lakes have tidal systems and currents, and can even affect weather patterns. The Great Lakes in the United States contain 22% of the world's fresh surface water. The largest them, Lake Superior, has a tide that rises and falls several centimeters each day. The Great Lakes are large enough to alter the weather system in Northeastern United States by the "lake effect," which is an increase in snow downwind of the relatively warm lakes. The Great Lakes are home to countless species of fish and wildlife. Lakes form in a variety of different ways: in depressions carved by glaciers, in calderas, and along tectonic faults, to name a few. Subglacial lakes are even found below a frozen ice cap.

As a result of geologic history and the arrangement of land masses, most lakes are in the Northern Hemisphere. In fact, more than 60% of all the world's lakes are in Canada — most of these lakes were formed by the glaciers that covered most of Canada in the last Ice Age.

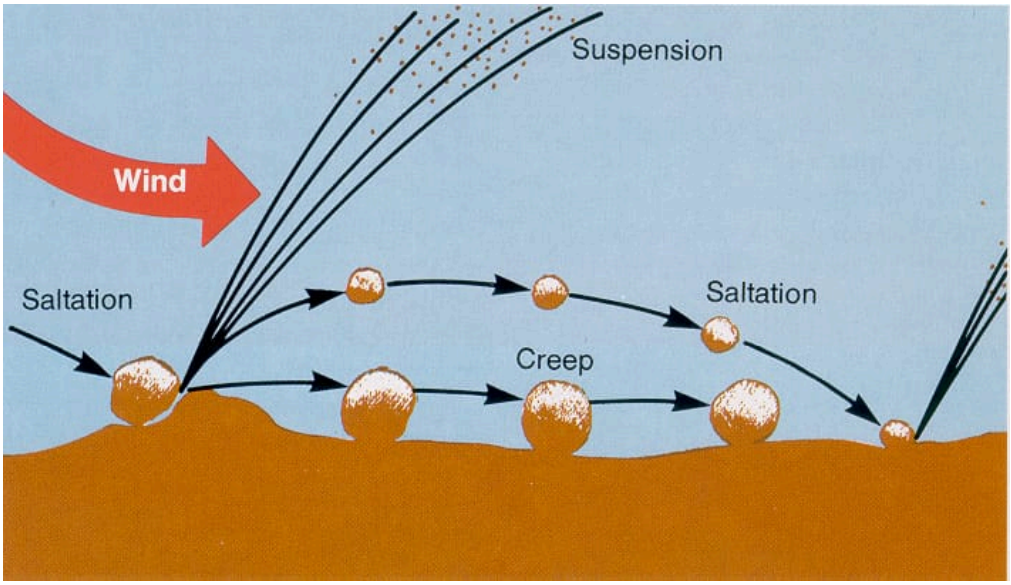
Limnology is the study of bodies of freshwater and the organisms that live there. The ecosystem of a lake is divided into three distinct sections: 1) The **surface** (**littoral**) **zone** is the sloped area closest to the edge of the water. 2) The **open-water zone** (also the **photic** or **limnetic zone**) has abundant sunlight. 3) The **deep-water zone** (also the **aphotic** or **profundal zone**) has little or no sunlight.

There are several life zones found within a lake. In the littoral zone, sunlight promotes plant growth, which provides food and shelter to animals such as snails, insects, and fish. In the open-water zone, other plants and fish, such as bass and trout, live. The deep-water zone does not have photosynthesis since there is no sunlight. Most deep-water organisms are scavengers, such as crabs and catfish that feed on dead organisms that fall to the bottom of the lake. Fungi and bacteria aid in the decomposition in the deep zone.

Though different creatures live in the oceans, ocean waters also have these same divisions based on sunlight with similar types of creatures that live in each of the zones.

Lakes are not permanent features of a landscape. Some come and go with the seasons, as water levels rise and fall. Over a longer time, lakes disappear when they fill with sediments, if the springs or streams that fill them diminish, or if their outlets grow because of erosion. When the climate of an area changes, lakes can either expand or shrink. Lakes may disappear if precipitation significantly diminishes.

WIND



The power of wind to erode depends on particle size, wind strength, and whether the particles are able to be picked up. Wind is a more important erosional force in arid than humid regions.

Wind transports small particles, such as silt and clay, over great distances, even halfway across a continent or an entire ocean basin. Particles may be suspended for days. Wind more easily picks up particles on ground that has been disturbed, such as a construction site or a sand dune. Just like flowing water, wind transports particles as both bed load and suspended load. For wind, bed load is made of sand-sized particles, many of which move by **saltation**. The suspended load is very small particles of silt and clay.

WIND EROSION

Wind is a stronger erosional force in arid regions than it is in humid regions because winds are stronger. In humid areas, water and vegetation bind the soil so it is harder to pick up. In arid regions, small particles are selectively picked up and transported. As they are removed, the ground surface gets lower and rockier, causing deflation. What is left is desert pavement, a surface covered by gravel sized particles that are not easily moved by wind.

Particles moved by wind do the work of **abrasion**. As a grain strikes another grain or surface it erodes that surface. Abrasion by wind may polish natural or human-made surfaces, such as buildings. Stones that have become polished and faceted due to abrasion by sand particles are called **ventifacts**.



Pictographs near Lewiston, ID. The black rock is weathered as Desert Varnish.

Exposed rocks in desert areas often develop a dark brown to black coating called

desert varnish. Wind transports clay-sized particles that chemically react with other substances at high temperatures. The coating is formed of iron and manganese oxides. Often times petroglyphs are carved into the desert varnish by earlier civilizations in arid regions.

WIND DEPOSITION



Sand Dunes from Wind Transport

Deserts and seashores sometimes have sand dunes. **Beach dunes** have different compositions depending on their location. Beach dunes are usually quartz because in humid areas other minerals weather into clays. In the tropics, sand dunes may be composed of calcium carbonate, which is common. In deserts, sand dunes may be composed of a variety of minerals. There is little weathering and so less stable minerals are left behind. **Dune sands** are usually very uniform in size and shape. Particles are sand-sized, because larger particles are too heavy for the wind to transport by suspension. They are rounded, since rounded grains roll more easily than angular grains.

For sand dunes to form there must be an abundant supply of sand and steady winds. A strong wind slows down, often over some type of obstacle, such as a rock or some vegetation and drops its sand. As the wind moves up and over the obstacle, it increases

in speed. It carries the sand grains up the gently sloping, upwind side of the dune by saltation. As the wind passes over the dune, its speed decreases. Sand cascades down the crest, forming the slip face of the dune. The slip face is steep because it is at the angle of repose for dry sand, about 34 degrees. Wind deposits dune sands layer by layer. If the wind changes directions, cross beds form. Cross beds are named for the way each layer is formed at an angle to the ground. The types of sand dune that forms depends on the amount of sand available, the character and direction of the wind, and the type of ground the sand is moving over.

LOESS



Loess Hills of Iowa

Windblown silt and clay deposited layer on layer over a large area are **loess**, which comes from the German word loose. Loess deposits form downwind of glacial outwash or desert, where fine particles are available. Loess deposits make very fertile soils in many regions of the world. Fine-grained mud in the deep ocean is formed from silts and clays brought from the land by wind. The particles are deposited on the sea surface, then slowly settle to the deep ocean floor, forming brown, greenish, or reddish clays. Volcanic ash may also settle on the seafloor.

GLACIERS

Glaciers cover about 10 percent of the land surface near Earth's poles and they are also found in high mountains. During the Ice Ages, glaciers covered as much as 30 percent of Earth. Around 600 to 800 million years ago, geologists think that almost all of the Earth was covered in snow and ice, called the **Snowball Theory**. Scientists use the evidence of erosion and deposition left by glaciers to do a kind of detective work to figure out where the ice once was and where it came from.

Glaciers are solid ice that move extremely slowly along the land surface. They erode and shape the underlying rocks. Glaciers also deposit sediments in characteristic landforms. The two types of glaciers are: *continental* and *alpine*. **Continental glaciers** are large ice sheets that cover relatively flat ground. These glaciers flow outward from where the greatest amount of snow and ice accumulate. **Alpine** or **valley glaciers** flow downhill through mountains along existing valleys.



Alpine glacier



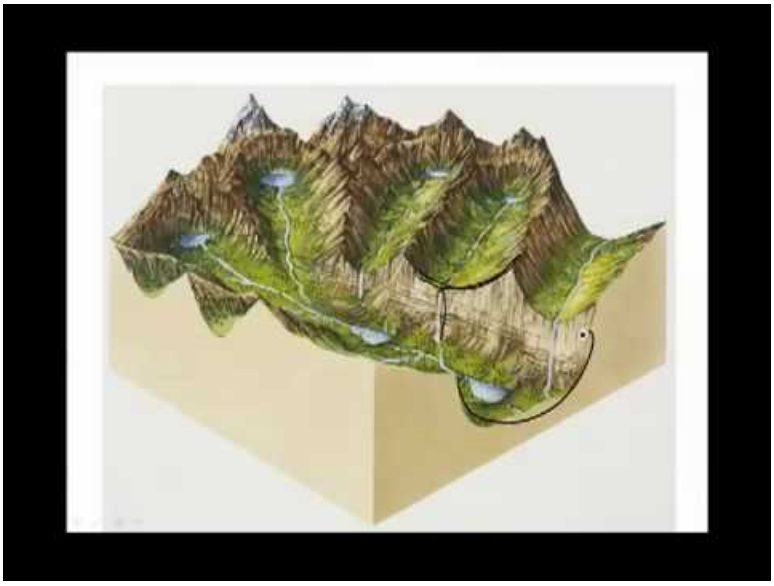
Greenland has one of the few remaining Continental Glaciers

GLACIAL EROSION

Glaciers erode the underlying rock by **abrasion** and **plucking**. Glacial meltwater seeps into cracks of the underlying rock, the water freezes and pushes pieces of rock outward. The rock is then plucked out and carried away by the flowing ice of the moving glacier. With the weight of the ice over them, these rocks can scratch deeply into the underlying bedrock making long, parallel grooves in the bedrock, called **glacial striations**. Mountain glaciers leave behind unique erosional features. When a glacier cuts through a 'V' shaped river valley, the glacier pucks rocks from the sides and bottom. This widens the valley and steepens the walls, making a 'U' shaped valley.

For example, Utah's landscape has been greatly influenced by glacial activity of the last ice age. Using Google Maps for our map, first look at Little Cottonwood Canyon and notice how linear the canyon is. That is a direct result of an alpine glacier carving down creating a U-shaped canyon that ultimately ended in Lake Bonneville. Now using the same map, compare Little Cottonwood Canyon with Big Cottonwood Canyon. If you were to drive from the Salt Lake Valley up the canyon, you would notice the canyon to be more V-shaped since because it was carved out by the stream and spring runoff instead of a glacier. The canyon is also more jagged in shape rather than linear like U-shaped canyons. But notice about half way up the canyon, the direction of the canyon changes from the northeast to running southeast. At that pivot point is where the canyon stopped being carved by a river and was

carved by another alpine glacier. From that pivot point to the end of the canyon, the canyon because linear and more U-shaped. The **cirque**, where the glacier originated, is at the head of the canyon is now home to Solitude Sky Resort and a portion of the melted cirque is now called Silver Lake.



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Smaller **tributary glaciers**, like tributary streams, flow into the main glacier in their own shallower 'U' shaped valleys. A hanging valley forms where the main glacier cuts off a tributary glacier and creates a cliff. Streams plunge over the cliff to create waterfalls. Up high on a mountain, where a glacier originates, rocks are pulled away from valley walls.



A U-shaped Glaciated Valley in Glacier National Park



A Glacial Erratic near Wilbur, WA

DEPOSITIONAL FEATURES OF GLACIERS

As glaciers flow, mechanical weathering loosens rock on the valley walls, which falls as debris on the glacier. Glaciers can carry rocks of any size, from giant boulders to silt. These rocks can be carried for many miles over many years and decades. These rocks that are different in type or origin from the surrounding bedrock are **glacial erratics**. Melting glaciers deposit all the big and small bits of rocky material they are carrying in a pile. These unsorted deposits of rock are called glacial till. **Glacial till** is found in different types of deposits. Linear rock deposits are called **moraines** and are named by their location relative to the glacier. . Geologists study moraines to figure out how far glaciers extended and how long it took them to melt away.



Glaciers merge and lateral moraines become medial moraines

Lateral moraines form at the edges of the glacier as material drops onto the glacier from erosion of the valley walls.

Medial moraines form where the lateral moraines of two tributary glaciers join together in the middle of a larger glacier. Sediment from underneath the glacier becomes a ground moraine after the glacier melts. Ground moraine contributes to the fertile transported soils in many regions.

Terminal moraines are long ridges of till left at the furthest point the glacier reached.

End moraines are deposited where the glacier stopped for a long enough period to create a rocky ridge as it retreated. Long Island in New York is formed by two end moraines.

While glaciers dump unsorted sediments, glacial melt water can sort and re-transport the sediments. As water moves through unsorted glacial till, it leaves behind the larger particles and takes away the smaller bits of sand and silt.

Several types of stratified deposits form in glacial regions but are not formed directly by the ice.

Varves form where lakes are covered by ice in the winter. Dark, fine-grained clays sink to the bottom in winter but melting ice in spring brings running water that deposits lighter colored sands. Each alternating dark/light layer represents one year of deposits. If during a year, a glacier accumulates more ice than melts away, the glacier advances downhill. If a glacier melts more than it accumulates over a year, it is retreating.

MASS WASTING

Once rock material has been broken down into smaller, unstable pieces by weathering, the material has the potential to move down slope called **mass wasting** (also called a **mass movement** or a **landslide**) because of gravity. Before looking into the various types of landslides, the factors that influence them must be examined. Ultimately, this comes down to the dynamics of two factors: gravity and steepness of slope. The steeper the slope, the greater potential for gravity to pull objects down. The shallower the slope, the less effect gravity has on pulling objects down.

There are several factors that influence mass wasting, but ultimately it is a **battle between friction and gravity**. If the friction on a rock is stronger than gravity for a particular slope, the rock material will likely stay. But if gravity is stronger, the slope will fail. The steeper the slope, the stronger the friction or rock strength must be to resist down slope motion. The steepest angle a slope can be before the ground will slide is about 35 degrees, called the angle of repose. Many times we will cut through a slope to make room for a road or other forms of development. So to help prevent the slope from sliding along these cut areas, retaining walls must be build. More on this later.

COMPOSITION OF SLOPE MATERIAL

Another factor that determines mass wasting is the slope's material. Mass wasting is more prone on slopes that contain clay and shale. Without going into great detail here, the shape and composition of individual clay particles can absorb water and prevent water from peculating through the ground. A layer of clay on a slope can prevent water from filtering through the slope. Instead, the water stays near the surface and saturates the ground. This can cause the surface layers to lose friction and slide.

WEIGHT AND FRICTION OF SLOPE

A third factor that influences whether a slope will fail is the load or weight of that slope. Adding weight to a weakened slope can obviously cause it to slide easier, especially on steep slopes. This added weight tends to occur by building on top of weak slopes, increasing the steepness of the slope, or over-saturating the slope. Friction has been mentioned as a factor several times already, but there are a few more things must be said here. As already noted, as long as the friction along the slope is stronger than gravity, the ground is unlikely to slide. But if that friction is weakened, slope fail becomes more likely. There are several other ways friction can be reduced along a slope: wildfires, removal of vegetation, or adding too much water. Gravity is probably the ultimate driving force of mass wasting. The force of gravity pulls all things on the planet toward the center of the Earth. Without gravity, mass wasting would not occur. But unlike many of the other factors, humans have no influence or control on gravity.

REGIONAL CLIMATE CONDITIONS

A region's climate can also determine the likelihood of a landslide. Climate is based on temperature and precipitation. Mass wasting is prone in the spring-time when snow melt, water saturation, and runoff is greatest. Also the type of climate will help determine the type of mass wasting. Humid climates tend to have slides, where water-saturated slopes fail and fall. Drier climates tend to have rocks that fall; especially early spring. Canyons and places prone to wildfires tend to have debris flows.

WATER CONTENT WITHIN SLOPES

The amount of water in the soil is a major factor in the stability of a slope. When you build a sand castle, water is needed to build the walls and towers. That is because water has surface tension and is attracted to each other. This allows you to build towers greater than the angle of repose. So a little water can actually prevent slopes from sliding. But too much water lubricates the individual grains of sediment decreasing friction between each grain, so the possibility of mass wasting increases. The increase of water within the soils can come from over watering, pipe or swimming pool leaks, or prolonged stormy weather. In Utah and many mountainous regions, spring runoff of snow melt increases the water content within the soil.

GRAVITY

Finally, gravity is the driving force of mass wasting. The force of gravity pulls all things on the planet toward the center of the Earth. When the force of gravity is greater than friction, the material will move. Friction can change primarily by adding or removing water. Adding water can increase the buoyancy of rock (it's easier to carry a big rock while it's under water) and water works as a lubricant to reduce friction. Adding water also increases mass. Friction can change, but gravity doesn't.

TYPES OF MASS WASTING

A **rock fall** are the fastest of all landslide types and occurs when a rock falls through the air until it comes to rest on the ground – not too complicated. In Utah, they are common in the spring and fall because of freeze-thaw weathering. In the daytime, temperatures in the spring and fall tend to be above freezing, which allows liquid water to enter cracks within rocks.

At night, the temperatures cool below freezing and the water within the rocks freezes and expands which causes the rock to break more. The following morning, the ice will melt and go deeper within the crack to refreeze later that night. This freeze-thaw action over time can cause rocks to break off and fall to the ground. The debris the accumulates at the base of these steep slopes is called **talus**.

But rock falls can also occur when heavy precipitation is falling on a steep slope, causing the rocks to lose friction and fall. The YouTube video on the right is a rock fall captured in Taiwan in late August 2013, following heavy precipitation in the region.

ROTATIONAL SLIDES

Rotational slides occur when the a landslide occurs in a curved manner concave to the sky. When this type of slide occurs, the upper surface of the slide tilts backwards toward the original slope and the lower surface moves away from the slope. They are common when the soil tends to be deep in clay or soft sediment deposits. The video on the right is a large landslide again in Taiwan in early September 2013 following every rainfall. Needless to say, they were having a bad few days in the region.

TRANSLATIONAL SLIDES



The Hope Slide, near Hope, BC was translational slide.

Rather than rotating, a **translational slide** occurs when slope failure occurs parallel to the slope. Often times the slope failure occurs on soil composed of clay or shale, or along old fault lines, or previous slide areas. What makes translational slides dangerous is that they tend to flow faster and travel farther than rotational slides. The most expensive translational slide in U.S. history actually occurred in Thistle, Utah in 1983.

DEBRIS FLOWS

Debris flows are one of the most common, but most dangerous of the various types of landslides because of their speed and consistency. Debris flows tend to be a mixture of rock and water with two to three times the density of flooding streams. That density allows debris flows strip away the land and pick up objects as large as school buses. Debris flows are most common at the mouth of canyons along alluvial fans. Lets first explain an alluvial fan. When floods occur within the mouth of a canyon, either because of intense thunderstorms or snow melt, the erosive power of the water can pick up sediment and boulders – a debris flow. Now once the debris flow reaches the mouth of a canyon, the sediment gets deposited in a fan-shaped delta called an alluvial fan. The problem is that people like to live along alluvial fans because of their scenic view on the canyon. Another influence of debris flows is wildfires. When a wildfire strips an area of its vegetation, the bare soil is easily eroded away in either a thunderstorm or snow melt creating these debris flows. Because of Utah's topography and tendency to wildfires, debris flows are quite common.

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1.12: Climate- Systems and Change

Learning Objectives

- Explain the controlling factors of global climates.
- Describe the various global climates and biomes classified using the Köppen Classification System.
- Analyze Earth's climatic past and how scientists measure and collect climate data.
- Describe the causes of short-term and long-term climate change.
- Determine why the overwhelming majority of scientists believe the current warming of the planet is because of human activity.

Essential Questions

- In what ways does climate influence regional culture?
- What impacts could a changing climate have on local, regional, and international social, economic, and geopolitical stability?
- Should global environmental issues like climate change be resolved by individuals, nations, or international institutions like the United Nations?
- What is your worldview on global environmental issues and how they should be addressed?

Controls of Climate: LACEMOPS

Although almost anything can happen with the weather, climate is more predictable. The weather on a particular winter day in San Diego may be colder than on the same day in Lake Tahoe, but, on average, Tahoe's winter climate is significantly colder than San Diego's. Climate then is the long-term average of weather. Good climate is why we choose to vacation in Hawaii in February, even though the weather is not guaranteed to be good!

Climate is the average of weather in that location over a long period of time, usually for at least 30 years. A location's climate can be described by its air temperature, humidity, wind speed and direction, and the type, quantity, and frequency of precipitation. Climate can change, but only over long periods of time. The climate of a region depends on its position relative to many things. These factors are described in the next sections.

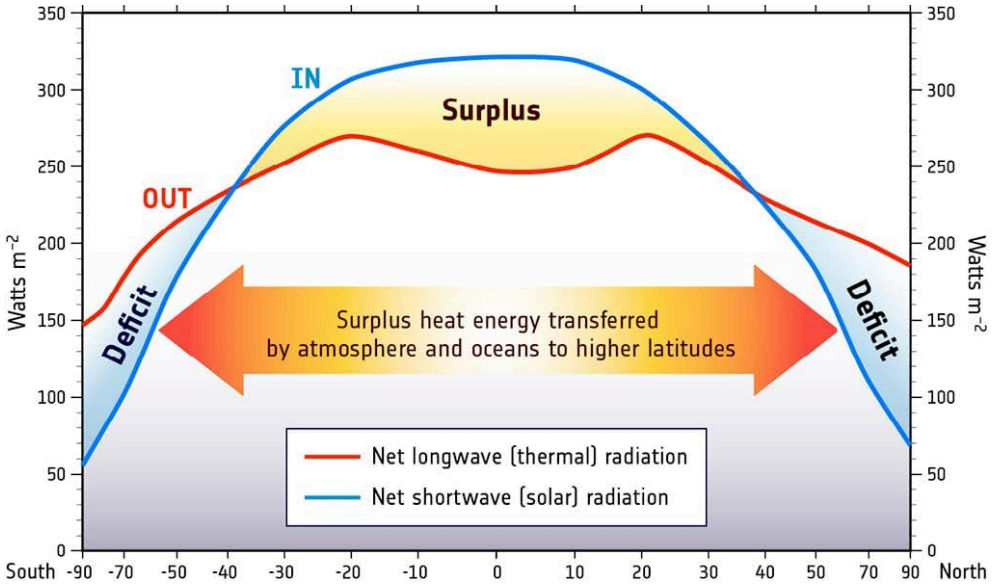
A useful mnemonic device for remembering all the major influences is LACEMOPS. These are the same factors influencing weather, but over a long period of time.

LACEMOPS

- Latitude
- Air Masses
- Continentality
- Elevation
- Mountain barriers (orographic effect)
- Ocean Currents
- Pressure Systems
- Storm Tracks

LATITUDE

The main factor influencing the climate of a region is latitude because different latitudes receive different amounts of solar radiation. To review from the Earth's Atmosphere chapter:



Energy moves from the equator to the poles.

The equator receives the most solar radiation. Days are equally long year-round and the sun is just about directly overhead at midday.

- The polar regions receive the least solar radiation. The night lasts six months during the winter. Even in summer, the sun never rises very high in the sky. Sunlight filters through a thick wedge of atmosphere, making the sunlight much less intense. The high albedo, because of ice and snow, reflects a good portion of the sun's light.

ATMOSPHERIC CIRCULATION

Recall from the Earth's Atmosphere chapter the circulation cells and global wind belts**.** The position of a region relative to the circulation cells and wind belts has a great effect on its climate. In an area where the air is mostly rising or sinking, there is not much wind.

The Intertropical Convergence Zone (ITCZ)

is the low pressure area near the equator in the boundary between the two Hadley Cells. The air rises so that it cools and condenses to create clouds and rain. Climate along the ITCZ is therefore warm and wet. Early mariners called this region the doldrums because their ships were often unable to sail because there were no steady winds.

The ITCZ migrates slightly with the season. Land areas heat more quickly than the oceans. Because there are more land areas in the Northern Hemisphere, the ITCZ is influenced by the heating effect of the land. In Northern Hemisphere summer, it is approximately 5o north of the equator while in the winter it shifts back and is approximately at the equator. As the ITCZ shifts, the major wind belts also shift slightly north in summer and south in winter, which causes the wet and dry seasons in this area.

HADLEY CELL AND FERRELL CELL BOUNDARIES

At about 30 °N and 30 °S, the air is fairly warm and dry because much of it came from the equator where it lost most of its moisture at the ITCZ. At this location the air is descending, and sinking air warms and causes evaporation. Mariners named this region the horse latitudes. Sailing ships were sometimes delayed for so long by the lack of wind that they would run out of water and food for their livestock. Sailors tossed horses and other animals over the side after they died. Sailors sometimes didn't make it either.

PREVAILING WINDS

The prevailing winds are the bases of the Hadley, Ferrell, and Polar Cells. These winds greatly influence the climate of a region because they bring the weather from the locations they come from. For example, in California, the predominant winds are the

westerlies blowing in from the Pacific Ocean, which bring in relatively cool air in summer and relatively warm air in winter. Local winds also influence local climate. For example, land breezes and sea breezes moderate coastal temperatures.

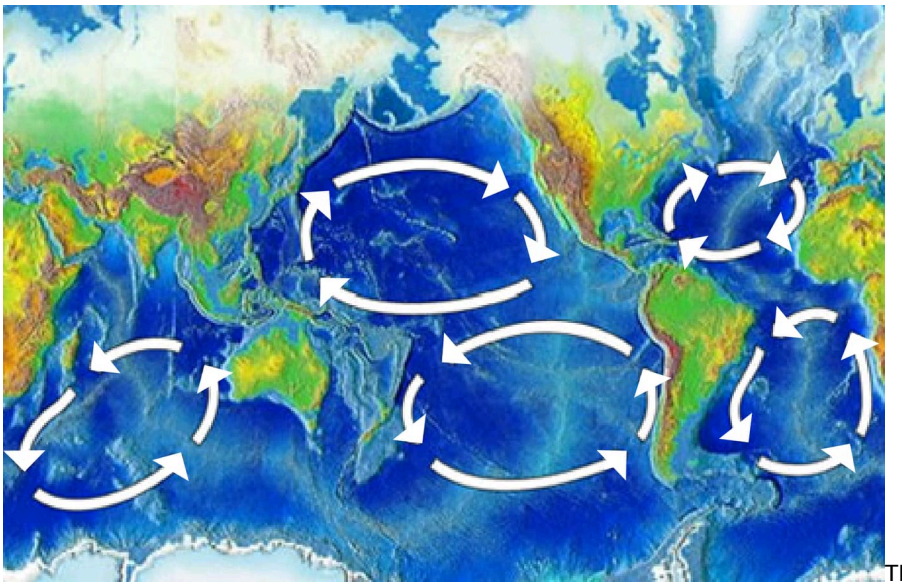
CONTINENTAL POSITION

When a particular location is near an ocean or large lake, the body of water plays an extremely important role in affecting the region's climate.

- A **maritime climate** is strongly influenced by the nearby sea. Temperatures vary a relatively small amount seasonally and daily. For a location to have a true maritime climate, the winds must most frequently come off the sea.
- A **continental climate** is more extreme, with greater temperature differences between day and night and between summer and winter.

The ocean's influence in moderating climate can be seen in the following temperature comparisons. Each of these cities is located at 37 °N latitude, within the westerly winds**.**

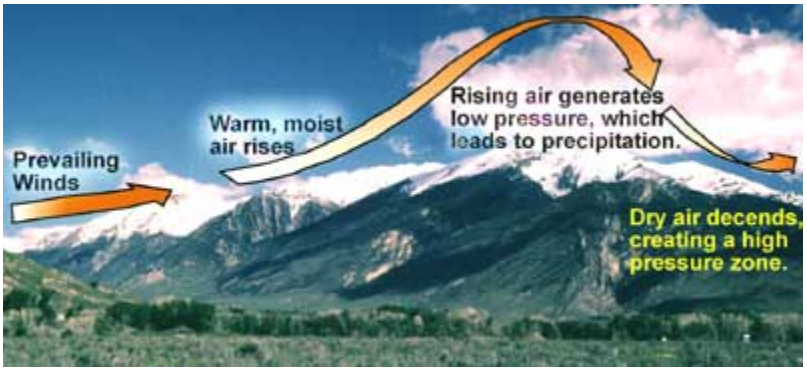
OCEAN CURRENTS



The temperature of the water offshore influences the temperature of a coastal location, particularly if the winds come off the sea. The cool waters of along the western United States is caused by a clockwise rotating ocean current that is bringing cold water from the arctic toward the equator. The climatic effect is that coastal regions of California, Oregon, and Washington are are cool. Coastal upwelling also brings cold, deep water up to the ocean surface off of California, which contributes to the cool coastal temperatures. But that same ocean current brings warm, tropical water to eastern Japan.

In the Atlantic Ocean, the northern ocean current, called the **Gulf Stream**, brings warm water from the tropics to the southern states. This is a major reason why the southern states experience humid conditions in the summer and tornadoes because of all this warm moisture. The Gulf Stream also impacts Europe by bringing warm water northward, making this region that is rather northward warmer than expected.

ALTITUDE AND MOUNTAIN RANGES



Air pressure and air temperature decreases with altitude. The closer molecules are packed together, the more likely they are to collide. Collisions between molecules give off heat, which warms the air. At higher altitudes, the air is less dense and air molecules are more spread out and less likely to collide. A location in the mountains has lower average temperatures than one at the base of the mountains. In Colorado, for example, Lakewood (5,640 feet) average annual temperature is 62 °F (17 °C), while Climax Lake (11,300 feet) is 42 °F (5.4 °C).

Mountain ranges have two effects on the climate of the surrounding region. The first is something called the **rainshadow effect**, which brings warm dry climate to the leeward size of a mountain range, was described in the Earth's Atmosphere chapter**.**

The second effect mountains have on climate systems is the ability to separate coastal regions from the rest of the continent. Since a maritime air mass may have trouble rising over a mountain range, the coastal area will have a maritime climate but the inland area on the leeward side will have a continental climate.

Climate Zones and Biomes

A **climate zone** results from the climate conditions of an area: its temperature, humidity, amount and type of precipitation, and the season. A climate zone is reflected in a region's natural vegetation. Perceptive travelers can figure out which climate zone they are in by looking at the vegetation, even if the weather is unusual for the climate on that day.

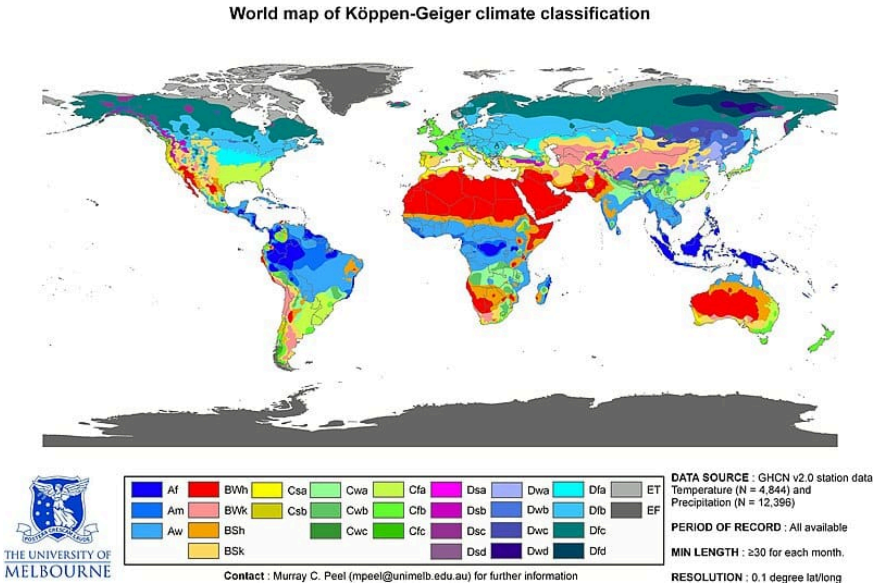
The major factors that influence climate determine the different climate zones. In general, the same type of climate zone will be found at similar latitudes and in similar positions on nearly all continents, both in the Northern and Southern Hemispheres. The one exception to this pattern is the climate zones called the continental climates, which are not found at higher latitudes in the Southern Hemisphere. This is because the Southern Hemisphere land masses are not wide enough to produce a continental climate.



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The most common system used to classify climatic zones is the **Köppen classification system**. This system is based on the *temperature*, the amount of *precipitation*, and the times of year when precipitation occurs. Since climate determines the type of vegetation that grows in an area, vegetation is used as an indicator of climate type.

A climate type together with its plants and animals make up a **biome**. The organisms of a biome share certain characteristics around the world, because their environment has similar advantages and challenges. The organisms have adapted to that environment in similar ways over time. For example, different species of cactus live on different continents, but they have adapted to the harsh desert in similar ways**.**





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The Köppen classification system recognizes five major climate groups, each with a distinct capital letter A through E. Each lettered group is divided into subcategories. Some of these subcategories are forest (f), monsoon (m), and wet/dry (w) types, based on the amount of precipitation and season when that precipitation occurs .

Tropical Moist Climates (Group A)



Tropical Moist (Group A) climates are found in a band about 15° to 25° N and S of the equator. What climate characteristics is the tropical moist climate group likely to have?

- Temperature: Intense sunshine; each month has an average temperature of at least 18°C (64°F).
- Rainfall: Abundant, at least 150 cm (59 inches) per year.

The wet tropics have almost no annual temperature variation and tremendous amounts of rain fall year round, between 175 and 250 cm (65 and 100 inches). These conditions support the tropical rainforest biome. **Tropical rainforests** are dominated by densely packed, broadleaf evergreen trees. These rainforests have the highest number of species or **biodiversity** of any

ecosystem.

TROPICAL MONSOON (Am)

The tropical monsoon climate has very low precipitation for one to two months each year. Rainforests grow here because the dry period is short, and the trees survive off of soil moisture. This climate is found where the monsoon winds blow, primarily in southern Asia, western Africa, and northeastern South America**.**

TROPICAL WET AND DRY

The tropical wet and dry climate lies between about 5° and 20° latitude, around the location of the ITCZ. In the summer, when the ITCZ drifts northward, the zone is wet. In the winter, when the ITCZ moves toward the equator, the region is dry. This climate exists where strong monsoon winds blow from land to sea, such as in India.

Rainforests cannot survive the months of low rainfall, so the typical vegetation is **savanna.** This biome consists mostly of grasses, with widely scattered deciduous trees and rare areas of denser forests.

Dry Climates (Group B)



The Dry Climates (Group B) have less precipitation than evaporation. Dry climate zones cover about 26% of the world's land area**.** What climate characteristics is the dry climate group likely to have?

- Temperature: Abundant sunshine. Summer temperatures are high; winters are cooler and longer than Tropical Moist climates
- Rainfall: Irregular; several years of drought are often followed by a single year of abundant rainfall

ARID DESERT (Bw)

Low-latitude, arid deserts are found between 15° to 30° N and S latitudes. This is where warm dry air sinks at high pressure zones. True deserts make up around 12% of the world's lands**.** In the Sonoran Desert of the southwestern United States and northern Mexico, skies are clear. The typical weather is extremely hot summer days and cold winter nights. Although annual rainfall is less than 25 cm (10 inches), rain falls during two seasons. Pacific storms bring winter rains and monsoons bring summer rains. Since organisms do not have to go too many months without some rain, a unique group of plants and animals can survive in the Sonoran desert**.**

SEMI-ARID OR STEPPE (Bs)



Semi-arid Steppe, Nevada

Higher latitude semi-arid deserts, also called **steppe**, are found in continental interiors or in rainshadows. Semi-arid deserts receive between 20 and 40 cm (8 to 16 inches) of rain annually. The annual temperature range is large. In the United States, the Great Plains, portions of the southern California coast, and the Great Basin are semi-arid deserts**.**

Moist Subtropical Mid-latitude (Group C)



C climate near Chattanooga, TN.

What climate characteristics is the moist subtropical group likely to have?

- Temperature: The coldest month ranges from just below freezing to almost balmy, between -3°C and 18°C (27° to 64°F). Summers are mild with average temperatures above 10°C (50°F). Seasons are distinct.
- Rainfall: There is plentiful annual rainfall.

DRY SUMMER SUBTROPICAL OR MEDITERRANEAN CLIMATES (Cs)

The Dry Summer Subtropical climate is found on the western sides of continents between 30° and 45° latitude. Annual rainfall is 30 to 90 cm (14 to 35 inches), most of which comes in the winter**.**

The climate is typical of coastal California, which sits beneath a summertime high pressure for about five months each year. Land and sea breezes make winters moderate and summers cool. Vegetation must survive long summer droughts. The scrubby, woody vegetation that thrives in this climate is called **chaparral**.

HUMID SUBTROPICAL (Cfa)

The Humid Subtropical climate zone is found mostly on the eastern sides of continents**.** Rain falls throughout the year with annual averages between 80 and 165 cm (31 and 65 inches). Summer days are humid and hot, from the lower 30's up to 40°C (mid-80's up to 104°F). Afternoon and evening thunderstorms are common. These conditions are caused by warm tropical air passing over the hot continent. Winters are mild, but middle-latitude storms called cyclones may bring snow and rain. The southeastern United States, with its hot humid summers and mild, but frosty winters, is typical of this climate zone.

MARINE WEST COAST CLIMATE (Cfb)

This climate lines western North America between 40° and 65° latitude, an area known as the Pacific Northwest**.** Ocean winds bring mild winters and cool summers. The temperature range, both daily and annually, is fairly small. Rain falls year round, although summers are drier as the jet stream moves northward. Low clouds, fog, and drizzle are typical. In Western Europe the climate covers a larger region since no high mountains are near the coast to block wind blowing off the Atlantic.

Humid Continental (Group D)



Confierous forest of D climates

Continental (Group D) climates are found in most of the North American interior from about 40°N to 70°N. What climate characteristics is the continental group most likely to have?

- Temperature: The average temperature of the warmest month is higher than 10°C (50°F) and the coldest month is below -3°C (-27°F).
- Precipitation: Winters are cold and stormy (look at the latitude of this zone and see if you can figure out why). Snowfall is common and snow stays on the ground for long periods of time.

Trees grow in continental climates, even though winters are extremely cold, because the average annual temperature is fairly mild. Continental climates are not found in the Southern Hemisphere because of the absence of a continent large enough to generate this effect.

HUMID CONTINENTAL (Dfa, Dfb)

The humid continental climates are found around the polar front in North America and Europe. In the winter, middle-latitude cyclones bring chilly temperatures and snow. In the summer, westerly winds bring continental weather and warm temperatures. The average July temperature is often above 20°C (70°F). The region is typified by deciduous trees, which protect themselves in winter by losing their leaves.

The two variations of this climate are based on summer temperatures.

- Dfa, long, hot summers: summer days may be over 38°C (100°F), nights are warm and the temperature range is large, perhaps as great as 31°C (56°F). The long summers and high humidity foster plant growth.
- Dfb, long, cool summers: summer temperatures and humidity are lower. Winter temperatures are below -18°C (0°F) for long periods.

SUBPOLAR (Dfc)

The subpolar climate is dominated by the continental polar air that masses over the frigid continent. Snowfall is light, but cold temperatures keep snow on the ground for months. Most of the approximately 50 cm (20 inches) of annual precipitation falls during summer cyclonic storms. The angle of the Sun's rays is low but the Sun is visible in the sky for most or all of the day during the summer, so temperatures may get warm, but are rarely hot. These continental regions have extreme annual temperature ranges. The boreal, coniferous forests found in the subpolar climate are called **taiga** and have small, hardy, and widely spaced trees. Taiga vast forests stretch across Eurasia and North America.

Polar Climates (Group E)



E climates, such as Denali, have short vegetation

Polar climates are found across the continents that border the Arctic Ocean, Greenland, and Antarctica. What climate characteristics is the polar climate group most likely to have?

- Temperature: Winters are entirely dark and bitterly cold. Summer days are long, but the sun is low on the horizon so summers are cool. The average temperature of the warmest month at less than 10°C (50°F). The annual temperature range is large.
- Precipitation: The region is dry with less than 25 cm (10 inches) of precipitation annually; most precipitation occurs during the summer.

POLAR TUNDRA (ET)

The polar tundra climate is continental, with severe winters. Temperatures are so cold that a layer of permanently frozen ground, called **permafrost** forms below the surface. This frozen layer can extend hundreds of meters deep. The average temperature of the warmest months is above freezing, so summer temperatures defrost the uppermost portion of the permafrost. In winter, the permafrost prevents water from draining downward. In summer, the ground is swampy. Although the precipitation is low enough in many places to qualify as a desert, evaporation rates are also low, so the landscape receives more usable water than a desert. Because of the lack of ice-free land near the South Pole, there is very little tundra in the Southern Hemisphere. The only plants that can survive the harsh winters and soggy summers are small ground-hugging plants like mosses, lichens, small shrubs, and scattered small trees that make up the **tundra**.

ICE CAP

Ice caps are found mostly on Greenland and Antarctica, about 9% of the Earth's land area. Ice caps may be thousands of meters

thick. Ice cap areas have extremely low average annual temperatures, e.g. -29°C (-20°F) at Eismite, Greenland. Precipitation is low because the air is too cold to hold much moisture. Snow occasionally falls in the summer.

Highland Climates (Group H)

When climate conditions in a small area are different from those of the surroundings, the climate of the small area is called a **microclimate**. The microclimate of a valley may be cool relative to its surroundings since cold air sinks. The ground surface may be hotter or colder than the air a few feet above it, because rock and soil gain and lose heat readily. Different sides of a mountain will have different microclimates. In the Northern Hemisphere, a south-facing slope receives more solar energy than a north-facing slope, so each side supports different amounts and types of vegetation. Altitude mimics latitude in climate zones**.** Climates and biomes typical of higher latitudes may be found in other areas of the world at high altitudes. A short distance up a mountain results in significant climate change compared to travelling the same distance on flat plains.

Climate Change in Earth History

For the past two centuries, climate has been relatively stable. People placed their farms and cities in locations that were in a favorable climate without thinking that the climate could change. But climate has changed throughout Earth history, and a stable climate is not the norm. In recent years, Earth's climate has begun to change again. Most of this change is warming because of human activities that release greenhouse gases into the atmosphere. The effects of warming are already being seen and will become more extreme as temperature rise.

Climate has changed throughout Earth history. Much of the time Earth's climate was hotter and more humid than it is today, but climate has also been colder, as when glaciers covered much more of the planet. The most recent ice ages were in the Pleistocene Epoch, between 1.8 million and 10,000 years ago. Glaciers advanced and retreated in cycles, known as glacial and interglacial periods. With so much of the world's water bound into the ice, sea level was about 125 meters (395 feet) lower than it is today. Many scientists think that we are now in a warm, interglacial period that has lasted about 10,000 years.

For the past 2,000 years, climate has been relatively mild and stable when compared with much of Earth's history. Why has climate stability been beneficial for human civilization? Stability has allowed the expansion of agriculture and the development of towns and cities.

Fairly small temperature changes can have major effects on global climate. The average global temperature during glacial periods was only about 5.5 °C (10 °F) less than Earth's current average temperature. Temperatures during the interglacial periods were about 1.1 °C (2.0 °F) higher than today**.**

Since the end of the Pleistocene, the global average temperature has risen about 4°C (7° F). Glaciers are retreating and sea level is rising. While climate is getting steadily warmer, there have been a few more extreme warm and cool times in the last 10,000 years. Changes in climate have had effects on human civilization.

- The Medieval Warm Period from 900 to 1300 A.D. allowed Vikings to colonize Greenland and Great Britain to grow wine grapes.
- The Little Ice Age, from the 14th to 19th centuries, the Vikings were forced out of Greenland and humans had to plant crops further south.

Short-term Climate Changes

Short-term changes in climate are common. The largest and most important of these is the oscillation between El Niño and La Niña conditions. This cycle is called the ENSO (El Niño southern oscillation). The ENSO drives changes in climate that are felt around the world about every two to seven years.

In a normal year, the trade winds blow across the Pacific Ocean near the equator from east to west (toward Asia). A low pressure cell rises above the western equatorial Pacific. Warm water in the western Pacific Ocean and raises sea levels by one-half meter. Along the western coast of South America, the Peru Current carries cold water northward, and then westward along the equator with the trade winds. Upwelling brings cold, nutrient-rich waters from the deep sea.

In an **El Niño** year, when water temperature reaches around 28 °C (82 °F), the trade winds weaken or reverse direction and blow east (toward South America)**.** Warm water is dragged back across the Pacific Ocean and piles up off the west coast of

South America. With warm, low-density water at the surface, upwelling stops. Without upwelling, nutrients are scarce and plankton populations decline. Since plankton form the base of the food web, fish cannot find food, and fish numbers decrease as well. All the animals that eat fish, including birds and humans, are affected by the decline in fish.

By altering atmospheric and oceanic circulation, El Niño events change global climate patterns.

- Some regions receive more than average rainfall, including the west coast of North and South America, the southern United States, and Western Europe.
- Drought occurs in other parts of South America, the western Pacific, southern and northern Africa, and southern Europe.

An El Niño cycle lasts one to two years. Often normal circulation patterns resume. Sometimes circulation patterns bounce back quickly and extremely, called **La Niña**.

In a La Niña year, as in a normal year, trade winds moves from east to west and warm water piles up in the western Pacific Ocean. Ocean temperatures along coastal South America are colder than normal (instead of warmer, as in El Niño). Cold water reaches farther into the western Pacific than normal.

Other important oscillations are smaller and have a local, rather than global, effect. The North Atlantic Oscillation mostly alters climate in Europe. The Mediterranean also goes through cycles, varying between being dry at some times, and warm and wet at others.

Causes of Long-term Climate Change

Many processes can cause climate to change. These include changes in the amount of energy the Sun produces over years; the positions of the continents over millions of years; in the tilt of Earth's axis; orbit over thousands of years; that are sudden and dramatic because of random catastrophic events, such as a large asteroid impact; in greenhouse gases in the atmosphere, caused naturally or by human activities.

PLATE TECTONICS

Plate movement and location can alter climate. Over millions to tens of millions of years as seas open and close, ocean currents may distribute heat differently. For example, when all the continents are joined into one supercontinent (such as Pangaea), nearly all locations experience a continental climate except for a small area along the coast. When the continents separate, heat is more evenly distributed because there's more coastal land and even interior land is, on average, closer to the ocean.

Plate tectonic movements may help start an ice age. When continents are located near the poles, ice can accumulate, which may increase albedo and lower global temperature. Low enough temperatures may start a global ice age.

Plate motions trigger volcanic eruptions, which release dust and CO_2 into the atmosphere. Ordinary eruptions, even large ones, have only a short-term effect on weather. Massive eruptions of the fluid lavas that create lava plateaus release much more gas and dust, and can change climate for many years. This type of eruption is exceedingly rare; none has occurred since humans have lived on Earth.

MILANKOVITCH CYCLES

The most extreme climate of recent Earth history was the Pleistocene. This time period began 2 million years ago. Scientists attribute a series of ice ages of the Pleistocene to variation in the Earth's position relative to the Sun, known as **Milankovitch cycles**. The Earth goes through regular variations in its position relative to the Sun. There appear to be three processes and each has a time period lasting tens of thousands of years. The **shape of the Earth's orbit** changes slightly as it goes around the Sun. The orbit varies from more circular to more elliptical in a cycle lasting between 90,000 and 100,000 years. When the orbit is more elliptical, there is a greater difference in solar radiation between winter and summer.

The **planet wobbles on its axis** of rotation. At one extreme of this 27,000 year cycle, the Northern Hemisphere points toward the Sun when the Earth is closest to the Sun. Summers are much warmer and winters are much colder than now. At the opposite extreme, the Northern Hemisphere points toward the Sun when it is farthest from the Sun. This results in chilly summers and warmer winters.

The **planet's tilt on its axis** varies between 22.1° and 24.5°. Seasons are caused by the tilt of Earth's axis of rotation, which is at

a 23.5° angle now. When the tilt angle is smaller, summers and winters differ less in temperature. This cycle lasts 41,000 years.

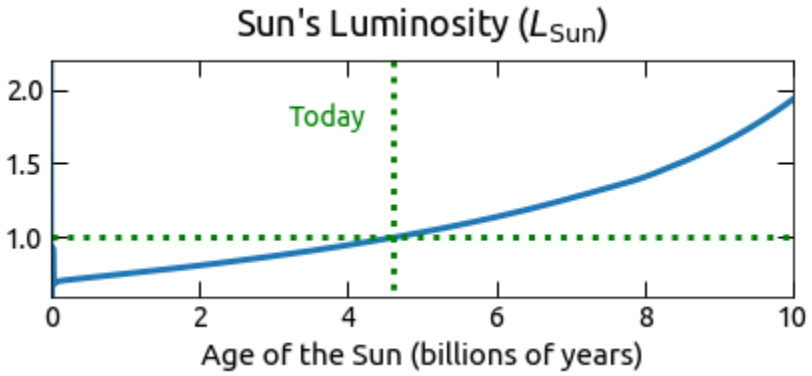
When these three variations are charted out, a climate pattern of about 100,000 years emerges. Ice ages correspond closely with Milankovitch cycles. Since glaciers can form only over land, ice ages only occur when landmasses cover the polar regions. Therefore, Milankovitch cycles are also connected to plate tectonics.

Video

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View this Video online

SUN VARIATION

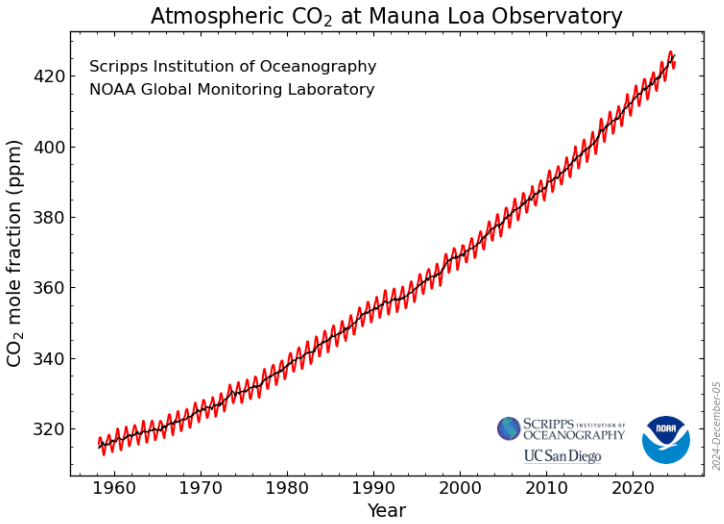


The Luminosity of the Sun has Increased about 33% over 4.6B years.

Stars have life cycles. Some grow, some contract. The Sun is still growing and over the last 4.6 B years the size of the sun has increased and the energy it releases has increased by about 33%.

The amount of energy the Sun radiates is variable. **Sunspots** are magnetic storms on the Sun's surface that increase and decrease over an 11-year cycle. When the number of sunspots is high, solar radiation is also relatively high. But the entire variation in solar radiation is tiny relative to the total amount of solar radiation that there is and there is no known 11-year cycle in climate variability. The Little Ice Age corresponded to a time when there were no sunspots on the Sun.

CHANGES IN ATMOSPHERIC GREENHOUSE GAS LEVELS



Atmospheric CO2 at Mauna Loa

Since greenhouse gases trap the heat that radiates off the planet's surfaces what would happen to global temperatures if atmospheric greenhouse gas levels decreased? What if greenhouse gases increased? A decrease in greenhouse gas levels decreases global temperature and an increase raises air temperature.

Greenhouse gas levels have varied throughout Earth history. For example, CO_2 has been present at concentrations less than 200 parts per million (ppm) and more than 5,000 ppm. But for at least 650,000 years, CO_2 has never risen above 300 ppm, during either glacial or interglacial periods. Natural processes add (volcanic eruptions and the decay or burning of organic matter) and remove absorption by plants, animal tissue, and the ocean) CO_2 from the atmosphere. When plants are turned into fossil fuels the CO_2 in their tissue is stored with them. So CO_2 is removed from the atmosphere. What does this do to Earth's average temperature? Fossil fuel use has skyrocketed in the past few decades more people want more cars and industrial products. This has released CO_2 into the atmosphere. Burning tropical rainforests, to clear land for agriculture, a practice called **slash-and-burn agriculture**, also increases atmospheric CO $_2$. By cutting down trees, they can no longer remove CO_2 from the atmosphere. Burning the trees releases all the CO_2 stored in the trees into the atmosphere.

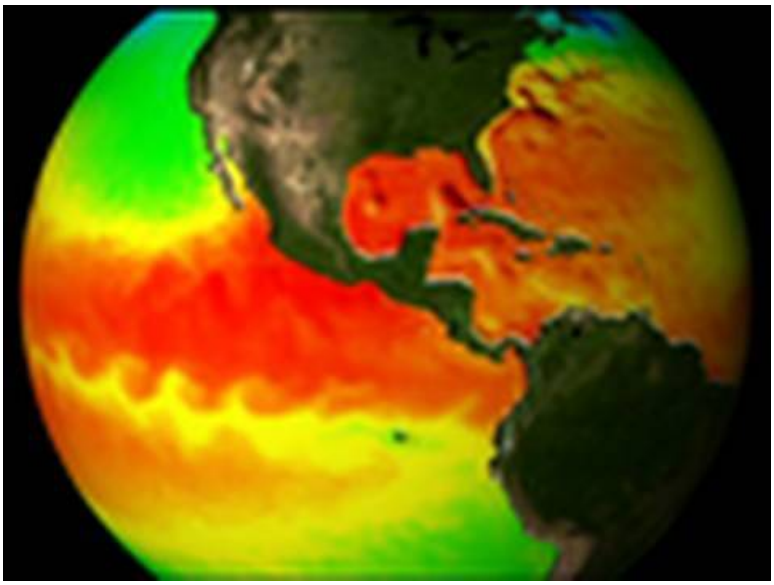
There is now nearly 40% more CO_2 in the atmosphere than there was 200 years ago, before the Industrial Revolution. About 65% of that increase has occurred since the first CO_2 measurements were made on Mauna Loa Volcano, Hawaii, in 1958. CO2 is the most important greenhouse gas that human activities affect because it is so abundant. But other greenhouse gases are increasing as well. A few are:

- Methane: released from raising livestock, rice production, and the incomplete burning of rainforest plants.
- Chlorofluorocarbons (CFCs): human-made chemicals that were invented and used widely in the 20th century.
- Tropospheric ozone: from vehicle exhaust, it has more than doubled since 1976.

Anthropogenic Climate Change

TEMPERATURES ARE RISING

With more greenhouse gases trapping heat, average annual global temperatures are rising. This is known as **global warming**. While temperatures have risen since the end of the Pleistocene, 10,000 years ago, this rate of increase has been more rapid in the past century, and has risen even faster since 1990. The nine warmest years on record have all occurred since 1998, and the 10 of the 11 warmest years have occurred since 2001 (through 2012). The 2000s were the warmest decade yet. Annual variations aside, the average global temperature increased about 0.8 °C (1.5 °F) between 1880 and 2010, according to the Goddard Institute for Space Studies, NOAA.



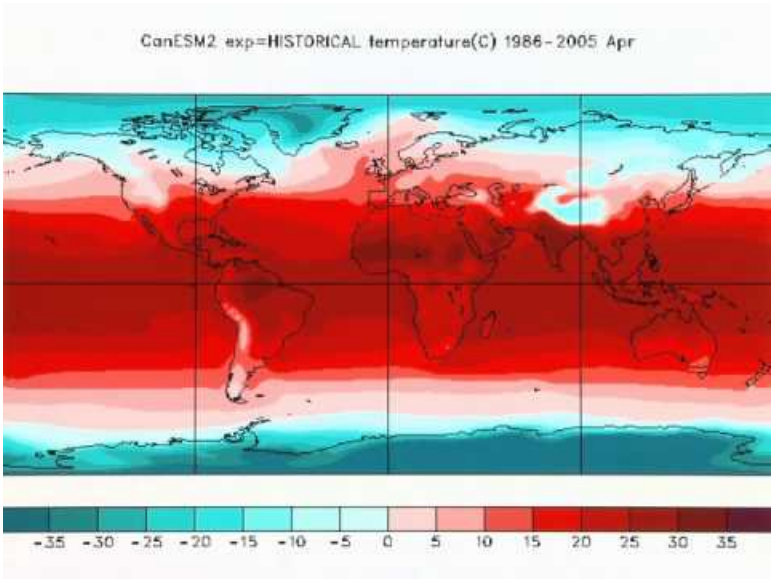
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The United States has long been the largest emitter of greenhouse gases, with about 20% of total emissions in 2004. As a result of China's rapid economic growth, its emissions surpassed those of the United States in 2008. However, it's also important to keep in mind that the United States has only about one-fifth the population of China. What's the significance of this? The average United States citizen produces far more greenhouse gases than the average Chinese person.

If nothing is done to decrease the rate of CO_2 emissions, by 2030, CO_2 emissions are projected to be 63% greater than they were in 2002.

FUTURE WARMING

The amount CO_2 levels will rise in the next decades is unknown. What will this number depend on in the developed nations? What will it depend on in the developing nations? In the developed nations it will depend on technological advances or lifestyle changes that decrease emissions. In the developing nations, it will depend on how much their lifestyles improve and how these improvements are made. Computer models are used to predict the effects of greenhouse gas increases on climate for the planet as a whole and also for specific regions.

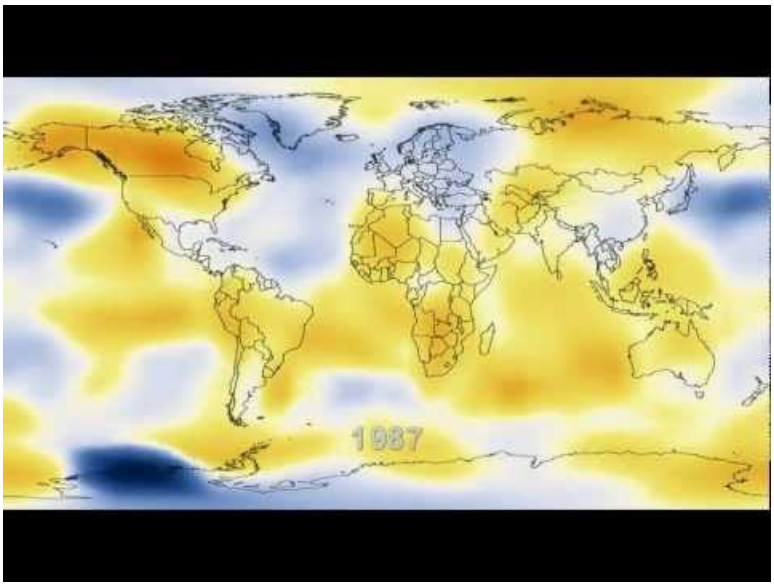


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If nothing is done to control greenhouse gas emissions and they continue to increase at current rates, the surface temperature of the Earth can be expected to increase between 0.5 °C and 2.0 °C (0.9 °F and 3.6 °F) by 2050 and between 2° and 4.5 °C (3.5° and 8 °F) by 2100, with CO_2 levels over 800 parts per million (ppm). On the other hand, if severe limits on CO_2 emissions begin soon, temperatures could rise less than 1.1 °C (2 °F) by 2100.

Whatever the temperature increase, it will not be uniform around the globe. A rise of 2.8 °C (5 °F) would result in 0.6° to 1.2 °C (1° to 2 F) at the equator, but up to 6.7 °C (12 °F) at the poles. So far, global warming has affected the North Pole more than the South Pole, but temperatures are still increasing at Antarctica**.**

The timing of events for species is changing. Mating and migrations take place earlier in the spring months. Species that can are moving their ranges uphill. Some regions that were already marginal for agriculture are no longer farmable because they have become too warm or dry.



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Hubbard Glacier (NPS)

Glaciers are melting and vegetation zones are moving uphill. If fossil fuel use exploded in the 1950s, why do

these changes begin early in the animation? Does this mean that the climate change we are seeing is caused by natural processes and not by fossil fuel use?

As greenhouse gases increase, changes will be more extreme. Oceans will become slightly more acidic, making it more difficult for creatures with carbonate shells to grow, and that includes coral reefs. A study monitoring ocean acidity in the Pacific Northwest found ocean acidity increasing ten times faster than expected and 10% to 20% of shellfish (mussels) being replaced by acid tolerant algae.

Plant and animal species seeking cooler temperatures will need to move poleward 100 to 150 km (60 to 90 miles) or upward 150 m (500 feet) for each 1.0 °C (8 °F) rise in global temperature. There will be a tremendous loss of biodiversity because forest species can't migrate that rapidly. Biologists have already documented the extinction of high-altitude species that have nowhere higher to go.

Decreased snow packs, shrinking glaciers, and the earlier arrival of spring will all lessen the amount of water available in some regions of the world, including the western United States and much of Asia. Ice will continue to melt and sea level is predicted to rise 18 to 97 cm (7 to 38 inches) by 2100**.** An increase this large will gradually flood coastal regions where about one-third of the world's population lives, forcing billions of people to move inland.

Summary

Weather will become more extreme with heat waves and droughts. Some modelers predict that the Midwestern United States will become too dry to support agriculture and that Canada will become the new breadbasket. In all, about 10% to 50% of current cropland worldwide may become unusable if CO2 doubles. There are global monitoring systems to help monitor potential droughts that could turn into famines if they occur in politically and socially unstable regions of the world and if appropriate action isn't taken in time. One example is FEWS NET, which is a network of social and environmental scientists using geospatial technology to monitor these situations. But even with proper monitoring, if nations don't act, catastrophes can occur like in Somalia from 2010-2012.

Although scientists do not all agree, hurricanes are likely to become more severe and possibly more frequent. Tropical and subtropical insects will expand their ranges, resulting in the spread of tropical diseases such as malaria, encephalitis, yellow fever, and dengue fever.

You may notice that the numerical predictions above contain wide ranges. Sea level, for example, is expected to rise somewhere between 18 and 97 cm — quite a wide range. What is the reason for this uncertainty? It is partly because scientists cannot predict exactly how the Earth will respond to increased levels of greenhouses gases. How quickly greenhouse gases continue to build up in the atmosphere depends in part on the choices we make.

An important question people ask is this: Are the increases in global temperature natural? In other words, can natural variations in temperature account for the increase in temperature that we see? The scientific data shows no, natural variations can not explain the dramatic increase in global temperatures. Changes in the Sun's irradiance, El Niño and La Niña cycles, natural changes in greenhouse gas, plate tectonics, and the Milankovitch Cycles cannot account for the increase in temperature that has already happened in the past decades.

In December 2013 and April 2014, the Intergovernmental Panel on Climate Change (IPCC) released a series of damaging reports on not only the current scientific knowledge of climate change, but also on the vulnerability and impacts to humans and ecosystems. Below are two videos detailing the physical science of climate change (Working Group I), and the risks and impacts to the planet (Working Group II). But it is important to get a strong, data driven understanding of climate change. Along with the IPCC, other organizations like the United Nations Environmental Programme (UNEP), World Health Organizations, World Meteorological Organization (WMO), NASA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA).



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1.13: Biogeography

Learning Objectives

By the end of this section, you will be able to:

- Define biogeography
- List and describe abiotic factors that affect the global distribution of plant and animal species
- Compare the impact of abiotic forces on aquatic and terrestrial environments
- Summarize the affect of abiotic factors on net primary productivity

Many forces influence the communities of living organisms present in different parts of the biosphere (all of the parts of Earth inhabited by life). The biosphere extends into the atmosphere (several kilometers above Earth) and into the depths of the oceans. Despite its apparent vastness to an individual human, the biosphere occupies only a minute space when compared to the known universe. Many abiotic forces influence where life can exist and the types of organisms found in different parts of the biosphere. The abiotic factors influence the distribution of biomes: large areas of land with similar climate, flora, and fauna.

Biogeography

Biogeography is the study of the geographic distribution of living things and the abiotic factors that affect their distribution. Abiotic factors such as temperature and rainfall vary based mainly on latitude and elevation. As these abiotic factors change, the composition of plant and animal communities also changes. For example, if you were to begin a journey at the equator and walk north, you would notice gradual changes in plant communities. At the beginning of your journey, you would see tropical wet forests with broad-leaved evergreen trees, which are characteristic of plant communities found near the equator. As you continued to travel north, you would see these broad-leaved evergreen plants eventually give rise to seasonally dry forests with scattered trees. You would also begin to notice changes in temperature and moisture. At about 30 degrees north, these forests would give way to deserts, which are characterized by low precipitation.

Moving farther north, you would see that deserts are replaced by grasslands or prairies. Eventually, grasslands are replaced by deciduous temperate forests. These deciduous forests give way to the boreal forests found in the subarctic, the area south of the Arctic Circle. Finally, you would reach the Arctic tundra, which is found at the most northern latitudes. This trek north reveals gradual changes in both climate and the types of organisms that have adapted to environmental factors associated with ecosystems found at different latitudes. However, different ecosystems exist at the same latitude due in part to abiotic factors such as jet streams, the Gulf Stream, and ocean currents. If you were to hike up a mountain, the changes you would see in the vegetation would parallel those as you move to higher latitudes.

Ecologists who study biogeography examine patterns of species distribution. No species exists everywhere; for example, the Venus flytrap is endemic to a small area in North and South Carolina. An endemic species is one which is naturally found only in a specific geographic area that is usually restricted in size. Other species are generalists: species which live in a wide variety of geographic areas; the raccoon, for example, is native to most of North and Central America.

Species distribution patterns are based on biotic and abiotic factors and their influences during the very long periods of time required for species evolution; therefore, early studies of biogeography were closely linked to the emergence of evolutionary thinking in the eighteenth century. Some of the most distinctive assemblages of plants and animals occur in regions that have been physically separated for millions of years by geographic barriers. Biologists estimate that Australia, for example, has between 600,000 and 700,000 species of plants and animals. Approximately 3/4 of living plant and mammal species are endemic species found solely in Australia.



(a) (b)

Fig 14.1 marsupials of Australia

Australia is home to many endemic species. The (a) wallaby (*Wallabia bicolor*), a medium-sized member of the kangaroo family, is a pouched mammal, or marsupial. The (b) echidna (*Tachyglossus aculeatus*) is an egg-laying mammal. (credit a: modification of work by Derrick Coetzee; credit b: modification of work by Allan Whittome.)

Sometimes ecologists discover unique patterns of species distribution by determining where species are *not* found. Hawaii, for example, has no native land species of reptiles or amphibians, and has only one native terrestrial mammal, the hoary bat. Most of New Guinea, as another example, lacks placental mammals.

Plants can be endemic or generalists: endemic plants are found only on specific regions of the Earth, while generalists are found on many regions. Isolated land masses—such as Australia, Hawaii, and Madagascar—often have large numbers of endemic plant species. Some of these plants are endangered due to human activity. The forest gardenia (*Gardenia brighamii)*, for instance, is endemic to Hawaii; only an estimated 15–20 trees are thought to exist.



Figure 14.2 Listed as federally endangered, the forest gardenia is a small tree with distinctive flowers. It is found only in five of the Hawaiian Islands in small populations consisting of a few individual specimens. (credit: Forest & Kim Starr)

Energy Sources

Sunlight

Energy from the sun is captured by green plants, algae, cyanobacteria, and photosynthetic protists. These organisms convert solar energy into the chemical energy needed by all living things. Light availability can be an important force directly affecting the evolution of adaptations in photosynthesizers. For instance, plants in the understory of a temperate forest are shaded when the trees above them in the canopy completely leaf out in the late spring. Not surprisingly, understory plants have adaptations to successfully capture available light. One such adaptation is the rapid growth of spring ephemeral plants such as the spring beauty (Figure 14.3}. These spring flowers achieve much of their growth and finish their life cycle (reproduce) early in the season before the trees in the canopy develop leaves.



Figure 14.3 The spring beauty is an ephemeral spring plant that flowers early in the spring to avoid competing with larger forest trees for sunlight. (credit: John Beetham)

In aquatic ecosystems, the availability of light may be limited because sunlight is absorbed by water, plants, suspended particles, and resident microorganisms. Toward the bottom of a lake, pond, or ocean, there is a zone that light cannot reach. Photosynthesis cannot take place there and, as a result, a number of adaptations have evolved that enable living things to survive without light. For instance, aquatic plants have photosynthetic tissue near the surface of the water; for example, think of the broad, floating leaves of a water lily—water lilies cannot survive without light. In environments such as hydrothermal vents, some bacteria extract energy from inorganic chemicals because there is no light for photosynthesis.

The availability of nutrients in aquatic systems is also an important aspect of energy or photosynthesis. Many organisms sink to the bottom of the ocean when they die in the open water; when this occurs, the energy found in that living organism is sequestered for some time unless ocean upwelling occurs. Ocean upwelling is the rising of deep ocean waters that occurs when prevailing winds blow along surface waters near a coastline (Figure 14.4). As the wind pushes ocean waters offshore, water from the bottom of the ocean moves up to replace this water. As a result, the nutrients once contained in dead organisms become available for reuse by other living organisms.

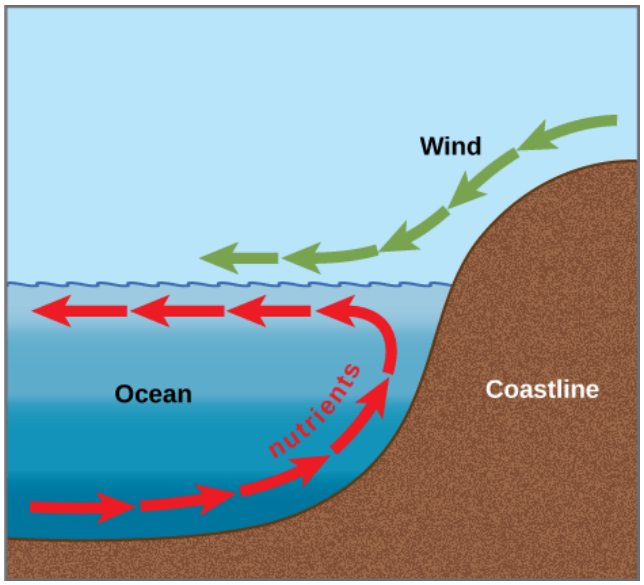


Figure 14.4 Ocean upwelling is an important process that recycles nutrients and energy in the ocean. As wind (green arrows) pushes offshore, it causes water from the ocean bottom (red arrows) to move to the surface, bringing up nutrients from the ocean depths.

In freshwater systems, the recycling of nutrients occurs in response to air temperature changes. The nutrients at the bottom of lakes are recycled twice each year: in the spring and fall turnover. The spring and fall turnover is a seasonal process that recycles nutrients and oxygen from the bottom of a freshwater ecosystem to the top of a body of water (Figure 14.5). These turnovers are caused by the formation of a thermocline: a layer of water with a temperature that is significantly different from that of the surrounding layers. In wintertime, the surface of lakes found in many northern regions is frozen. However, the water under the ice is slightly warmer, and the water at the bottom of the lake is warmer yet at 4 °C to 5 °C (39.2 °F to 41 °F). Water is densest at 4 °C; therefore, the deepest water is also the densest. The deepest water is oxygen poor because the decomposition of organic material at the bottom of the lake uses up available oxygen that cannot be replaced by means of oxygen diffusion into the water due to the surface ice layer.

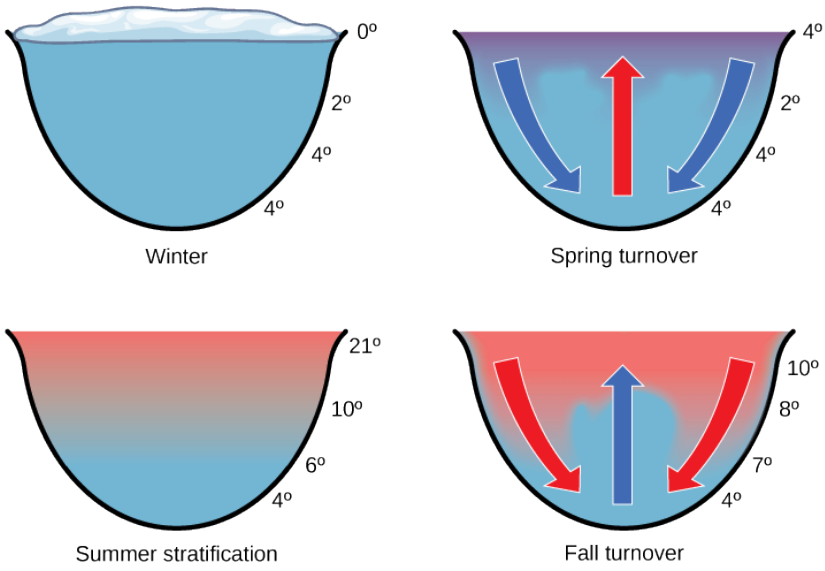


Figure 14.5 The spring and fall turnovers are important processes in freshwater lakes that act to move the nutrients and oxygen at the bottom of deep lakes to the top. Turnover occurs because water has a maximum density at 4 °C. Surface water temperature changes as the seasons progress, and denser water sinks.

How might turnover in tropical lakes differ from turnover in lakes that exist in temperate regions?

In springtime, air temperatures increase and surface ice melts. When the temperature of the surface water begins to reach 4 °C, the water becomes heavier and sinks to the bottom. The water at the bottom of the lake is then displaced by the heavier surface

water and, thus, rises to the top. As that water rises to the top, the sediments and nutrients from the lake bottom are brought along with it. During the summer months, the lake water stratifies, or forms layers, with the warmest water at the lake surface.
As air temperatures drop in the fall, the temperature of the lake water cools to 4 °C; therefore, this causes fall turnover as the heavy cold water sinks and displaces the water at the bottom. The oxygen-rich water at the surface of the lake then moves to the bottom of the lake, while the nutrients at the bottom of the lake rise to the surface. During the winter, the oxygen at the bottom of the lake is used by decomposers and other organisms requiring oxygen, such as fish.

Temperature

Temperature affects the physiology of living things as well as the density and state of water. Temperature exerts an important influence on living things because few living things can survive at temperatures below 0 °C (32 °F) due to metabolic constraints. It is also rare for living things to survive at temperatures exceeding 45 °C (113 °F); this is a reflection of evolutionary response to typical temperatures. Enzymes are most efficient within a narrow and specific range of temperatures; enzyme degradation can occur at higher temperatures. Therefore, organisms either must maintain an internal temperature or they must inhabit an environment that will keep the body within a temperature range that supports metabolism. Some animals have adapted to enable their bodies to survive significant temperature fluctuations, such as seen in hibernation or reptilian torpor. Similarly, some bacteria are adapted to surviving in extremely hot temperatures such as geysers. Such bacteria are examples of extremophiles: organisms that thrive in extreme environments.

Temperature can limit the distribution of living things. Animals faced with temperature fluctuations may respond with adaptations, such as migration, in order to survive. Migration, the movement from one place to another, is an adaptation found in many animals, including many that inhabit seasonally cold climates. Migration solves problems related to temperature, locating food, and finding a mate. In migration, for instance, the Arctic Tern (*Sterna paradisaea*) makes a 40,000 km (24,000 mi) round trip flight each year between its feeding grounds in the southern hemisphere and its breeding grounds in the Arctic Ocean. Monarch butterflies (*Danaus plexippus*) live in the eastern United States in the warmer months and migrate to Mexico and the southern United States in the wintertime. Some species of mammals also make migratory forays. Reindeer (*Rangifer tarandus*) travel about 5,000 km (3,100 mi) each year to find food. Amphibians and reptiles are more limited in their distribution because they lack migratory ability. Not all animals that can migrate do so: migration carries risk and comes at a high energy cost.
Some animals hibernate or estivate to survive hostile temperatures. Hibernation enables animals to survive cold conditions, and estivation allows animals to survive the hostile conditions of a hot, dry climate. Animals that hibernate or estivate enter a state known as torpor: a condition in which their metabolic rate is significantly lowered. This enables the animal to wait until its environment better supports its survival. Some amphibians, such as the wood frog (*Rana sylvatica*), have an antifreeze-like chemical in their cells, which retains the cells' integrity and prevents them from bursting.

Water

Water is required by all living things because it is critical for cellular processes. Since terrestrial organisms lose water to the environment by simple diffusion, they have evolved many adaptations to retain water.

- Plants have a number of interesting features on their leaves, such as leaf hairs and a waxy cuticle, that serve to decrease the rate of water loss via transpiration.
- Freshwater organisms are surrounded by water and are constantly in danger of having water rush into their cells because of osmosis. Many adaptations of organisms living in freshwater environments have evolved to ensure that solute concentrations in their bodies remain within appropriate levels. One such adaptation is the excretion of dilute urine.
- Marine organisms are surrounded by water with a higher solute concentration than the organism and, thus, are in danger of losing water to the environment because of osmosis. These organisms have morphological and physiological adaptations to retain water and release solutes into the environment. For example, Marine iguanas (*Amblyrhynchus cristatus*), sneeze out water vapor that is high in salt in order to maintain solute concentrations within an acceptable range while swimming in the ocean and eating marine plants.

Inorganic Nutrients and Soil

Inorganic nutrients, such as nitrogen and phosphorus, are important in the distribution and the abundance of living things. Plants obtain these inorganic nutrients from the soil when water moves into the plant through the roots. Therefore, soil structure (particle size of soil components), soil pH, and soil nutrient content play an important role in the distribution of plants. Animals obtain

inorganic nutrients from the food they consume. Therefore, animal distributions are related to the distribution of what they eat. In some cases, animals will follow their food resource as it moves through the environment.

Other Aquatic Factors

Some abiotic factors, such as oxygen, are important in aquatic ecosystems as well as terrestrial environments. Terrestrial animals obtain oxygen from the air they breathe. Oxygen availability can be an issue for organisms living at very high elevations, however, where there are fewer molecules of oxygen in the air. In aquatic systems, the concentration of dissolved oxygen is related to water temperature and the speed at which the water moves. Cold water has more dissolved oxygen than warmer water. In addition, salinity, current, and tide can be important abiotic factors in aquatic ecosystems.

Other Terrestrial Factors

Wind can be an important abiotic factor because it influences the rate of evaporation and transpiration. The physical force of wind is also important because it can move soil, water, or other abiotic factors, as well as an ecosystem's organisms.
Fire is another terrestrial factor that can be an important agent of disturbance in terrestrial ecosystems. Some organisms are adapted to fire and, thus, require the high heat associated with fire to complete a part of their life cycle. For example, the jack pine—a coniferous tree—requires heat from fire for its seed cones to open (Figure 14.6). Through the burning of pine needles, fire adds nitrogen to the soil and limits competition by destroying undergrowth.



Figure 14.6 The mature cones of the jack pine (Pinus banksiana) open only when exposed to high temperatures, such as during a forest fire. A fire is likely to kill most vegetation, so a seedling that germinates after a fire is more likely to receive ample sunlight than one that germinates under normal conditions. (credit: USDA)

Abiotic Factors Influencing Plant Growth

Temperature and moisture are important influences on plant production (primary productivity) and the amount of organic matter available as food (net primary productivity). Net primary productivity is an estimation of all of the organic matter available as food; it is calculated as the total amount of carbon fixed per year minus the amount that is oxidized during cellular respiration. In terrestrial environments, net primary productivity is estimated by measuring the aboveground biomass per unit area, which is the total mass of living plants, excluding roots. This means that a large percentage of plant biomass which exists underground is not included in this measurement. Net primary productivity is an important variable when considering differences in biomes. Very productive biomes have a high level of aboveground biomass.
Annual biomass production is directly related to the abiotic components of the environment. Environments with the greatest amount of biomass have conditions in which photosynthesis, plant growth, and the resulting net primary productivity are optimized. The climate of these areas is warm and wet. Photosynthesis can proceed at a high rate, enzymes can work most efficiently, and stomata can remain open without the risk of excessive transpiration; together, these factors lead to the maximal amount of carbon dioxide (CO_2) moving into the plant, resulting in high biomass production. The aboveground biomass produces

several important resources for other living things, including habitat and food. Conversely, dry and cold environments have lower photosynthetic rates and therefore less biomass. The animal communities living there will also be affected by the decrease in available food.

Movement in Biogeography

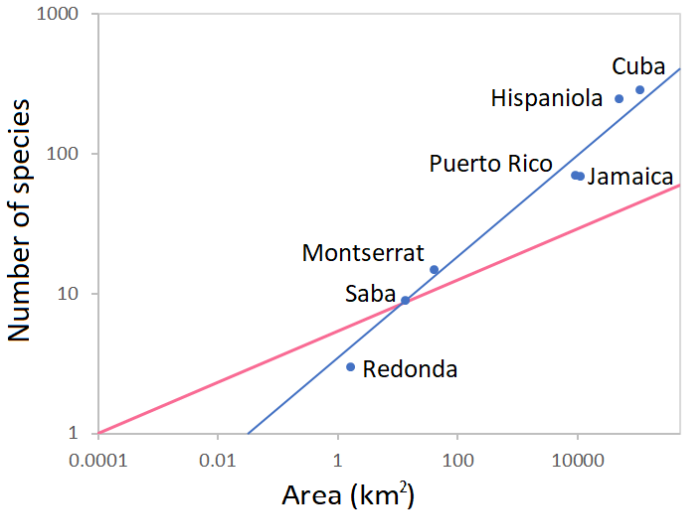
Living organisms must find suitable habitat in order to survive. One individual animal might be able, or need to, move short distances over a lifetime, perhaps only a few cm or m, while another individual may need to move 1000s of km. An individual plant won't move on it's own, but the species may move through seed dispersal. Think of the wings on a maple tree seed or the 'stickiness' of a cocklebur and how that helps the species find new suitable habitat.

Island Biogeography

Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation, and habitat area. The latter pattern, often called the species-area relationship, has long been a fascination for biogeographers.



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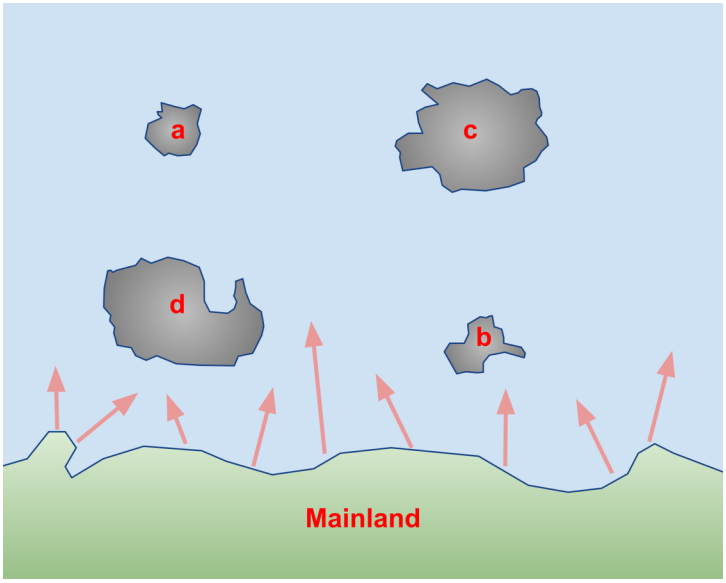


Species-area relationship for amphibians and reptilians on seven different islands in the West Indies.

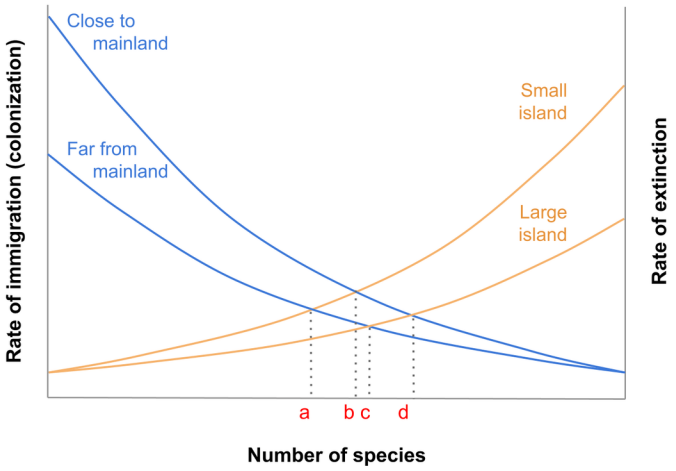
The figure below demonstrates this species-area relationship for amphibians and reptiles in the West Indies. A study from around 1957 was included in Robert H. MacArthur and Edward O. Wilson's famous book "The Theory of Island Biogeography", and showed that among seven islands studied, the largest, Cuba, had the most species, and the smallest, Redonda, had the fewest. This general pattern has been found in many different islands groups, and across various different taxa.
An original study (Darlington c. 1957), published in "*The Theory of Island biogeography*", showed a strong positive correlation between island size and number of species (blue line). A more recent study by Gao and Perry (2016) included data for many additional small islands (smaller than Redonda) and found that while the pattern holds, the relationship is flatter than in the original study–indicated by the pink line. Figure drawn by Andy Wilson, based on Figure 4 in Gao and Perry (2016).

While studying these species-area relationships MacArthur and Wilson were drawn to another of the four geographic gradients–that of isolation. They observed that some large Islands had fewer species than would be expected for their size, while conversely, some small islands had more species than expected. These are exceptions to the **species-area relationship**. These patterns were explained by MacArthur and Wilson's **Equilibrium Theory of Island Biogeography**, which takes into account the fact that islands are colonized by species from elsewhere, and natural extinctions will occur on those islands, over long periods of time. Imagine there are two islands located off the coast of the mainland. Although the two islands are about the same size, one island is located much farther away than island. If you are a bird that lives on the mainland, which island are you most likely to find? The answer is generally island. This means immigration (or colonization) is influenced by the distance of an island from the mainland (a source of colonists). Therefore, islands that are closer to the island are more likely to receive immigrants than islands that are further away. Two offshore islands–the Theory of Island Biogeography suggests that fewer species will colonize the more distant island a, in comparison to island b.

Once a species manages to reach and colonize an island, the rate of extinction is largely influenced by size of the island. This is because smaller islands tend to hold smaller populations (which are more likely to experience extinction due to stochastic effects like genetic drift). Larger habitat size reduces the probability of extinction of the colonized species due to chance events. Smaller islands are also likely to hold fewer populations in general because they have fewer resources and less diversity of resources. Larger islands have larger and more habitat areas, which typically leads to more differences in habitat or habitat heterogeneity. Higher heterogeneity means that there are more opportunities for a variety of species to find their suitable niches. Habitat heterogeneity also helps increase the number of species to successfully colonize after immigration. Now let's consider the situation if we had two different islands sizes in our offshore archipelago, with, much bigger than. We would expect extinction rates to be much lower on islands than on the two smaller islands.



Four offshore islands–the Theory of Island Biogeography suggests that fewer species will go extinct on the larger islands c and d, in comparison to islands a and b (credit: Andy Wilson, redrawn from Wikipedia [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)]We could plot both immigration and extinction relationships on a single image as seen in the graph below. Note the y-axis is the number of species (either colonizing or going extinct). Now we see that of the four islands in the above figures, island (small and far) would likely have the fewest species, island (large and close), would have the most, and islands and would fall between the two extremes.



Equilibrium Theory of Island Biogeogaphy (credit: Andy Wilson, redrawn from Wikipedia [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)]This basic graph makes a lot of assumptions but also offers a lot of insight. In this graph, immigration rates (blue lines) depend on proximity to mainland. Immigration rates also decline with species richness. That's because its' easiest to immigrate to an island when it is empty because all the resources on the island are available. As the islands get more and more full, colonizing the island becomes more difficult. Extinction rates (orange lines), as noted above, depend on island size. We also see that extinction rates tend to increase with the number of species. This should make sense: If there are no species on an island, extinction is impossible, but as more and more species arrive (and compete!) extinction becomes more likely. The graph shows the basic Equilibrium Theory of Island Biogeography. It suggests that islands will reach an equilibrium, or stable, number of species when immigration and extinction rates are equal! Note this model could be modified in multiple ways. Size of an island, for example, likely also impacts immigration rate (larger islands are easier to hit!), and islands that are close together may also share individuals (the Rescue effect!), but even this simple conceptualization has proven useful for understanding global species richness patterns. One interesting point to note is that an equilibrium number of species is reached when immigration and extinction rates are equal, not when those processes stop! This means islands may consistently be changing species composition but should maintain fairly consistent levels of species richness. As odd as this sounds, early tests of the Equilibrium Theory of Island Biogeography supported these assumptions. When mangrove islands off the coast of Florida were fully cleared of their invertebrate (insect and

arachnid) communities and allowed to recolonize, islands eventually stabilized with communities of about the same richness as they had before disturbance. The island biogeography model has crucial applications for wildlife management because wildlife reserves or patches of habitat can be considered “islands” of habitat in “an ocean” of an inhabitable area. For this reason, the Theory Island Biogeography has become central to our understanding of how habitat fragmentation leads to biodiversity loss.

Stream Drift Paradox

The stream drift paradox looks at the distribution of individuals of a single species along a stream. Some insects in particular are poor swimmers in their aquatic juvenile stages and therefore tend to move downstream with the current rather than upstream against the current. The paradox is how did they arrive upstream to begin with? One theory is the adults of the species tend to hatch at a time of day with breezes going up the valley towards the headwaters. So the direction of movement depends on the life stage of the insect. There is a problem with this when you realize that not all species have a life stage out of the water (Humphries and Duxton, 2002).

Invasive Species

Invasion of a region by new species is normal. Species are constantly testing new areas as seeds are deposited and animals wander. What’s not normal is the number of species that are moving so far from their hearth regions. This change is because of human activity, deliberate or not. As humans more often, greater distances, at greater speed, there’s more opportunity for species to move with the humans.

The Washington Invasive Species Council monitors and coordinates projects related to invasive species in the state. For many years the executive coordinator of the council was a trained geographer.

Most species fail to survive in the new location. The conditions the species need for survival simply don’t exist there. However, once in a while, the right conditions do exist. The new location may have fewer predators or more food. As the new species thrives, it removes space and nutrients that would have been available to local indigenous species.

The zebra mussel is believed to have come to the US Great Lakes on a ship from the Black Sea region in 1988. In 10 years it spread to all of the Great Lakes and many tributaries as shown in the video below.



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NUTRIENT CYCLING

Consider different nutrient cycles such as Nitrogen, Water, Phosphorus, Potassium and many others. Where are they stored, for

how long? What are their paths of movement from storage to storage. Think in Systems: There are locations of long term storage and paths of movement between them.

Large scale movement of animals represent mass movement. The animals have mass. But represents chemical and nutrient movement. Imagine the skies and trees in the 1800s as carrier pigeons migrated and roosted and clear the land of food, but left behind manure. Salmon mature in the ocean and concentrate nutrients found in the ocean only to die in coastal rivers and release those nutrients far inland. Without that natural movement of nutrients, humans need to do the movement instead or risk diminished biological productivity.

CONCLUSION

Biogeography helps explain and interpret the existing distribution of species, how they arrived there, and how species continue to move.

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2: HUMAN GEOGRAPHY

2.1: Natural Resource Geography
2.2: Population and Migration
2.3: Human Geography
2.4: Geography of Religion
2.5: Geography of Language
2.6: Urban Geography
2.7: Urban and Suburban Spaces
2.8: Social and Economic Development
2.9: Economy and Development
2.10: Political Geography
2.11: Power, Politics, and Place
2.12: Economic Geography

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2.1: Natural Resource Geography

Learning Objectives

- Analyze why natural resources are being depleted
- Describe the various types of environmental pollution
- Explain the idea, purpose, and types of renewable energies

Essential Questions

- What is our responsibility as individuals and citizens to protect Earth's natural resources?
- Do species have the right to exist even if they don't have an economic value to humans? If so, does your lifestyle support this?

INTRODUCTION

The planet can only support so many people before natural resources begin become depleted and can not support human needs, called Earth's **carrying capacity** for humans. Many geographers and other scientists believe that humans have grown beyond earth's carrying capacity; a concept called **overshooting**. In less developed countries, this has occurred because of population growth; in more developed countries it has to do with our consumption of natural resources. A **natural resource** is something found within the natural environment that is accessible and economically valuable to humans including food, water, soil, plants, animals, and minerals. But most resources are not renewable, and humans are either consuming them faster than the planet can replenish them or in the case of water and air are polluting them.

Resource geographers study where resources are found, where they are used, and transportation routes connecting those locations. Understanding the natural processes that create resources is necessary. Since a resource is by definition something that humans find useful, once it is no longer useful we are left with waste. Environmental geography combines the study of natural resources, with the waste that is associated with their consumption, along with the political situation of controlling access to resources.



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DEPLETION OF NATURAL RESOURCES

There are primarily two types of resources: energy and minerals. As noted, a natural resource only has “value” as long as humans need it. As it turns out, humans need more and more energy and mineral resources, resulting in increased costs. There has also been a steady rise in the cost of petroleum, gold, copper, platinum, and titanium.

Throughout history, most of the world’s energy came from animate power; the use of animals such as mules, ox, and horses. But following the Industrial Revolution, most of the energy in Europe and the United States was used for machinery. The energy used to power the machinery came from inanimate power such as biofuel and fossil fuels. Currently the most used energy source for less developed nations are biofuel such as trees and dung. But in more developed nations and nations transitioning, fossil fuels such as coal and petroleum have become the central source of energy.



FINITENESS OF FOSSIL FUELS

So what is fossil fuel? Everything that is or was alive is made out of carbon. Millions of years ago when the planet was a lot warmer, plant life was quite abundant. Over geologic time, these carbon bodies were buried and ultimately converted to **fossil fuels** (i.e. coal, petroleum, and natural gas). So when you fill your car up at the gas station, you are actually putting ancient plant life into your vehicle. When you drive off, the fuel is burned, and the ancient carbon is released into the environment in the form of carbon dioxide.

There are two concerns with fossil fuels. One is that the carbon dioxide released is a greenhouse gas and the other is that it is considered a finite resource. A natural resource is considered a **renewable resource** if the nature can reproduce it within a human lifetime. Energy sources such as solar energy, wind power, and geothermal are considered renewable energy sources. Fossil fuels are not considered renewable because it requires millions of years for the earth to replenish them. Ultimately humans will run out of fossil fuels, but the question is when. At current rates of consumption, the world has well over 200 years of coal, but with petroleum the question becomes more complicated. Currently there are over a trillion barrels of petroleum, called **proven reserves**, that we are aware of with current technology. **Potential reserves** are resources of petroleum not discovered yet by society. Currently there is a lot of concern about how many reserves of petroleum are left to discover. Technology today is allowing industry to discover reserves deeper than ever before and tap into petroleum reserves in ways never allowed before.



UNEVEN DISTRIBUTION OF FOSSIL FUELS

Another global problem in terms of fossil fuels is that it is not found uniformly around the planet. Coal forms in tropical regions where there are lots of vegetation and swamps. As the vegetation falls into oxygen poor water, it is converted into a carbon-based rock over geologic time. Because of plate tectonics, the slow movement of continents around the planet, most of the mid-latitude countries such as China, Russia, and the United States were located near the equator 250 million years ago. Today these countries have abundant amounts of coal. Petroleum and natural gas forms on the ocean floor under high pressure from overlying water and sediment. Some of these areas are still under water such as in the Persian Gulf and Gulf of Mexico. Other regions are no longer underwater such as the Middle East. Most of the world's sources of fossil fuels exist in more developed countries, which has greatly helped in their development.

Today the United States and China are the largest consumers of fossil fuels on the planet. Yet in the 21st century, the demand for coal, petroleum, and natural gas will shift to less developed nations as they move through the demographic transition model. The majority of the world's petroleum prices is determined by As noted earlier, mid-latitude countries such as the United States, Russia, and China have the largest supply of coal. In terms of petroleum, the mission of the Organization of Petroleum Exporting Countries (OPEC) "is to coordinate and unify the petroleum policies of its Member Countries and ensure the stabilization of oil markets in order to secure an efficient, economic and regular supply of petroleum to consumers, a steady income to producers and a fair return on capital for those investing in the petroleum industry." OPEC formed in 1960. Some of you might have also heard about the energy crisis of the 1970s. This occurred when Arab countries of OPEC were angered by the Europe and the United States' support over Israel during the 1973 war with Egypt, Jordan, and Syria. The Arab OPEC members refused to supply oil to the United States, which immediately created a fuel shortage. During the 1980s and 1990s, prices of oil dropped dramatically stimulating global economies all around the world. After the fall of the Soviet Union, Russia struggled to survive as a modern society. But starting in the late 1990s, Russia began exporting its petroleum and coal resources and its political, economic, and military power grew substantially. Cheap fuel in the United States spurred the automotive industry to build large SUVs with low miles-per-gallon. But the mid-2000s saw a sharp increase in fuel prices with record prices occurring in the summer of 2008. Following the summer of 2008, SUV sales plummeted risking the possibility of Ford and GM becoming extinct.

NONRENEWABLE SUBSTITUTES FOR PETROLEUM



With the increased cost of oil the last few years, there has been a desire to find alternatives. There has been a sharp increase natural gas vehicles because natural gas is cheaper and pollutes less than oil. But basic economics of supply and demand state that as natural gas is used more (demand), cost is likely to follow. Since the world has plenty of coal to last hundreds of years, some have pushed more coal burning. But there are several environmental concerns with coal. First, coal is the “dirtiest” fossil fuel in terms of air pollution. Burning coal releases vast amounts of sulfur and mercury. Sulfur combustion creates acid rain and mercury damages our neurological system. Coal combustion also releases the largest amount of carbon dioxide which is a greenhouse gas. With the current concern with global warming, there has been a lot of talk about carbon sequestration. The goal of carbon sequestration is to capture the carbon dioxide before it is released, then “lock” it deep within the earth and thus prevent it from contributing to global warming. But the technology is far from proven.

A third source of nonrenewable energy is nuclear. Since Chernobyl in 1986 in the former Soviet Union and the Three-Mile Island incident in the United States, our country has been very apprehensive in creating new nuclear power plants. The benefit of nuclear power is that incredible amounts of energy can be generated without polluting the atmosphere. But there are serious concerns about potential accidents and the radioactive waste it generates. There has been recent heated debate in the West as to where to store radioactive waste. In Utah, there has been talk of storing nuclear waste at the Goshute Indian Reservation as a short-term stop to Yucca Mountain in Nevada. But many in Utah believe that nuclear waste, which takes tens of thousands of years to decompose, in Utah will never leave even though we don’t have a nuclear **power plant**. In Nevada, there is concern about the actual safely of storing nuclear waste in a mountain with nearby fault lines. And after the September 11 terrorist attacks, there is renewed interest of nuclear power plants becoming targets.

NATURAL SUBSTITUTES FOR PETROLEUM

 Since the Industrial Revolution began roughly 150 years ago, societies have shifted from wood which concentrates solar energy over a period of decades to perhaps centuries, to coal and petroleum which in turn concentrate that solar energy still further and additionally represent stored tectonic energy and gravity. Overall, society tends to shift to more and more concentrated forms of energy. Nuclear energy is the most concentrated form of energy that we have harnessed so far. All of these fuels have other environmental drawbacks, the most urgent being carbon dioxide and global warming. Several other substitutes for petroleum exist, including hydropower, wind, and geothermal. These are discussed below.

ENVIRONMENTAL POLLUTION

Pollution of the environment occurs when humans contaminate the air, water, or land. Pollution can also be broken down into two categories: primary and secondary. Primary pollution is when humans directly contaminate the earth in some manner. Examples include mercury, sulfur, and even carbon dioxide. Secondary pollution happens when a primary pollutant reacts with another primary pollutant, sunlight, and/or water to create a different pollutant. An example is acid rain. Sulfur dioxide is a primary pollutant, but when it reacts with precipitation is becomes a secondary pollutant called acid rain. One of the biggest problems with pollution is that those who pollute are usually not the ones affected by it; rather the down-winders are.

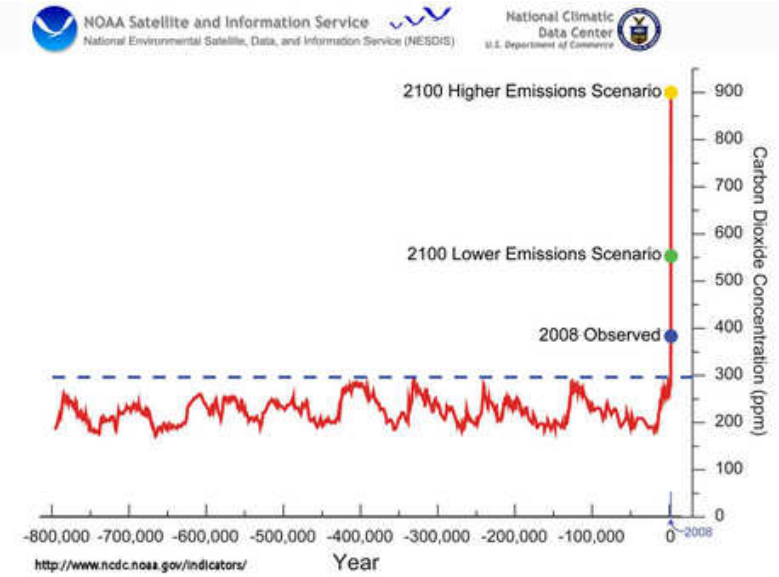


AIR POLLUTION

The atmosphere is mostly made of 78 percent nitrogen, 21 percent oxygen, and small percent's of other trace molecules such as ozone, carbon dioxide, water vapor, and aerosols. Air pollution occurs when humans add unnatural substances into the

atmosphere. Most of the air pollution from industry comes from coal while automotive pollute vast amounts of ozone, carbon dioxide, and sulfur into the atmosphere. But in the 1970s the United States created the Clean Air Act, which has greatly enhanced the quality of our nation's air. Check out this video from National Geographic on the world's air quality.

Those who pollute are usually not the ones affected by it. The location of impact is often different from the location of creation. Industrialization in eastern North American and eastern Europe have generated large-scale pollutants such as sulfur oxides and nitrogen oxides through the burning of fossil fuels. When these pollutants react with water, they form **acid precipitation**. Acid precipitation can cause large-scale damage to aquatic life and forests by making the vegetation very sick and dying. In forests, this can lead to disease through pest infestation. Acid precipitation can also damage or destroy buildings and monuments made out of marble such as tombstones.

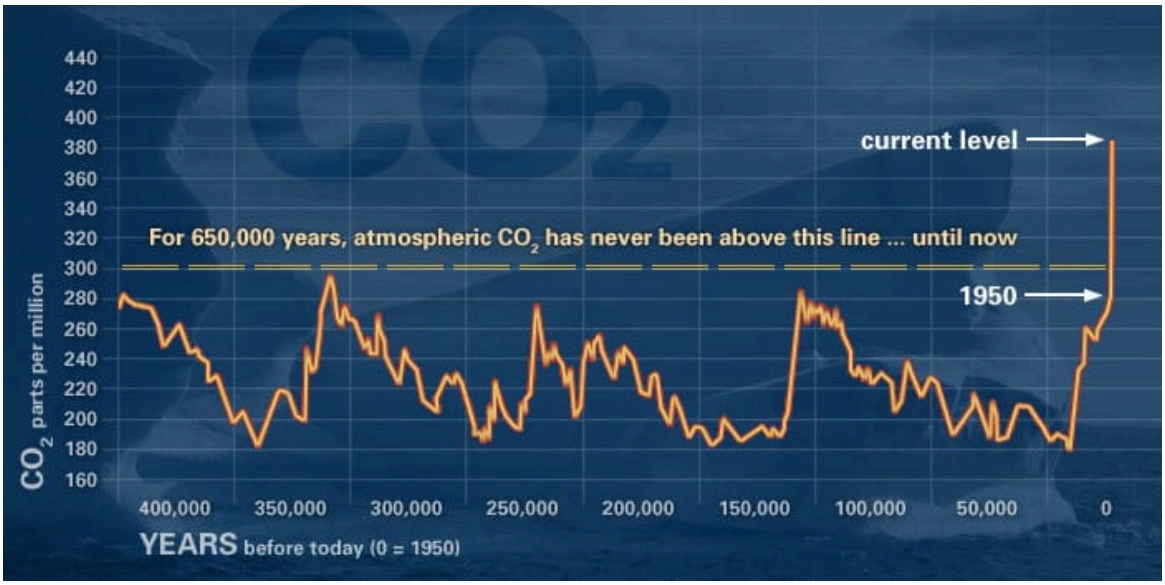


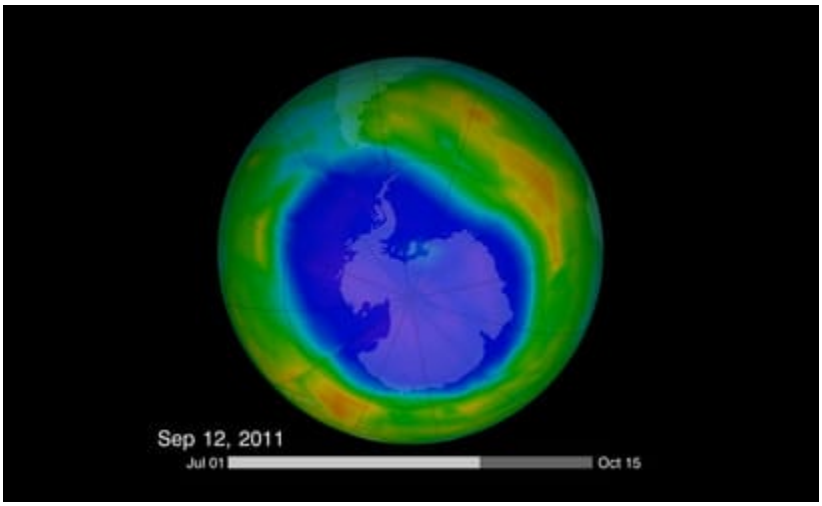
ANTHROPOGENIC CLIMATE CHANGE

This is a very complicated issue to discuss in this short section, but here we go. In the scientific community, there is very little discussion if **anthropogenic climate change**, also called **global warming**, is happening or if it's human induced. What scientists are now focusing on are what the possible effects might be. The earth has gone through dramatic climatic changes from temperatures much warmer today to ice ages. There are several reasons for climatic shifts, but they include changes in earth's orbit and tilt around the sun and the movement of continents. Recently scientists have stated that the planet is beginning to warm up because of the greenhouse gases humans are emitting into the atmosphere. We know that carbon dioxide is a greenhouse gas, and we are quite grateful for the greenhouse effect. Without the greenhouse effect, humans could not live on this planet.

The basic idea with the greenhouse effect is that the earth absorbs energy coming from the sun. When the earth tries to re-radiate this energy back into space, specific gases can actually trap the heat in our atmosphere. Scientists are stating, with empirical data backing their claims, that by adding more greenhouse gasses such as carbon dioxide into the atmosphere the earth has the ability to absorb more outgoing energy, which will make the planet get warmer. What scientists now know is that there is more carbon dioxide in the atmosphere today than in the last 1,000,000 years and by 2100 there will be more carbon dioxide than there has been in the last 65 million years.

To learn more about climate change, check out NOAA's National Climate Data Center.





OZONE HOLE

In the 1920s, humans developed a chemical called chlorofluorocarbons (CFCs) for things such as refrigerating and air conditioners. In the 1970s, two American scientists discovered that these CFCs were breaking down atmospheric ozone and creating a hole in the ozone layer over Antarctica. When the CFCs reach the ozone layer, ultraviolet radiation from the sun breaks the chlorine off of the CFC. That free chloride ion can chemically react with, and destroy, over 100,000 ozone molecules and continue in the upper atmosphere for over 100 years. Ozone blocks shortwave UV light coming from the sun and protects the earth's surface from this high energy radiation. The destruction of the ozone is bad for the health of humans and other life forms.

Over time and much debate, the world got together and signed the Montreal Protocol in 1987 to phase out CFCs. Today, most industrialized countries have eliminated the use of CFCs, but the ozone hole is not expected to heal for another 50-100 years. Learn more about what's currently going on with the ozone hole at NASA's Ozone Hole Watch.



WATER AND LAND POLLUTION

Water is the most valuable resource on the planet, but humans keep polluting it in various ways. Manufactures use water to create and process food. Vast amounts of water is polluted by farmers through fertilizer and waste from pigs and cows in unhealthy feed lots. Where does the water go when you pour it down the gutter? Most of the time into a river or ditch. So when you wash your car in the driveway, you are polluting your local water.

Water pollution can greatly harm aquatic life in rivers, lakes, and the ocean. Many of the fertilizers in farmers and the cleaners we use can create algae blooms in our local rivers. When the algae dies, it can also remove the oxygen from the water which can kill fish and other aquatic life. These are called dead zones and one of the biggest in the world is forming in the Gulf of Mexico because of the pollution in the Mississippi River. Just like our air, the nation's water has greatly improved since the 1970s because of the Clean Water Act.

The country has seen a dramatic increase in recycling because of the interest of solid waste disposal and that our landfills are filling up. Not only is there concern for our national landfill waste, but how chemicals are seeping from our landfills are also polluting our groundwater.

RENEWABLE RESOURCES

Humans cannot sustain the path we've been taking with our consumption of resources and global population expected to peak at 9 billion by 2050. We need to learn how to live differently without decreasing our quality of life. One such possibility is to move towards a renewable energy economy. The following are the diverse types of renewable energy.



BIOMASS

Biomass is when humans burn vegetation as a fuel source. Many argue that this not a viable option for human energy consumption. Burning biomass releases large amounts of carbon dioxide into the atmosphere and requires the destruction of ecosystems such as deforestation. There has also been a recent push for ethanol as a “green” source of energy. In the United States, corn has been used and subsidized to make ethanol. The effects have been a spiraling rising in the cost of corn-based food. Plus many would argue that humans should not be using food for fuel when humans are now consuming more food than we are producing. In Brazil, they are using sugarcane to produce ethanol. Because there is a lot of money to be made in the ethanol industry, Brazil is cutting down the Amazon rainforest to produce more sugarcane for their energy economy. So it can be argued that ethanol is not really a “green” energy if it requires deforesting the rain forests along with causing food prices to rise.



HYDROELECTRIC POWER

Hydroelectric power is also questionable as an energy source even though it is renewable. Hydroelectric power requires dams being built in order for flowing water to turn turbines within the dam to generate electricity. Their are numerous problems with power coming from hydroelectric dams. It requires flooding usable and often time fertile land to create a lake. Over time, the lake can fill up as sediment gets deposited into the lake. Dams can also harm aquatic wildlife such as salmon because the prevent them from returning to their spawning locations. In fact, many northwestern states in American have dismantled damns because salmon are near extinction. But it must be said that it is “clean” energy in that hydroelectric power does not pollute the air or water.



WIND POWER AND GEOTHERMAL ENERGY

Windmills have been around for hundreds of years, but only recently have they been used to generate electricity. Until last year, wind power was the fastest growing energy source in the world. And with the rising costs of fossil fuels, wind power is now cheaper to produce than energy from fossil fuels. Farmers are getting onboard with wind power because power companies will rent space to place the windmills, which will provide a steady income for the farmer. But the farmer can still grow their crops or have their cattle and maintain their way of life. Energy created by wind is similar to dams because the wind turns the blades, which turns a turbine within the windmill to generate electricity.

There are a few concerns with wind power though. Some do not like how windmills look because they require being out in the open; whereas coal power plants are easier to hide behind mountains. There is also concern that windmills, can harm migratory birds and bats. But wildlife is more likely to be hurt by changing climates than by small-scale windmills. Now out in Europe, they have been real serious about wind power. Some of the windmills along the continental shelf – where the winds are steadily consistent – have windmills so large you can land a helicopter on them. They are so large that each blade is over 300 feet long (said another way, each blade is taller than the Statue of Liberty). The United States is still far behind other countries in Europe, but that is starting to change. It is now possible to purchase wind power from various energy companies. The largest wind power program in the United States is called the Blue Skies Program by Rocky Mountain Power.

The Earth's interior is still extremely hot because of Earth's formation. A new technique being implemented is to use water and the internal heat the earth to produce steam, which can turn turbines to generate electricity. It requires using existing ground water or actually pumping ground water into the earth so the heat can evaporate the water into steam and turn a turbine. The image below is a geothermal plant in Iceland where they plan to use the heat from their volcano (Iceland is a volcanic island) to power their entire country.

SOLAR POWER



With the sun still having 5 billion years of life in it, our star is the ultimate renewable energy source. There is actually two types of solar energy: passive and active. Passive solar energy requires no special devices, rather south-facing windows and dark surfaces to light and heat buildings. This is a very inexpensive alternative, and it is surprising that it is not used more often. Active solar energy captures heat and generates electricity by using photovoltaic cells with solar panels. The panel's cells are made from silicon which is the second most abundant mineral on Earth's crust and when combined with other materials become sensitive to sunlight – called the photovoltaic effect. The electrons within the cells move through the silicon and produce an electrical current. In 2008 solar panels surpassed windmills as the fastest growing energy source in the world.

As you probably noticed with the different types of renewable energy, most require turning a turbine to generate electricity. Renewable energy is being used to supply electricity into the grid system for all the appliances that require electricity. Another use of renewable energy is for water heaters which require vast amounts of energy. In less developed nations, renewable energy such as solar panels is being used to provide electricity to people who are not connected to a grid system. There is also a new movement to include solar panels to the tops of hybrids and electric cars. In 2009, the new Toyota Prius will have an upgrade option to have solar panels on the top to charge the battery.



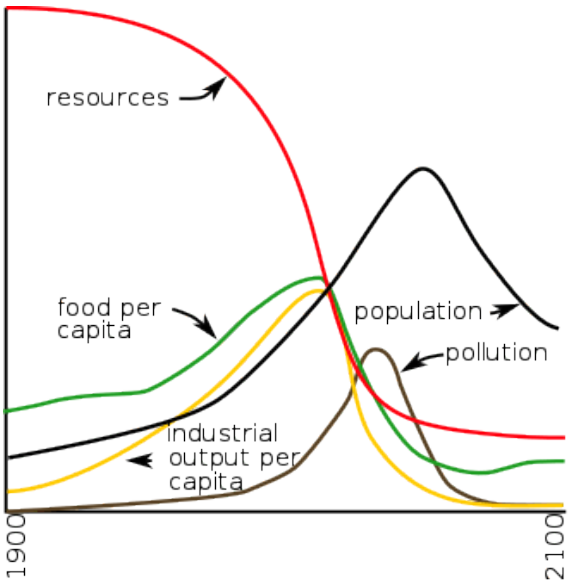
RECYCLING

There has also been a steady demand to recycle rather than through products into our landfills. But recycling is not only about saving landfill space, it's about water, natural resources and energy. It requires a lot less energy, water, and resources from the earth to re-create something than to mine and process the raw material. Take a soda can. How long do you keep a soda can once you open it? Did you know that it may take up to three years for the material to be mined from the mountain, processed, shipped, filled with soda, and shipped to you? That is a lot of power, yet if you recycle products then there is more savings than just landfill space.

There is now a variety of ways someone can recycle. Many cities around the nation have curb-side recycling much like your garbage cans. There are also several drop-off sites, which are often found at retail and grocery stores. Buy-back centers are commercial businesses that purchase your recyclable goods. But it is important to note that what you can recycle for each can vary – so don't think you can dump anything you want into a recycling can just because you see one.

So once you recycle something, where does it go? There are four major manufacturing sectors that account for over half of the world's recycled products – paper mills, plastic converters, steel mills, and iron factories. The easiest items to make from recycled material is newspaper, paper towels, aluminum cans, steel, and glass. The problem with recycling comes with plastics because there are so many different types, and they can't be mixed in the recycling process. Many of you are aware that, at the bottom of plastic containers, there is a number from 1-7; these are different types of plastics. But you cannot recycle plastics of various types; they must be sorted out. If a #5 is mixed within a batch of #2 plastics, the entire batch is ruined. So make sure you are conscious of what you are doing when you recycle. Now some recycling companies have the ability to sort through the different types of plastics; so check with your recycling company if you are not sure which plastics you can recycle.

As the global population increases and we try to improve standards of living by increasing our consumption of resources, we will create waste and pollution. In "Limits to Growth", MIT researchers explain these factors may lead to collapse. However, they also acknowledged the human capacity for logical change and adaptation. This chapter focused on energy sources, but there are other resources, such as minerals, that can limit human growth.



Limits to Growth

SUMMARY

This chapter focused on the human-environment connection. More specifically, it looks module will look at the direct impacts humans have on the planet. I have always believed that the greatest strength of geography is its ability to analyze the interconnection between humans and the planet. Recently humans have reached a critical point on the planet where we are consuming more natural resources than is sustainable on the planet.

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2.2: Population and Migration

Learning Objectives

- Understand the basics of global population distribution.
- Understand population trends and how those impact population growth and dynamics.
- Recognize population change, where those changes occur, and what the implications of population change are for the future of different places around the globe.
- Compare population rates and food production to determine if their is a possible global food shortage or not.
- Demonstrate how the movement of population is affected by both push and pull factors, and explain how these factors are key to understanding new settlement patterns.

Introduction

The purpose of this chapter is to introduce students to the population distribution and growth issues. Geographers study where and why people live in particular locations. Neither people nor resources are distributed uniformly across Earth. In regards to population growth, geographers emphasize three elements: the population size; the rate of increase of world population; the unequal distribution of population growth. Geographers seek to explain why these patterns exist.

The subject of overpopulation can be highly divisive given the deep personal views that many hold on abortion. This course emphasizes a geographic perspective on population growth as a relative concept. Population, from a geography perspective, should be viewed in the context of the availability of resources. Human-environment interaction and overpopulation can be discussed in the contexts of carrying capacity, as well as the relationship between people and resources.

The study of population has never been more important than it is today. There are over 7 billion people on the planet, but the majority of this growth has occurred in the last 100 years, mostly in developing nations. Humans do not live uniformly around the planet, but rather in clusters because of earth's physical geography. Environments that are too dry, wet, cold, or mountainous create a variety of limiting factors to humans. Two-thirds of the world's population is located within four major clusters: East Asia (China), South Asia (India and Indonesia), Southeast Asia, and Europe, with the majority in East and South Asia.

Demographers, scientists that study population issues, and other scientists say there is more to the story than simple population growth. Ecologists believe that humans have out-grown the Earth's **carrying capacity**, which is a scientific way of saying that the planet can no longer sustain or support human activity. Simply put, there is just not enough of the world's resources to give every human a standard of living expected by most Americans. If fact, if all 7 billion people on the planet lived the average American lifestyle, it would require over three Earth's. This raises several issues: that the planet cannot sustain a population of 7 billion, though we are expected to reach 9 billion by 2100, and that the planet cannot sustain Western lifestyles for the entire planet.

Some useful websites

- World Population Review
- US Census: Data & Maps
- World Bank Open Data

Distribution of the World's Population

Economist Jeffrey Sachs, the former head of the United Nations Millennium Project, believes that there are two reasons why global population and extreme poverty occur where they do: 1) capitalism distributes wealth to nations better than socialism or communism; 2) geography is a major factor in population distribution in relationship to wealth. For example, population tends to be lower in extreme environments such as arid climates, rainforests, polar or mountainous regions. Another example is a nation that has a large body of water within its borders, or has large minerals deposits/resources is likely to have more wealth and population. Humans only occupy five percent of the Earth's surface because oceans, deserts, rainforests, and glaciers cover

much of the planet. The term for areas where humans permanently settle is called **ecumene** . Population growth and technology dramatically increase the ecumene of humans, which affects the world's ecosystems.

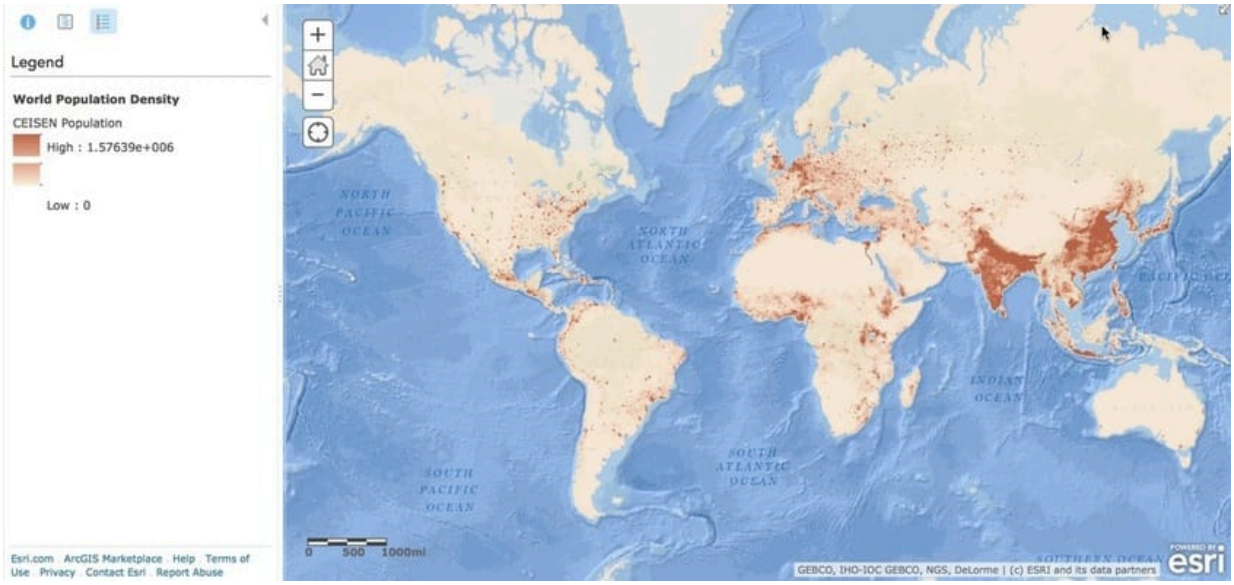
It has been argued that the world can't support all the humans on the planet. On some level that's true and on another it is not. For example, we could actually pack all 7 billion humans in California, but that's not desirable, sanitary, or sustainable. The reality is that humans cannot live in many parts of the world due to moisture, temperature, or growing season issues. For example, 20 percent of the world is too dry to support humans. This mostly has to do with high pressure systems around 30 degrees north and south of the equator where constant sunny conditions have created some of the world's largest deserts. Some of these include the Sahara, Arabian Peninsula, Thar, Takla Makan, and Gobi deserts. Most deserts do not provide enough moisture to support agriculture for large populations. Those who do live in these regions tend to raise animals and are considered **nomads**.

Regions that receive too much moisture also cause problems for human settlement. These are tropical rainforest regions located between the Tropic of Cancer (23.5 degrees North) and the Tropic of Capricorn (23.5 degrees South). The problem with these regions of the world has to do with the soil erosion due to high precipitation. High levels of precipitation greatly hinder agricultural production because nutrients in the soil are quickly washed away. This is partly why slash-and-burn agriculture occurs in these regions. Locals will burn part of the forest to put nutrients back into the ground. This only works for a short period of time because the precipitation washes away nutrients within a few years, so farmers move on to other parts of the forest with their slash-and-burn practices.

Additionally, regions that are too cold pose problems for large population clusters and food production. The cold polar regions have a short growing season and many of the polar regions have limited amounts of moisture because they are covered by high pressure systems (much like the desert regions). Thus, cold polar regions are not only limited by temperature, they are also limited by lack of moisture despite access to snow, ice, and glaciers. Mountainous and highland regions lack population clusters for similar reasons: steep slopes, snow and ice cover, and short growing seasons.

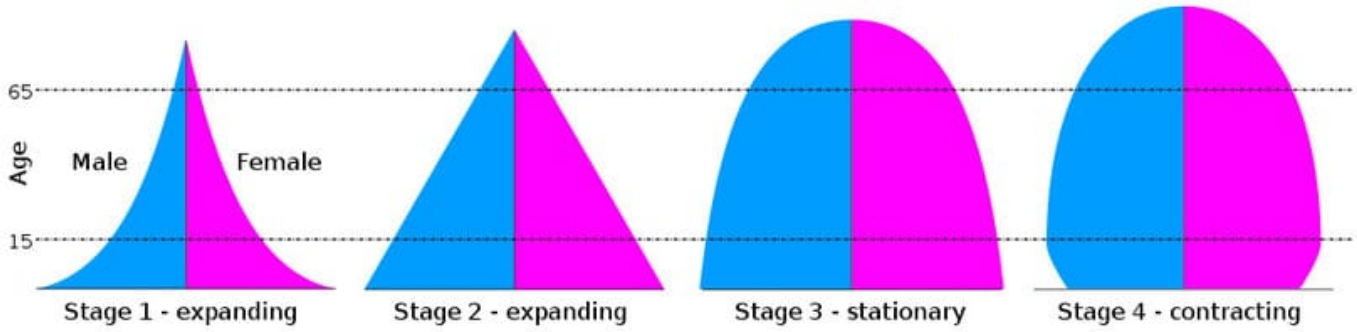
Population Profiles

Demographers use various ways to measure and analyze population density. The **arithmetic density**, also called **population density**, of a population is the total number of people in proportion to the area of land (land size). But that's not the best indicator of population density because there are many environments humans can't live well in (i.e. deserts, arctic, tropical forests, etc.). Plus it doesn't consider if the ground is usable for producing food. The physiological density of a population is the total population in proportion to the area of arable land suited for agriculture. Even more specifically, **agricultural density** refers to the amount of farmers valuable to arable land. A high agricultural density suggests that the available agricultural land used for farming and the farmers who are capable of producing and harvesting food is reaching its limit for that region. If the demand for food continues or rises, the risk is that there will not be enough arable land to feed their people. In contrast, an area with a low agricultural density actually has a higher potential for agricultural production. Economically, a low agricultural density would be favorable for future growth.



Population Pyramids

A useful and key tool used by scientists that focus on demographics, this included geographers, demographers, and social scientists, is a **population profile** (also called a **population pyramid**). A population profile visually demonstrates a particular region's demographic structure in relation to males and females, and is often expressed in numbers or percentages.



The following are some characteristics of population profiles:

- A bell-shaped graph will indicate that a country has experienced high population growth in the early past but is experiencing a slow decrease.
- Narrow triangles show countries with high population growth.
- As a country's population boom begins to age, a strange profile shape can develop with a wider top and a narrower base.
- Populations that have stabilized have profiles where the bulge is of past high birth rates migrates to older populations moderately and not quickly, while the base has a moderately smaller but not dramatic base.
- When a country has a large immigrant population, specifically "guest workers" than usually tend to be men, the male side of the graph will be dramatically wider than the women side of the graph.
- If a country has experienced war, a catastrophic disaster, or a genocide that eliminates an entire generation, that generation will have a smaller number or percent than the generations before or after. For example, a major war may cause a reduction in populations in their mid-20s and 30s, which would appear on the profile graph.

Click here for a great, interactive website on population pyramids around the world.

Global Population Trends



Crude Birth Rate



Crude Death Rate



Fertility Rate

A region's population will grow as long as their crude birth rates are greater than their crude death rates.

A **crude birth rate** (CBR) is the total number of live births for every 1,000 people in a given year. So a crude birth rate of 10 would mean 10 babies are born every year for every 1,000 people in that region.

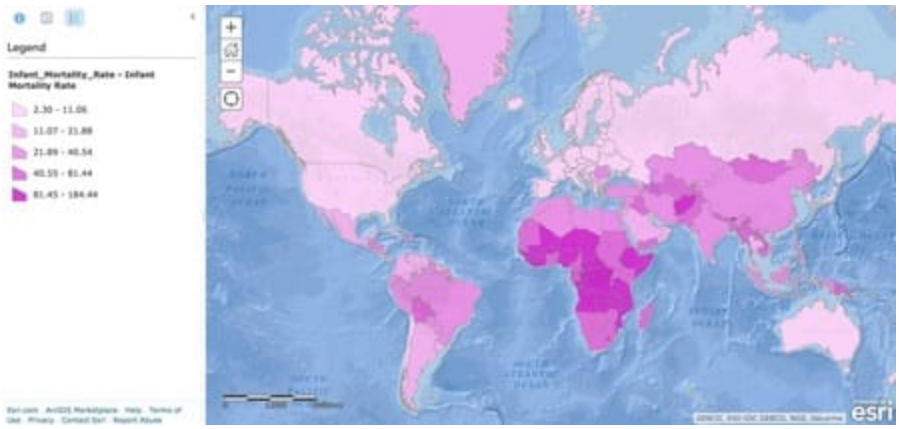
Crude death rates (CDR) are the total number of deaths per 1,000 people in a given year. *Click on the sequence of maps above to make them bigger to view.* When CBRs are compared to CDRs, a region's natural increase rate can be determined.

A **natural increase rate** (NIR) is the percent a population will grow per year, excluding annual migration. Usually a NIR of 2.1 is required to maintain or stabilize a region's population. Any more than that and the population will grow, any less than an NIR of 2.1 causes population contraction. The reason why the NIR percent is 2.1 and not 2.0 for stability is because not every human will pair up and have a child because of genetics, choice, or death before child bearing years. Once we know the NIR, we can determine doubling time.

Doubling time is the how may years would it take for a defined population to double in size, assuming that NIR stays the same over time. Currently about 82 million people are added to world's global population every year.

STRUCTURAL CHANGES OF POPULATIONS

Before we look at the model used to analyze how populations change, it's important to look at key factors that influence the structure of a population The first is called the **total fertility rate** (TFR). The TFR is the average number of children a woman would be expected to have during childbearing years (between 15-49 years old). The global average for TFRs is about 2.5, but in less developed countries it's as high as 5.0 or higher and in more developed countries it's as low as 2.0 or less. The total fertility rate is a direct expression of a nation's health care system because it reflects a population's access to doctors, nurses, hospitals, and medicine.



Infant Mortality Rate

The next important term to understand is the **infant mortality rat**e (IMR). The IMR is determined by calculating how many children die before the age of 1 per 1,000 live births annually. The highest IMRs are in less developed countries where rates can be as high as 80 or more. Conversely, in place like Europe it's as low as 5.

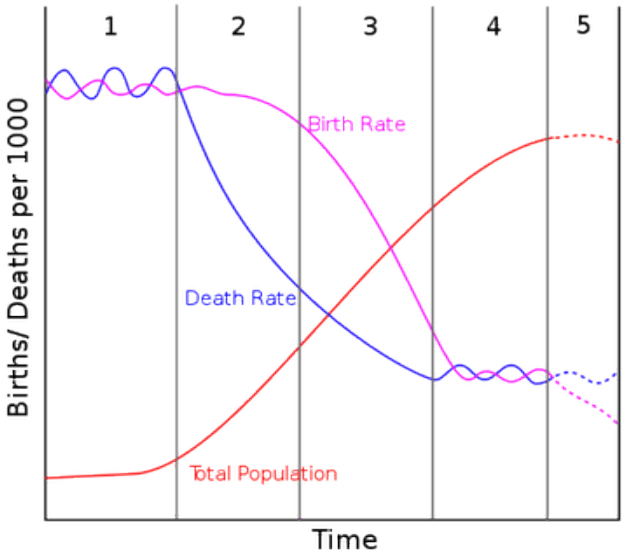


Life Expectancy

Life expectancy at birth is pretty straight forward—it's an average of how many years a newborn is expected to live, assuming that mortality rates stay consistent. In more developed countries, the average life expectancy is over 80 years old and in less developed countries it is only around 40 years. When we compare CBRs, CDRs, and TFRs, we find that the world has a large population of youth with the largest percent in less developed countries. This causes great stress on the education systems and to some extent the health care systems within poorer countries. But more developed countries tend to have older demographics, which tends to cause stresses on the health care and social safety nets of those countries. The **dependency ratio, discussed later in this chapter,** is used to understand these stresses and is the number of people who are too young or too old to work compared to the number of people who are in their "productive years." The larger the ratio, the greater the economic stress on those nations.

Demographic Transition Model

Human geographers have determined that all nations go through a four-stage process called the **demographic transition model** (DTM). The DTM's function is to demonstrate the natural sequence of population change over time based on development and modernization. This can help geographers and other scientists examine the causes and consequences of fertility, mortality, and natural increase rates. Though controversial, the DTM has been used as the benchmark for forecasting human population growth regionally and globally.



The Demographic Transition Model

STAGE 1: LOW GROWTH RATE

We have lived in the first stage of the DTM for most of human existence. In this first stage, CBRs and CDRs fluctuated greatly regionally, globally, and over time because of living conditions, food output, environmental conditions, war, and disease. But ultimately, the natural increase of the world was pretty stable because CBRs and CDRs where about equal. But around 8,000 BC, the world's population began to grow dramatically due to the **agricultural revolution**. During this time, humans learn to domesticate plants and animals for personal use and became less reliant on hunting and gathering for sustenance. This allowed for more stable food production and allowed village populations to grow. Yet, war and disease prevented population growth to truly occur on a global scale.

STAGE 2: HIGH GROWTH RATE

Around the mid-1700s, global populations began to grow 10 times faster than in the past for two reasons: the **Industrial Revolution** and increased wealth. The Industrial Revolution brought with it a variety of technological improvements in agricultural production and food supply. Increased wealth in Europe, and later North America, because of the Industrial Revolution meant that more money and resources could be devoted to medicine, medical technology, water sanitation, and personal hygiene. Sewer systems were installed in cities, thus public health improved. All of this dramatically caused CDRs to drop around the world. At first, CBRs stayed high as CDRs dropped, this caused populations to increase in Europe and North America. Over time, this would change.

Africa, Asia, and Latin America moved into Stage 2 of the demographic transition model 200 years later for different reasons than their European and North American counterparts. The medicine created in Europe and North America was brought into these less developed nations creating what is now called the **medical revolution**. This revolution, or diffusion of medicine to this region caused death rates to drop quickly. While the medical revolution reduced death rates, it did not bring with it the wealth and improved living conditions, and development that the Industrial Revolution created. Global population growth is greatest in the regions that are still in Stage 2.

STAGE 3: MODERATE GROWTH RATE

Today, Europe and North America have moved to Stage 3 of the demographic transition model. A nation moves from Stage 2 to Stage 3 when CBRs begin to drop while CDRs remain low or even continue to fall. It should be noted that the natural rate of increase in nations within Stage 3 is moderate because CBRs are somewhat higher than CDRs. The United Sates, Canada, and nations in Europe entered this stage in the early 20th Century. Latin American nations entered this stage later in the century.Advances in technology and medicine cause decreases in IMR and overall CDR during Stage 2. Social and economic changes bring about a decrease in CBR during Stage 3. Nations that begin to acquire wealth tend to have fewer children as they move away from rural-based development structures toward urban-based structures because more children survive childhood

and the need for large families for agricultural work decreases. Additionally, women gain more legal rights and chose to enter the workforce, own property, and have fewer children as nations move into Stage 3.

STAGE 4: LOW GROWTH RATE

A nation enters Stage 4 of the demographic transition model when CBRs equal to or become less than CDRs. When CBRs are equal to CDRs, a nation will experience **zero population growth (ZPG)**. NOTE: Sometimes a nation could have a slightly higher CBR, but still experience ZPG. This occurs in many countries where girls do not live as long before they reach their childbearing years due to **gender inequality**. When a country enters Stage 4, the population ages meanwhile fewer children are born. This creates a great strain on the social safety net programs of a country as is tries to support older citizens who are no longer working and contributing to the economy. Most of Europe has entered Stage 4. The United States would be approaching this stage if it weren't for migration into the country. A nation in the first two stages of the transition model will have a large base of young people and smaller proportion of older people. A nation in the Stage 4 will have a much smaller base of young people (less children), but a much larger population of elderly (decreased CDR). A nation with a large youth population is more likely to be rural with high birthrates and possibly high death rates. This can tell geographers a lot about the health care system of that nation. Moreover, a nation in Stage 4 with a large elderly population will have much fewer young people supporting the economy. These two examples represent the **dependency ratio**, mentioned earlier in this chapter. This ratio is the number of people – young and old – who are dependent on the working force.

Human geographers like to focus on the following demographic groups: 0-14 years old, 15-64 years old, and 65 and older. Individuals who are 0-14 and over 65 are considered dependents (though this is changing in older generations). One third of all young people live in **less developed nations** (LDN). and this places great strain on those nations infrastructure such as schools, hospitals, and day-care. Older individuals in **more developed nations** (MDL) benefit from health care services, but require more help and resources from the government and economy. Another ratio geographers look at is the number of males compared to females. This is called the **sex ratio** . Globally, more males are born than females but males have a higher death rate than females. But understanding a nation's sex ratio and their dependency ratio helps human geographers analyze fertility rates and natural increase.

As noted earlier, population growth has increased dramatically in the last century. No country is still in Stage 1 and very few have moved in to Stage 4. The majority of the world is either in Stage 2 or 3 which both have higher CBRs than CDRs. This is why the world's population is over 7 billion today.In summary, the demographic transition model is a model that helps human geographers understand and predict the demographics of individual nations. In Stage 1, CBR and CDR are very high and thus produce a low natural increase. In Stage 2, a nation's CBR stays relatively high but the CDR drops dramatically, producing the highest growth in population. In Stage 3, CDR stays low; however, changes in social customs and economic conditions. Finally, nations in Stage 4 have nearly equal CBR and CDR (sometimes higher CDR), creating a drop in natural increase.

Human Overpopulation

OVERPOPULATION CONCERNS

In 1798, Thomas Malthus published a short but revolutionary work called "An Essay on the Principle of Population." Malthus states that future population growth would be determined by two facts and one opinion. The facts were that food is necessary for survival and that men and women would continue to have sex, thus producing offspring. His opinion is that if population is not restrained by war, famine, and/or disease, population growth would occur exponentially. An example of exponential growth is 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024 and so on. He also argues that agricultural production of food could only grow arithmetically. An example of arithmetic growth is 1, 2, 3, 4, 5, 6, 7 and so on.

The overall assumption is that population growth will quickly grow beyond food production leading to food shortages and famines. Malthus' theory has not come to fruition, yet, due to technological advances in agriculture (fertilizers, insect and drought resistance and better farming techniques). Some discredit Malthus because his hypothesis is based on a world supply of resources being fixed rather than expanding. Humans have the ability to expand the supply of food and other resources by using new technologies to offset scarcity of minerals and arable land. Thus, we can use resources more efficiently and substitute new resources with scarce ones. Even with a global human population of 7 billion, food production has grown faster than the global rate of increase (NIR). Better growing techniques, higher-yielding and genetically modified seeds, as well as cultivation of more land have helped expand food supplies.

While new technologies have helped to increase food production, there are not enough emerging technologies to handle supply

and demand. Adding to the problem is the fact that many insects have developed a resistance to pesticides. These problems have cause a slow down and leveling off of food production in many regions of the world. Without breakthroughs in safe and sustainable food production, food supply will not keep up with population growth. Others believe that population growth isn't a bad thing. A large population could stimulate economic growth, and therefore, production of food. Population growth could generate more customers and more ideas for improving technology. Additionally, some maintain that no cause-and-effect relationship exists between population growth and economic development. They argue that poverty, hunger, and other social welfare problems associated with lack of economic development, famines, and war are a result of unjust social and economic institutions, not population growth.

In the last few decades, there has been a rise in neo-Malthusians (new or recent supports of Malthus). One notable figure is Paul Ehrlich. In his very popular book, *The Population Bomb,* Ehrlich argues that population growth cannot continue without controls because the planet will reach the carrying capacity of our species. In short, we must consider environmental factors as we discuss overpopulation concerns. For example, even though humans produce four times the amount of food that we consume, we produce our food at the price of the environment. The rapid population growth of the world has caused massive deforestation in the Boreal Forests and rainforests, increasing desertification that encroaches into arable land, over-fishing of the oceans, mass extinction of species, air and water pollution, and anthropogenic (human-induced) climate change. All of these things have economic and environmental costs that we must consider.

FUTURE OF POPULATION GROWTH

Governments and other entities have the ability to dramatically influence population change as a way to increase or decrease population growth in a particular country. For example, some countries take dramatic steps to reduce their population. China's **One-Child Policy** dictated that each family (husband and wife) could legally have only one child. Families that followed this policy were often times given more money by the government or better housing. If a family illegally had another child, the family would be fined heavily. Children born illegally can not attend school and have a difficult time finding jobs, getting government licenses, or even getting married. Some have reported that the government would force abortions on families with more than one child. One of the major consequences of this policy was a dramatic increase in abortions and infanticides, especially of females. Female infanticide is linked directly to a global cultural trend that privileges males over females—baby boys are desired, especially if the family is only allowed one child. This specific focus on eliminating women is called **gendercide**. *Half the Sky*, written by Nicholas Kristof and Sheryl WuDunn, documents global gendercide and what is being done to combat this problem. After the two great world wars, the **United Nations Population Commission** and the **International Planned Parenthood Federation** began to advocate for more global population control. Many groups who advocate for population control focus on:

- Changing cultural attitudes that keep population rates high (or low)
- Providing contraception to LDCs
- Helping countries study population trends by improving census counts
- Empowering women and emphasizing gender equality

It is believed that worldwide, over 60 percent of women between ages 15-49 use some form of contraception. This varies regionally. In the United States contraception use is at nearly 75 percent, whereas in Africa it is around 30 percent. The general consensus today is that the focus on population planning should be on gender equality and improving the social status of women around the world. This is the focus of the **International Conference on Population and Development**.Religious organizations are also concerned with population growth; however, they focus on contraception issues and not strictly population growth. Some religions and political entities find contraception use immoral which has influenced some governments to make the access to them and use of them illegal. Urbanization and empowering women seems to have the greatest impact in reducing fertility rates. China's fertility rate began dropping before the one-child policy was implemented. Recent attempts to allow or encourage more births in China and other countries have had minimal effect.

Migration Geography

Some interesting patterns occur with migration. Most people that migrate travel only a short distance from their original destination and usually within their country, usually due to economic factors. This is called **internal migration**. Internal migration can be divided up even further into **interregional migration** (the permanent movement from one region of a country to another region) and **intraregional migration** (the permanent movement within a single region of a country).The other type of migration is called **international migration**, which is the movement from one country to another. Some people are allowed to **voluntarily migration** based on individual choice. At other times, an individual leaves against his or her will. This is **forced migration**. Ultimately, the distance people migrate is depends on economic, gender, family-status, and cultural factors. For example, long-

distance migration tends to involve males looking for employment and traveling by themselves rather than risk taking their families.

Migration is very dynamic around the world with peaks in different regions at different times. As noted earlier, there are several reasons *why* people migrate, but where are people migrating to or from? **Migration transition is** the change in migration patterns within a society caused by industrialization, population growth, and other social and economic changes that also produce the demographic transition. A critical factor in all forms of migration is **mobility**—the ability to move either permanently or temporarily. There has been a dramatic increase of immigration into the United States from Latin America, Africa and the Middle East. Some from these regions migrate to the U.S. out of economic necessity. We hear quite a lot about **guest workers** in the United States. These are individuals who migrate *temporarily* to take up jobs in other countries. Others migrate to escape conflicts such as the civil wars in Somalia, Sudan, and Ethiopia. Genocides in Rwanda (1994) and more recently Darfur, Sudan have forced internal and international migration. The wars in Afghanistan and Iraq have also forced migration from these regions. *Washington Post* reporter Sudarsan Raghavan reported on February 4, 2007 that the U.N. High Commission for Refugees estimates that over 2 million Iraqis (nearly 8 percent of the pre-war population) have been forced to migrate to nearby nations of Jordan, Syria, and Lebanon.

There are several reasons why people migrate and these are called *push* and *pull factors* and they occur on economic, cultural, or environmental lines. **Push factors** are events and conditions that compel an individual to move from a location. **Pull factors** are conditions that influence migrants to move to a particular location. The number one reason why people migrate is for economic reasons. This is because people either get "pushed" away from where they live due to a lack of employment opportunities, or pulled because somewhere else either offers more jobs/higher paying jobs.**Cultural push factors** usually involve slavery, political instability, ethnic cleansing, famine, and/or war. People who choose to flee or are forced to flee as a result of these problems are often refugees. The **United States Committee for Refugees** classifies a **refugee** as someone who has been forced from their homes and can not return because of their religion, race, nationality, or political opinion. In 2010, the United Nations High Commission for Refugees estimated that there are over 44 million people worldwide that have been forcibly displaced. The number grows to another 27 million when you consider **internally displaced persons** (IDPs). **Cultural pull factors** could include people who want to live in democratic societies, gender equality, or educational or religious opportunities. A variety of **environmental push** and **pull factors** also influence migration patterns. Environmental pull factors can include people wanting to live in particular environments. For example, many elderly people like to live in St. George because they prefer the recreational opportunities that are provided for retired individuals. Some people want to live where snow activities are available or near an ocean. Push factors often are related to the frequency of natural disasters such as earthquakes, tsunamis, hurricanes, or flash floods that a region could experience. Climatic push/pull factors, such as droughts, also influence migration patterns. A very recent example of this is the famine in Somalia. **US AID** and the **Famine Early Warning System** track potential famines globally so that relief organizations can have a heads up and be more proactive when events occur. People who have been pushed for environmental reasons are called **environmentally displaced persons** (also called **environmental refugees**). The problem with these refugees is that they are not protected or given the same rights under the 1951 Refugee Convention. Under the convention, a refugee is a person with: "well-founded fear of being persecuted for reasons of race, religion nationality, membership of a particular social group or political opinion, who is outside the country of his nationality ad is unable o, owing to such fear, is unwilling to avail himself of the protection of that country." But more and more people are becoming environmental refugees because of climate change, droughts, flooding from massive storm systems, water shortages, and more.

Summary

The issue of global human populations is often times controversial because there is no clear consensus on how to deal with it. What demographers do know is that there are over 7.3 billion on the planet, but they are not evenly distributed evenly around the world. One global pattern that is consistent is water; nearly 80 percent of the world's population lives near a large body of water. There are a variety of ways that geographers and demographers study population dynamics and profiles, often times representing this data in the form of diagrams, graphs, and most importantly maps. One way social scientists have tried to describe historical, current, and future population trends is with the Demographic Transition Model. The model tries to describe how more developed countries progressed with their demographics through as compared to less developed countries today. But some argue that though the model predicts demographic trends in North America and Europe, the model does not accurately represent population trends other regions of the world. Others say the model is too simplistic because environmental and cultural factors are not considered. Another area of debate is what the potential ramifications could be as the human population exceeds past 8 and 9 billion by 2050. This debate started a while ago with the Malthus theory. Many ecologists believe humans have reached the earth's carrying capacity and can not sustain such large populations. Other argue that technology has consistently kept ahead of food scarcity concerns and that high populations could actually be a benefit for less developed countries as a way to improve development. Geographers also understand that humans are migrating species and with technology today can move across great distances. The reason for migration varies, but it all comes down to push or pull factors related to economic, political, social, or

environmental reason. Many of these travelers are temporary living as guest workers until they need to move on. Today, many migrants are refugees, living in a variety of living conditions from complex metropolitans to squatter towns or refugee camps. But one thing we do know about human migration is that the majority of humans will die in the same town they were born in.

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2.3: Human Geography

Learning Objectives

- Compare the differences between race and ethnicity.
- Describe where other language families are distributed.
- Explain why people preserve local languages and why languages around the planet are disappearing.
- Describe where religions originated and diffused around the world.
- Determine why territorial conflicts arise among religious groups.

Race and Ethnicity

WHAT IS RACE?

Race, in biological terms, refers to the concept and practice of categorizing people into groups based on shared physical characteristics resulting from genetic ancestry. Shared genetic ancestry is a result of geographical isolation. Geographic isolation, since the era of colonization and even before then, has significantly decreased in most areas of the world. Less geographic isolation results in the mixing of racial groups. Thus, classifying people by their race with any accuracy is difficult.

From a sociological perspective, race is a social construct. Many social scientists argue that race is a social construct and that the scientific basis for it is very weak because, as Larry Adelman (2003) argues, "most variation is within, not between, 'races': Of the small amount of total human variation, 84% exists within any local population. About 94% can be found within any continent" (p. 1). Race, in this sense, presumes real or assumed shared biology or genes and in 19th century, racial differences were used to justify colonization, racial inequities, immigration quotas, and slavery (in the U.S.).PBS has created an interesting website called RACE – The Power of an Illusion that looks at whether race truly is a biological characteristic of humans or a social construct.

WHAT IS ETHNICITY?

Ethnicity refers to a population of people whose members identify with each other based on real or presumed shared ancestry (shared cultural and historical past). Shared geography, language and religion can often, but not always, factor into ethnic group categorizations. Ethnic groups distinguish themselves differently from one time period to another. Ethnicity can be used by individuals to identify themselves with others who have shared geographic, cultural, historical, linguistic, and/or religious ancestry; however, like race, ethnicity has been defined by the stereotypes created by dominant groups as a method of "Othering." Othering is a process in which one group, usually the dominant group, views and represents themselves as "us/same" and another group as "them/other."

Take the sorting quiz and watch *The Human Family Tree* and *Black in Latin America: An Island Divided* to "witness" how migration and geography play a role in the complex issues surrounding race and ethnicity. Pay attention to how the racial and ethnic landscape of the island of Hispaniola impacts cultural identity and the geopolitics both within Hispaniola and beyond its shores.

Click on this button to take the Sorting People Quiz. How did you do? What did you learn about Race and Ethnicity from taking the quiz?

The 20th Century was also the deadliest century, in terms of war, in human history. This century experienced two world wars, multiple civil wars, genocides in Rwanda (Tutsis and moderate Hutus), Sudan, Yugoslavia, and the Holocaust that decimated the Jewish population in Europe during WWII. In addition to WWI and WWII, this century experienced the Korean War, Vietnam War, the Cold War, and the first Gulf War. Additionally, this century saw regional and civil conflicts such as those experienced in the Congo (6 million people died), as well as an upsurge in **child soldiers** and modern **slavery**.
Some of the worst acts by humans have been in the terms of ethnic cleansing and genocide. The United Nations Security Council established Resolution 780, which states that **ethnic cleansing** is "a purposeful policy designed by one ethnic or religious group to remove by violent and terror-inspiring means the civilian population of another ethnic or religious group from certain geographic areas."



>Genocide is similar to ethnic cleaning, but only goes deeper. **Genocide** is usually defined at the intentional killing of large sums of people targeted because of their ethnicity, political ideology, religion, or culture. At first glance, it appears that ethnic cleansing and genocide are similar. With ethnic cleansing, the aim is to remove a group of people with similar ethnic backgrounds from a specific geographic region by any means possible. This could include forced migration, terror and rape, destruction of villages, and large scale death. With genocide, the true intent is the *death* of a group of people at any scale possible until they are extinct. This has happened many times in recent history including Bosnia-Herzegovina, Burma, Cambodia, Democratic Republic of the Congo, Rwanda, Sudan, and now Syria. Sadly, with all these ethnic conflicts, most were not officially declared as genocides by the United Nations Security Council, but the conditions on the ground and the reasons why the were occurring fit the definition.

There are many violent conflicts around the world at any one time. The good news is the death rate per capita has plummeted since the end of WWII and is now considered the lowest in at least centuries at the global scale.

Classifying Languages

Language and religion are two essential cultural characteristics for human geographers to study. Geographers describe the historical and spatial distributions of language and religion across the landscape as a way of understanding cultural identity. Furthermore, when geographers study religion, they are less concerned with theology and more concerned with the diffusion and interaction of religious ideologies across time and space and the imprint it has on the cultural landscape.



Location of the World's Major Language Families

DEFINING LANGUAGE

Languages relate to each other in much the same way that family groups (think of a family tree) relate to each other. **Language** is a system of communication that provides meaning to a group of people through speech. Nearly all languages around the world have a **literary tradition**: a system of written communication. Most nations have an **official language**. Most citizens of a nation with an official language speak and write in that language. Additionally, most official or governmental documents, monetary funds, and transportation signs are communicated in the official language. However, some regions such as the European Union have 23 official languages. A **language family** is a collection of languages related through a common prehistorical language that makes up the main trunk of a language identity. A language tree will have **language branches**, a collection of languages related through a common ancestral language that existed thousands of years ago. Finally, a **language group** is a collection of languages within a single branch that share a common origin from the relatively recent past and display relatively few differences in grammar and vocabulary.

DIALECTS

There are various dialects within any language, and English in the United States is no exception. A **dialect** is a regional variation of a language, such as English, distinguished by distinctive vocabulary, spelling, and pronunciation. In the United States, there is a dialect difference between southern, northern, and western states. We can all understand each other, but the way we say things may sound accented or "weird" to others. There is also a dialect difference between American English and English spoken in Britain, as well as other parts of the British Commonwealth.

Origins and Diffusions

ORIGINS OF LANGUAGES

All modern languages originate from an ancient language. The origin of every language may never be known because many ancient languages existed and changed before the written record. Root words within languages are the best evidence that we have to indicate that languages originated from pre-written history. The possible geographic origin of ancient languages is quite interesting. For example, several languages have similar root words for winter and snow, but not for ocean. This indicates that the original language originated in an interior location away from the ocean. It wasn't until people speaking this language migrated toward the ocean that the word ocean was added to the lexicon (a catalogue of a language's words).

The video is from the famous Explorer-in-Residence of the National Geographic Society, the anthropologist Wade Davis. He has traveled all around the world and he brings back the knowledge and wisdom of exploring ancient cultures. Davis says humans all around the world try to understand what it means to be human and it is expressed 7,000 ways in the form of language. "The other cultures of the world are not failures to be us; rather, they show us what it means to be human." There are many layers within the **Indo-European** language family, but we will focus on the specifics. Though they sound very different, German and English come from the same **Germanic branch** of the Indo-European language group. The Germanic branch is divided into **High German** and **Low German**. Most Germans speak High German, whereas English, Danish, and Flemish are considered subgroups of Low German. The **Romance branch** originated 2,000 years ago and is derived from Latin. Today, the Romance languages are Spanish, Portuguese, French, and Italian. The **Balto-Slavic branch** use to be considered one large language called Slavic in the 7th Century, but subdivided into a variety of smaller groups over time. Today the Balto-Slavic branch is composed of the following groups: East Slavic, West, Slavic, South Slavic, and Baltic. The Indo-European language branch spoken by most people around the world is **Indo-Iranian** with over 100 individual languages.

DISTRIBUTION OF LANGUAGE FAMILIES

The next question that must be asked is why are languages diffused where they are diffused? Social scientists, specifically linguistics and archaeologists disagree on this issue because some believe that languages are diffused by war and conquest, whereas others believe diffusion occurs by peaceful/symbiotic means such as food and trade. For example, English is spoken by over 2 billion people and is the dominant language in 55 countries. Much of this diffusion has to do with British imperialism. The primary purpose of British imperialism was to appropriate as much foreign territory as possible to use as sources of raw materials. Imperialism involves diffusion of language through both conquest and trade.

The linguistic structure of the Sino-Tibetan language family is very complex and different from the Indo-European language family. Unlike European languages, the Sino-Tibetan language is based on hundreds of one-syllable spoken words. The other

distinctive characteristic of this language is the way it is written. Rather than letters used in the Indo-European language, the Chinese language is written using thousands of characters called **ideograms**, which represent ideas or concepts rather than sounds. Sino-Tibetan language family exists mainly in China—the most populous nation in the world—and is over 4,000 years old. Of the over 1 billion Chinese citizens, 75 percent speak Mandarin, making it the most common language used in the world. There are a large variety of other language families in Eastern and Southeast Asian. There is **Austronesian** in Indonesia, **Austro-Asiatic** that includes Vietnamese, **Tai Kadai** that is spoken in Thailand and surrounding countries, **Korean** and **Japanese**. In Southwest Asia (also called the Middle East), there are three major language families.

The **Afro-Asiatic** languages are spoken by over 200 million people in several countries in the form of Arabic and is the written language of the Muslim holy book called the Quran. Hebrew is another Afro-Asiatic language and is the language of the Torah and Talmud (Jewish sacred texts). The largest group of the **Altaic language** family is Turkish. The Turkish language use to be written with Arabic letters, but in 1928 the Turkish government required the use of the Roman alphabet in order to adapt the nation's cultural and economic communications to those in line with their Western-European counterparts. Finally, the **Uralic** language family originated 7,000 years ago, near the Ural mountains in Siberia. All European countries speak Indo-European languages except Estonia, Finland, and Hungary, which speak Uralic instead. The countries that make up Africa have a very rich and complex family of languages. Africa has thousands of languages that have resulted from 5,000 years of isolation between the various tribes. Just like species that evolve differently over thousands of years of isolation, Africa's languages have evolved into various tongues. But there are three major African language families to focus on. The **Niger-Congo** language family is spoken by 95 percent of the people in sub-Saharan Africa. Within the Niger-Congo language is Swahili, which is the official language of only 800,00 people, but a secondary language spoken by over 30 million Africans. Only a few million people in Africa speak languages from the Nilo-Saharan language family. The **Khoisan** language family is spoken by even fewer, but is distinctive because of the "clicking sounds" when spoken. In a world dominated by communication, globalization, science and the Internet, English has grown to be the dominant global language. Today English is considered a **lingua franca** (a language mutually understood and commonly used in trade by people who have different native languages). It is now believed that 500 million people speak English as a second language. There are other lingua franca such as Swahili in Eastern Africa and Russian in nations that were once a part of the Soviet Union.

PIDGINS AND CREOLES

Pidgins, also called **contact languages**, which develop out of contact between at least two groups of people who do not share a common language. A pidgin language is a usually a mixture of two or more languages, contains simplified grammar and vocabulary in, and is used for linguistic communication between groups, usually for trading purposes, who speak different languages. Pidgins are not first/native languages and are always learned as a second language. Many pidgins developed during European colonization of Asia, Africa, and other areas of the world during the seventeenth to nineteenth centuries.

Creole languages are stable languages that develop from pidgins. Different from pidgins, creole languages are primary languages that are nativized by children. Additionally, creoles have their own formal grammar and vocabulary. The grammar of a creole language often has grammatical features that differ from those of both parent languages. However, the vocabulary of a creole is primarily taken from the language of the dominant contact group.

ENDANGERED LANGUAGES AND PRESERVING LANGUAGE DIVERSITY

An **isolated language** is one that is unrelated to any other language, thus it cannot be connected to any language family. These remote languages, and many others, are experiencing a mass extinction and are quickly disappearing off the planet. In fact, it is believed that nearly 500 languages are in danger of being lost forever. Think about the language you speak, the knowledge and understanding acquired and discovered through that language. What would happen to all that knowledge if your language suddenly disappeared? Would all of it be transferred to another language or would major components be lost to time and be rewritten by history? What would happen to your culture if your language was lost to time? Ultimately, is it possible that the Information Age is causing a Dis-information Age as thousands of languages are near **extinction**?

Consider the impact of language on culture, particularly religion. Most religions have some form of written or literary tradition or history, which allows for information to be transferred to future generations. But some religions are only transferred verbally and when that culture disappears (which is happening at a frightening rate), so does all of the knowledge and history of that culture.

Luckily, there is an effort to preserve many of the world's languages before extinction occurs. Recently the National Geographic Society created a campaign called the Enduring Voices Project, which is focusing on bringing awareness and protecting many of the world's endangered languages. In 2012, Google announced its own project to protect half of the world's total languages–3,054

to be exact–called Endangered Languages. Please take a moment and study these two important projects

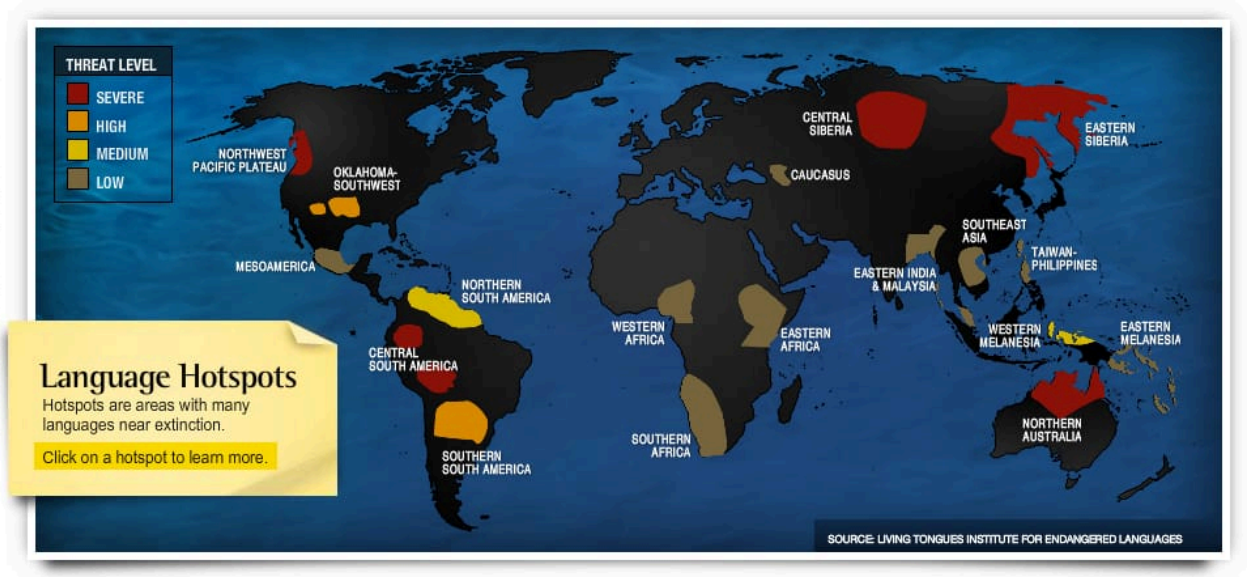


Image taken from National Geographic's Enduring Voices Project.

Origins and Diffusion of Religion

Our world's cultural geography is very complex with language and religion as two cultural traits that contribute to the richness, diversity, and complexity of the human experience. Nowadays, the word "diversity" is gaining a great deal of attention as nations around the world are becoming more culturally, religiously, and linguistically complex and interconnected. Specifically in regards to religion, these important cultural institutions are no longer isolated in their place of origin, but have diffused into other realms and regions with their own religious history and cultural dominance. In some parts of the world, this has caused religious wars and persecution; in other regions it has help initiate cultural tolerance and respect for others.

These trends are in some ways the product of a history of migratory push and pull factors along with demographic change that have brought together peoples of diverse religious and even linguistic backgrounds. It is critical that people critically learn about diverse cultures by understanding important cultural traits, such as the ways we communicate and maintain spiritual beliefs. Geographers need to be aware that even though our discipline might not be able to answer numerous questions related to language structure or address distinctive aspects of theological opinion, our field can provide insight by studying these cultural traits in a spatial context. In essence, geography provides us the necessary tools to understand the spread of cultural traits and the role of geographic factors, both physical and cultural, in that process. People will then see that geography has influenced the distribution and diffusion of differing ideologies, as well as the diverse ways they practice their spiritual traditions.

As is the case with languages, geographers have a method of classifying religions so people can better understand the geographic diffusion of belief systems. Although religions are by themselves complex cultural institutions, the basic method for categorizing them is simple. In essence, there are two main groups: **universalizing religions**, which actively invite non-members to join them, and **ethnic religions**, which are associated with particular ethnic or national groups. Everyone can recount moments in his or her life in which there was interaction with individuals eager to share with others their spiritual beliefs and traditions. Also, that same person might have encountered individuals who are very private, perhaps secretive, when it comes to personal religious traditions deemed by this individual as exclusive to his or her family and national group. A discussion of these life experiences can generate very interesting examples that serve as testimony to our world's cultural richness when it comes to differing religious traditions.

ORIGINS AND WORLD RELIGIONS

A significant portion of the world's universalizing religions have a precise hearth, or place of origin. This designation is based on events in the life of a man, and the hearths where the largest universalizing religions originated are all in Asia. Of course, not all religions are from Asia, and you can open up a discussion of the origins of other faiths outside Asia. The three universalizing religions diffused from specific **hearths**, or places of origin, to other regions of the world. The hearths where each of these three

largest universalizing religions originated are based on the events in the lives of key individuals within each religion. Together, Christianity, Islam, and Buddhism have over 2.5 billion adherents combined. Below are links to websites that analyze the diffusion of Christianity, Islam, and Buddhism.

RELIGIOUS CONFLICT

Religion is often times the catalyst of conflict between local values or traditions with issues and values that come with nationalism or even globalization. Religion tends to represent core beliefs that represent cultural values and identity, which along with language, often times represent local ideology rather than national or international ideology. There are a number of reasons why, but some include:

- Culture is often the manifestation of core belief systems determined by the interplay between language and religion.
- Universal religions try to appeal to the many, whereas ethnic religions focus on the few in a specific region.
- Cultural landscapes or language and religion are often represented in the physical landscape. When opposing forces come and threaten the physical landscape, it threatens the cultural landscape.
- Universal religions require adoption of values that make conflict with local traditions and values. If the universal religion is forced upon another universal religion or ethnic religion, conflict may ensue.
- Migrants tend to learn and simulate the language of the region they migrate to, but keep the religion they originated from. This can be viewed as a threat to the people the migrant moved to.

Types of Religions

UNIVERSAL RELIGIONS

Most of you probably have not thought of religion in this sense, but geographers distinguish religion into two categories: *universal* and *ethnic*. **Universal religions** try to appeal to everyone globally rather than specific cultures or regions. **Ethnic religions** try to focus and appeal to specific groups of people. Sixty two percent of the world's population belongs to a universal religion, whereas only 24 percent belong to ethnic religions. The other 14 percent do not have any religious affiliation.

Christianity is divided into three branches: Roman Catholic, Protestant, and Eastern Orthodox. The largest of the three is Roman Catholic with nearly 52 percent of the Christian population. In the western hemisphere, where nearly 90 percent of the population is Christian, there are strong divides between the Christian branches. In Latin America, 93 percent are Roman Catholic compared to just 29 percent in North America. In the United States, Roman Catholics are clustered in the southwest and northeast. Nearly 28 percent of North America is Protestant with Baptist being the major denomination followed by Methodist, Pentecostal, Lutheran, and Mormon. Most major religions have laws, rules, commandments, or beliefs that all members should follow. In Christianity, they are the **Ten Commandments** and they are written as direct commandments from God.

1. You shall have no other gods before Me.
2. *You shall not make for yourself a carved image – any likeness of anything that is in heaven above, or that is in the earth beneath, or that is in the water under the earth.*
3. *You shall not take the name of the LORD your God in vain.*
4. *Remember the Sabbath day, to keep it holy.*
5. *Honor your father and your mother.*
6. *You shall not murder.*
7. *You shall not commit adultery.*
8. *You shall not steal.*
9. *You shall not bear false witness against your neighbor.*
10. *You shall not covet your neighbor's house; you shall not covet your neighbor's wife, nor his male servant, nor his female servant, nor his ox, nor his donkey, nor anything that is your neighbors.*

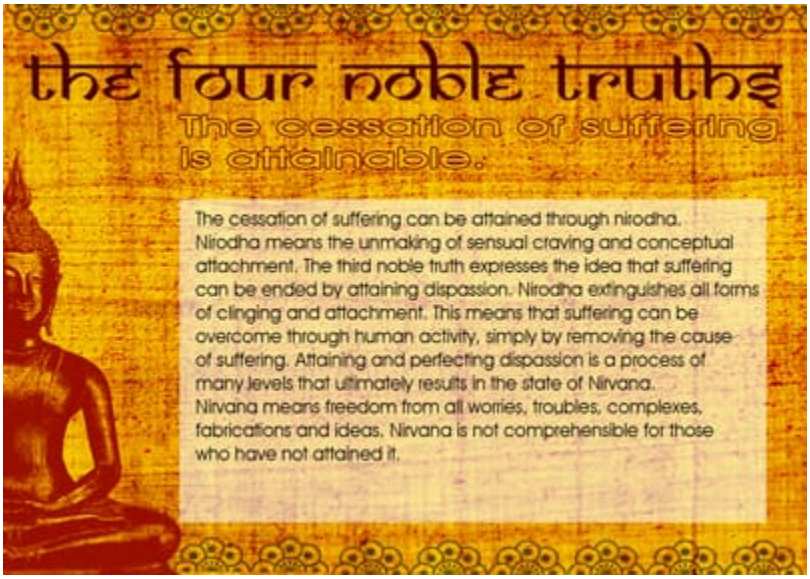
Probably one of the most misunderstood religions in the world is **Islam**. Though predominantly centered in the Middle East and Northern Africa, Islam is the fastest growing religion in the world with 1.3 billion and is only second to Christianity is members. Founded by Muhammad, the core beliefs of Islam are called the **Five Pillars of Faith** and they include:

1. *There is no god worthy of worship except the one God, the source of all creation, and Muhammad is the messenger of God.*
2. *Five times daily, a Muslim prays, facing the city Makkah (Mecca), as a direct link to God.*
3. *A Muslim gives generously to charity, as an act of purification and growth.*

4. *A Muslim fasts during the month of Ramadan, as an act of self-purification.*
5. *If physically and financially able, a Muslim makes a pilgrimage to Makkah–this is called the Hajj.*

Probably one of the most misunderstood religions in the world is **Islam** . Though predominantly centered in the Middle East and Northern Africa, Islam is the fastest growing religion in the world with 1.3 billion and is only second to Christianity is members. Islam is also divided into two major branches: Sunni and Shiite. The **Sunni** branch is the largest composing of 83 percent of all Muslims. The **Shiite** branch is more concentrated in clusters such as Iran, Iraq, and Pakistan. Founded by the Prophet Muhammad, the core beliefs of Islam are called the **Five Pillars of Faith** and they include:

1. *There is no god worthy of worship except the one God, the source of all creation, and Muhammad is the messenger of God.*
2. *Five times daily, a Muslim prays, facing the city Makkah (Mecca), as a direct link to God.*
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5. *If physically and financially able, a Muslim makes a pilgrimage to Makkah–this is called the Hajj.*



The third largest universal religion is **Buddhism** with 400 million followers. This religion is mainly clustered in China and Southeast Asia. Buddhism is actually a break-off of Hinduism and founded by Siddhartha Gautama. After seeing the suffering of people in India, Siddhartha left his riches to learn the root causes of pain and suffering. After a long journey, he became enlightened and became the Buddha. In order to transcend pain and suffering, the Buddha presented the **Four Noble Truths**, which leads to the **Eight-fold Path**.

1. *All living beings must endure suffering.*
2. *Suffering, which is caused by a desire to live, leads to reincarnation (repeated rebirth in new bodies or forms of life).*
3. *The goal of all existence is to escape from suffering and the endless cycle of reincarnation into Nirvana (a state of complete redemption), which is achieved through mental and moral self-purification.*
4. *Nirvana is attained through an Eightfold Path, which includes rightness of belief, resolve, speech, action, livelihood, effort, thought, and mediation.*



Image from Hindu Web

Eightfold Path: *Right view*; *Right intention*; *Right speech*; *Right action*; *Right livelihood*; *Right effort*; *Right mindfulness; Right concentration.* After Siddhartha Gautama died, Buddhism split between the Mahayanist, Theravada, and Tantrayana branches. The Mahayanist branch is by far the most popular and tends to be the most universal. It also more of philosophical practice/way of life rather than a religion. The Theravada and Tantrayana branches are centered on spiritual ideologies and practices, thus making them religious sects of Buddhism.



HOLY RELIGIOUS PLACES

Some of the places that in some ways contributed to the foundation and development of a faith oftentimes gain sacred status, either by the presence of a natural site ascribed as holy, or as the stage for miraculous events, or by some historical event such as the erection of a temple. When a place gains that “sacred” reputation, it is not unusual to see peoples from different parts of the world traveling or making a pilgrimage to this site with the hope of experiencing spiritual and physical renewal.

Buddhists have eight holy sites because they have special meaning or important events during the Buddha’s life. The first one is in Lumbini, Nepal where the Buddha was born around 563 B.C. The second holy site is in Bodh Gaya, Nepal, where it is believed Siddhartha reached enlightenment to become the Buddha. The third most important site is in Sarnath, India where he gave his first sermon. The fourth holiest site is Kusinagara, India where the Buddha died at the age of 80 and became enlightened. The other four holy sites are where Buddha performed/experienced specific miracles. People who practice Buddhism or Shintoism erect and use **pagodas** to house relics and sacred texts. Pagodas are also used for individual prayer and meditation.



Islam's holiest sites are located in Saudi Arabia. The holiest city is Mecca, Saudi Arabia where the Prophet Muhammad was born. It is also the location of the religion's holiest objects called the **Ka'ba**, a cube-like structure believed to have been built by Abraham and Ishmael. The second holiest site to Muslims is Medina, Saudi Arabia where Muhammad began his leadership and gained original support by the people. Every healthy, and financially able Muslim is suppose to make at least one pilgrimage to Mecca in their lifetime. For Muslims, a **mosque** is considered a holy site of worship, but also a place for community assembly. Usually assembled around a courtyard, the pulpit faces Mecca so that all Muslims pray toward their holiest site. Mosques will have a tower called a **minaret** where someone summons people to worship.



Meaning lord, master, or power, a Christian **church** is a place of gathering and worship. Compared to other religions, churches play a more important role because they are created to express values and principles. Churches also play a vital role to the landscape. In earlier days and in smaller towns, churches tend to be the largest buildings. Also because of their importance, Christian religions spend lots of money and commitment to the building and maintenance of their churches.

To learn more about various world religions, click on the following links:

Universal religions: Buddhism, Christianity, Islam Ethnic religions: Hinduism, Judaism, Taoism, Shinto, Zoroastrianism, Sikhism, Animists. Returning to our original discussion on genocide, below is a documentary by PBS on the subject titled "Genocide: Worse Than War." As quoted by Danial Goldhagen "By the most fundamental measure — the number of people killed — the perpetrators of mass murder since the beginning of the twentieth century have taken the lives of more people than have died in military conflict. So genocide is worse than war," reiterates Goldhagen. "This is a little-known fact that should be a central focus of international politics, because once you know it, the world, international politics, and what we need to do all begin to look substantially different from how they are typically conceived" (Genocide: Worse Than War).

Summary

Few things determine human characteristics than ethnicity and culture. Many believe that humans can be categorized by ethnicity and by race. But biological science is starting to show that race is more of a social construct and not grounded or supported by genetics.

For human geographers and sociologists, a culture is largely determined by language and religion. Language is a complex way humans have learned to communicate with each other. Like a family tree, the history of a language can be traced back using language branches and language families. Linguists are concerned that globalization is causing many of the world's languages to become extinct. The extinction of a language is also the extinction of knowledge that may not be replaceable.

There are a variety of religions, but most can be divided as being either universal and ethnic. Universal religions tend to focus a lot on missionaries and the spread of their religion, whereas ethnic religions do not focus on spreading their religion. The places of worship are and complex and the religions themselves because they are the symbols of the religion.

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2.4: Geography of Religion

Religion and geography

Religion plays a strong role in the culture of believers, shaping values, actions, food, and even dress. A religion is a system of beliefs and practices that recognize a higher power beyond humanity. Religions commonly have varying rituals. Prominently there are often rituals revolving around life changes recognized as important to the religious community, such as birth, coming-of-age, marriage, and death. While culture also has **secular**, or non-spiritual, rituals at these life moments, many religious traditions have specific rituals such as baptisms and bar mitzvahs along with traditional religious practices of marriage and death. Additional rituals, beliefs, and practices surround holidays (or, Holy days).

Basic features of major religions

Judaism

- Monotheistic and ethnic
- Major splits of Orthodox, Conservative, Reform
- Religion of the Hebrews
- Focus on this life and obeying God's commandments

Hinduism

- Polytheistic and ethnic
- Associated with India
- Extremely diverse
- Humans seek release from cycle of rebirth

Buddhism

- Polytheistic and universalizing
- Major splits of Theravada, Mahayana, and Vajrayana
- There is no permanence; gain enlightenment to leave the cycle of rebirth

Christianity

- Monotheistic and universalizing
- Major splits of Catholic, Orthodox, and Protestant
- One God as a Trinity, salvation comes through Christ

Islam

- Monotheistic and universalizing
- Major splits of Sunni, Shi'a, and Sufi
- One God named Allah, humans submit to Allah to gain paradise

Animism

- Polytheistic and often ethnic
- Includes traditional folk religions, Wicca
- Nonhumans and inanimate features have spirits or souls

Taoic religions

- Generally polytheistic and ethnic
- Major faiths include Taoism, Confucianism, Shinto
- Often moralistic codes/ethics with polytheistic animism
- Often syncretic with Buddhism

Religion, like any other cultural practice, can readily be assessed from a geographic lens. Geographers study the spatial distribution of organized religious systems, specific religious practices, and the impact of religion on the landscapes of culture and institutions. Religion tends to have a patchwork nature; individual belief and practice is quite nuanced and intrinsic. At a global scale, it is difficult to view specific practices, but geographers can categorize and look at major religious trends. Major religions are those that share basic tenets of faith among believers, even if there exists wide sectarian differences within these faith families. Generally, five major world religions are identified:

- Hinduism
- Buddhism
- Judaism
- Christianity
- Islam

Like other cultural practices, major religions started in hearth areas of origin and have spread over time. Beyond these five, **Taoic** and **Animistic** religions are looser categories but still are important as belief systems.

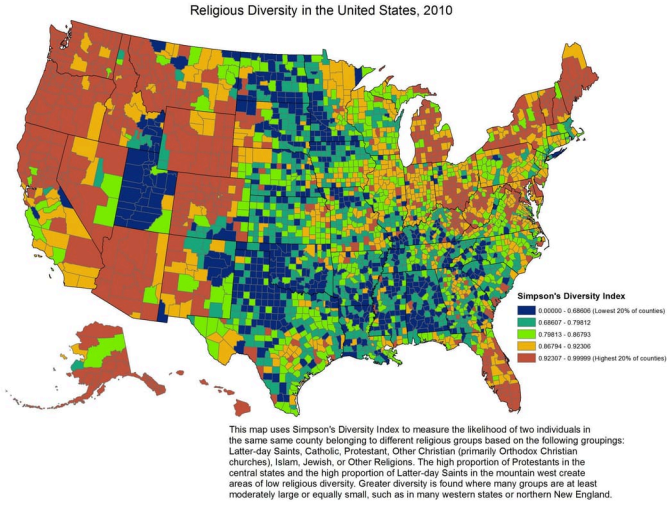
Exercise: Religions around the World

Explore maps of religions worldwide at https://mpt.pbslearningmedia.org/resource/sj14-soc-religmap/world-religions-map/. This interactive map shows prevailing religions around the world along with country-based breakdowns by major religious group.

In looking at beliefs and practices of religion, there are several ways to further categorize religions. How many gods do adherents believe in? **Monotheistic religions** have a belief in only one God, while **polytheistic religions** have many gods. Does the religion **proselytize**, or seek new converts to the faith? **Ethnic religions** are those that do not proselytize and are associated with a specific place or ethnic group, while **universalizing religions** breaks from bounds of place and ethnicity to seek converts. How “pure” is the faith of the religion, or more likely the sect or denomination? **Syncretism** is the melding of various religious traditions and systems in to one, while **orthodoxy** is a specific emphasis on purity of faith within a sect.

These and other religions have diffused geographically through three major methods. First, adherents have migrated to new places, bringing religious practices with them. Second, religion has spread through **contact conversion**, which is similar to the concept of expansion diffusion. Third, religion has spread through the use of **organized missions**. This is similar to the concept of relocation diffusion.

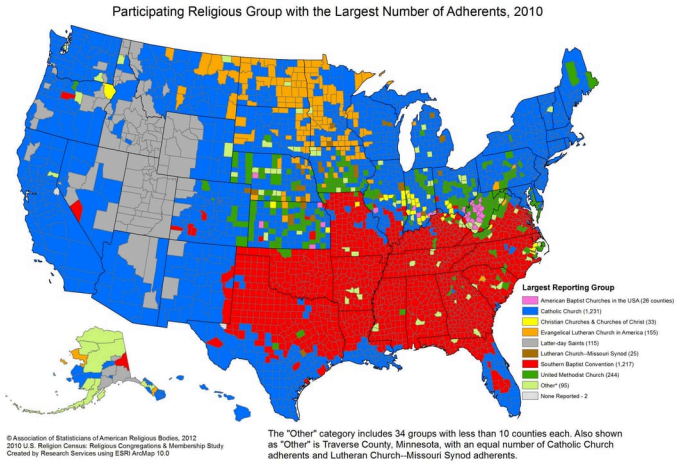
The religious landscape of the United States



Source: 2010 U.S. Religion Census, sponsored by the Association of Statisticians of American Religious Bodies

Before European colonization of the Americas, there were myriad indigenous religions practiced by Native Americans. The colonists brought various forms of Christianity to the Americas. Christian denominations were not randomly distributed, but rather clustered along denominational lines in certain colonies or regions. In the New England colonies, Congregationalists were most prominent. Southern colonists were largely Anglican (or Episcopalian as it became known after the American Revolution). The colony of Maryland was chartered for Catholics. As more people migrated and more churches were founded, these early patterns of regional domination by particular sects changed. Three major changes caused this diffusion and confusion of American religion:

- American-style freedom, which encouraged experimentation of spiritual matters and departure from establishment churches
- Westward expansion, where new and eclectic worship practices developed in the vacuum of established churches
- Immigration, as new migrants to the United States held on to the security of their homeland's religious practice



Source: 2010 U.S. Religion Census, sponsored by the Association of Statisticians of American Religious Bodies

As a result, there are few counties in the United States that have a single, dominant religion. The map above shows the religious diversity in the United States by county. However, there are four general 'dominant' or pluralistic regional religions in America, as seen in the map on the right.

- Mormonism around Utah and southern Idaho
- Baptist in the South
- Lutheranism in the Upper Midwest
- Catholicism in the Northeast and the West

The Catholic patterns themselves come from two different patterns of migration. Those mostly urban strongholds in the Northeast were started from European Catholic migration of Ireland, Italy, and other European countries. The West is largely influenced from Hispanic or **Latinx** immigration.

Some scholars of religion have posited that the United States, in addition to being religiously pluralistic, also possesses a **civil religion**. Put forward by Robert Bellah, a civil or civic religion recognizes an implicit religion practiced by members of a nation. As described at the beginning of this chapter, religions often have associated rituals, symbols, and practices associated with adherents. The argument for the existence of an American civil religion is that many Americans are connected by civic culture that works in a quasi-religious manner. American culture celebrates sacred documents like the Constitution, sacred times like the Fourth of July, and sacred places like Arlington Cemetery, and these cultural artifacts are not dissimilar from, for example, how Catholics may treat the Bible, Christmas, and the Vatican.

Questions about American Civil Religion video

The video above outlines several arguments about the theory of existence for an American civil religion. What do you think?

- What are three arguments for there being an American civil religion?
- What are three arguments against?
- Overall, what do you think? Is there an American civil religion, and does it rise to the level of 'religion'?

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2.5: Geography of Language

Talking about talking

If you're reading or listening to this book and understand it, then you comprehend at least one language: English. **Language** is a spoken, written, or spoken and written system of communication that is understood by groups of people. English is the current global **linguafranca**, or a language of international business and exchange. In terms of sheer numbers, here's how the 5 most spoken* languages rank according to Ethnologue in terms of native and second-language speakers:

- English.....1.3 billion
- Mandarin Chinese...1.1 billion
- Hindi.....637 million
- Spanish.....538 million

*NOTE: if we *only* consider native speakers, Chinese has by far the highest number of speakers.

Sign language is an un-spoken and un-written form or mode of language for people who are deaf or hearing-impaired (certain systems of sign language like **American Sign Language (ASL)** are considered stand-alone languages complete with their own grammar) and **braille** is "a code by which many languages [...] may be written and read" (https://www.afb.org/blindness-and-low-vision/braille/what-braille).

Exercise: Language map

Check out this map by Ethnologue of the ~7,000 languages of the world.

One of the most common questions when it comes to languages is: how many are there? Just as it's not so straightforward to declare how many countries there are in the world due to variation in definition and recognition, so too is the case with languages. However, according to Ethnologue, a leading source on all-things-language, there are just over 7,000 language in the world with about 4,000 of them being written.

In addition to size and whether the language is written or oral, languages can be classified in terms of health, referring to the level of robustness and growth they experience or if they are **threatened** and/or **dying**, to be discussed towards the end of this chapter. Furthermore, **linguists**, or scholars who specialize in studying language, organize language hierarchically as follows:

- **Language family** (ex: Sino-Tibetan, Afro-Asiatic, Indo-European)
- **Language branch** (ex: Tibeto-Burman, Semitic, Romance)
- **Language group** (ex: Burmese, Arabic, Romanian)

Using the model of a tree, you can think of each language family as a trunk (stretching furthest back in time), each giving rise to branches, and then leaves (language groups). This chapter examines language from a geographical standpoint, using a spatial perspective, by providing an overview of the spatial distribution and diffusion of languages and how language relates to power, culture, and place.

Please note that examples used in this chapter tend to be centered around Indo-European languages, in particular English. This is because English is the language of this text and therefore it is presumed that readers have much familiarity with it and its history more-so than other languages.

Distribution & Diffusion of language

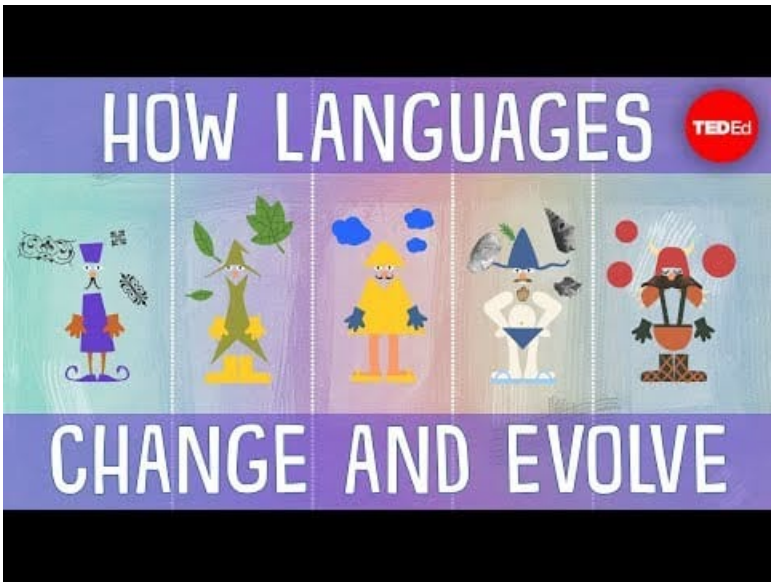
Let's start with an exercise to warm up our brains: examine this map of language distribution through ArcGIS. Click the hold to drag the map and use the +/- on the top left corner to zoom in and out and consider:

- How does the distribution of major language families align or not align with major world regions?
- Which regions have the most diversity in language families?
- What processes might explain how a language part of the Indo-European family ended up being dominant in a place far away

from it's origin point?
- White space appears and is not labeled. These areas are not completely unpopulated, so what kinds of languages do you think are present there?

From the map and section linked above, you'll see the major language families associated with each major world region and how the distribution of language families spans world regions, even ones that are not connected by land.

So, how did these languages get *WHERE* they are? Check out the video below for a quick overview and then see below for more.



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The most common theories as to how language diffuses, in particular the largest language family, Indo-European, are through:

1. Peaceful, passive interactions.

Agricultural theory holds that the Indo-European language spread from its likely origin point, also known as a **linguistic hearth**, of Anatolia (modern-day Turkey) alongside farmers who moved further and further out from the **agricultural hearth**. Agriculture provided the opportunity for settlements with large numbers of people residing in one spot needing a way to interact and communicate with one another.

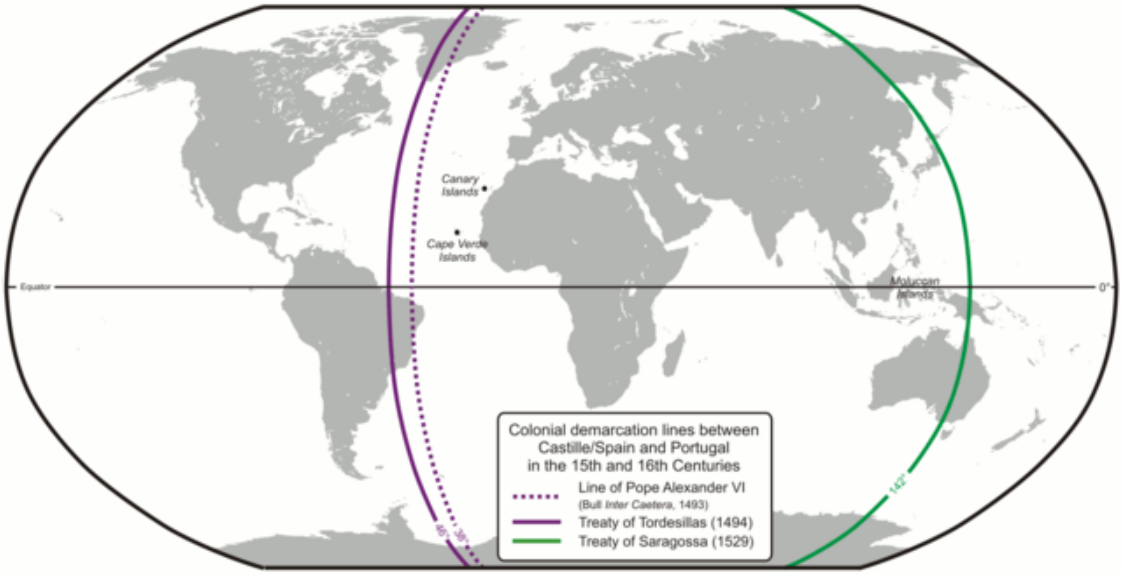
2. Conquest/war/invasion.

In contrast with the agricultural theory, **conquest theory** or **nomadic warrior theory** refers to the claim that the Indo-European language family diffused due to violent expansion and take-over by people from Anatolia to other parts of Europe.

2.5. Colonialism.

We can look to a more contemporary but still historical example of how colonialism, which tends to involve violent forms of conquest usually coupled with less violent forms of influence, as a related mechanisms that facilitates language diffusion.

Latin America provides a tidy example of this. The red vertical line on the map below, from the Library of Congress, divided territory in the "new world" between Spain and Portugal in 1794 as part of the Treaty of Tordesillas. Area to the west of the line came under Spanish colonial rule and area to the east, Portuguese.



Demarcation lines of the Treaty of Tordesillas

The linguistic impact of this is evident today: Central and South America are largely Spanish-speaking (with notable pockets and second languages of various Amerindian and Indigenous languages) except for Brazil, where Portuguese is predominant. In fact, the reason this region is widely referred to as Latin America and people from this region are called Latinos/Latinas/**Latinx** (the latter term is a gender-neutral way to refer to Latino men and Latina women) instead of Hispanic America, for instance, is because of the two Indo-European linguistic influences of Spanish and Portuguese. Take a look at a colonial/second-language map of of Africa, and you'll see a similar colonial legacy. **Proselytizing**, or trying to convert people to a particular religion, tends to be part of colonial practices and as such also plays a direct role in language diffusion.

3. Cultural imperialism and the internet?

When thinking about how language–entire communication systems or even parts of the system, like particular words or even gestures–spreads today in the 21st century, we must consider forces of **cultural imperialism**, referring to how more indirect (but strong) cultural influences (largely American, referring here to the US) are imposed on usually less developed and less powerful regions of the world. Take a look at these charts of language used on the internet and compare the most common internet languages with the most spoken languages.

Pidgins, Creoles, & Place-Making

In the context on language, pidgins don't refer to the birds (i.e. pigeons) and creole doesn't exactly refer to delicious food from Louisiana (although it is related, as we will see below). Instead, these terms refer to types of communication that emerge alongside human interaction.

A **pidgin** is a simplified language that emerges when two people who each speak different languages come up with another language by which they can communicate. That new language is a pidgin, or sometimes just called pidgin. For example, if I speak Spanish and you speak Korean, we may come up with a simplified pidgin language drawing from each of our own languages that, mixed with gestures and other symbols, is mutually intelligible to each of us. We may also draw from a language that we both already know, like a lingua franca, and use that as base for our simplified communication.

Pidgins are very geographical in nature because they emerge as people traverse through space, arriving in a place where they don't speak the language. Pidgins have historically sprung up along historic trading routes and at ports where people needed to communicate in order to conduct business and interact. For this reason, pidgins are often called **contact languages**. Check out the video below and ponder the accompanying questions.



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Questions about Hawaiian Pidgin

After watching the video above, consider the following:

- From what languages is Hawaiian pidgin drawn?
- How was Hawaiian pidgin perceived in the past and what things indicate that these past perceptions are changing?
- How does Hawaiian pidgin relate to cultural identity?
- If someone grew up speaking Hawaiian pidgin as her first language, would the communication system of "Hawaiian pidgin" be a pidgin language or a creole language (see below)?

A **creole** is a formalized, developed pidgin that has a complete grammar and **lexicon** (vocabulary) and has native speakers, meaning that babies are born who grow up learning the creole language (sometimes just called creole) as their first language. Perhaps familiar examples of creole languages within North America and the Caribbean include Louisiana creole (which also refers to a style of cuisine), and Haitian creole, spoken in Haiti. Many creoles emerged within **maroons**, or communities of Africans (and often later Indigenous peoples) who were formerly enslaved or were descendants of formerly enslaved parents. One such example of this is **Garifuna**, referring to a language and a group of people who were marooned in the Caribbean after a slave-ship shipwreck. Read more about the status of the language and group here and note how much overlap there is between language, culture, identity, and even cuisine and how these aspects are written about in the article.

Exercise: The Gullah

Learn about the Gullah here by reading the following pages and answering the questions below: "Introduction," "Origin of the Gullah," and "The Gullah Language."

- What does Gullah refer to?
- From what languages is Gullah creole derived?
- What factors explain why the Gullah emerged as a distinct and persisting group?
- What information did Dr. Lorenzo Turner discover about the Gullah in terms of the linguistic knowledge and even cultural practices of the Gullah?

By learning about the various creoles and pidgins above, you can hopefully start to see the **power** that language has in making meaning regarding identities across a range of scales: from the individual, to the cultural/sub-cultural/counter-cultural, and even to a specific place or entire region. As a dimension of culture, language plays a big role in creating the identity of a place, or **place-identity**, and a

Think of words that you may use from another language and how those give you a sense of your own individual heritage and cultural identity, and may even identify you with a particular place or region. Or perhaps you avoid using certain words to signal a distance between what they signify or have come to signify and your own values and identity.

Language then, including place names or toponyms, street names, plaza names, and school names is an element of a cultural landscape and contributes to the overall place-identity of a location. Language is a form of and canvas for power and power is exercised from above and below, equally including efforts to enforce authority and contest authority. We can see what this looks like on the ground by analyzing some examples of naming and re-naming or un-naming. Check out the links below:

1. **Swaziland becomes eSwatini.**
2. **Former Yugoslav Republic of Macedonia becomes Republic of North Macedonia.**
3. **Robert E. Lee High School in Springfield, VA to get a new name**

Words & Sports

It is not uncommon for sports teams–local, state, and national–to have controversial names. This just points to the power of language and naming. Read up on The Washington Redskins for a case study here .

The first example reflects a trend among formerly colonized places to re-name places based in languages and systems of meaning that pre-date colonial influence. Re-naming, thus, is a way to symbolically and sometimes materially throw off or reject colonial power, possession, influence, and identity.

The second example illustrates how naming is deeply and inherently tied to cultural, national, and place identities.

The third example may strike much closer to home and illustrates how the choice *or* avoidance of certain names and words themselves is a way to signal allegiance with or distance from widely perceived meanings of those names. Controversies surrounding the changing of names (not to mention removing statues), in this case, associated with the Confederacy in the US, abound among everyday individuals, public historians, businesses, and local, state, and national governing bodies and policy-makers. The controversies are based around language–a system of communication that produces meaning.

We as individuals and a society have to determine which particular words and symbols we want to be associated with and accept, reject, or re-interpret popular and contemporary meanings of said words and symbols. The process is and should be continuous.

Linguistic Variations

You learned about two major linguistic variations above, pidgins and creoles, but let's pause and talk briefly about two more commonly discussed features of language: dialect and accent. The basic distinction is that a dialect differs from its base language in vocabulary, grammar and spelling, and pronunciation whereas an accent differs from its base language in terms of pronunciation style. Think of it like this: dialects are place-based variations of language and the aspect of a dialect that includes variations in pronunciations is called an accent. See the video below for more and consider how dialects and accents are tied to conceptions of identity across many scales.



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Exercise: English accent quiz

Take this quiz from Babbel (scroll below video to see quiz) to see if it can determine from which region of the US you are from or learned English. Did it guess correctly?

Check out these heat maps of language use in the US for fun.

The Language Lifespan

By now, you should already have a good sense of how languages are born and how they grow through time and across space, but you might be wondering: do languages die? The answer is yes, more or less.

UNESCO, the United Nations Educational, Scientific, and Cultural Organization, classifies languages in terms of several levels of endangerment, ranging from safe, referring to languages that are spoken and transmitted across generations, to vulnerable, referring to languages typically only spoken in certain spaces or circumstances, to endangered, referring to languages that are not spoken nor transmitted across generations, to extinct, referring to languages with no native speakers (extinct languages can possibly be revitalized, so you can think of them as technically dormant). See UNESCO's chart of endangerment for more.

Exercise: Endangered Languages

Read through UNESCO's Frequently Asked Questions on Endangered Languages to learn more about causes of language endangerment, examples of extinct languages, and what might be done to preserve and revitalize vulnerable and extinct languages.

The number of speakers of a language is certainly a key criterion in determining its overall health status or level of endangerment. As a general rule of thumb, areas that have high linguistic diversity are most susceptible to some kind of endangerment or extinction. Papua New Guinea, which is an island-nation in the world region of Oceania, is

the most linguistically diverse place in the world. Of the approximate 7,000 known languages, over 800 of them are spoken in this country. What?! But more importantly, why? The most commonly cited reason includes the fact that the mountainous terrain creates isolated communities of people who have little interactions with each other over time. Thus, pockets of speakers of one language exist in relative isolation from other geographically proximate pockets of speakers of another language and languages do not collide or co-evolve due to contact. We see here a clear example of how the physical geographic layer of place plays a role in shaping human systems, in this case, language. As a very linguistically diverse place, Papua New Guinea is also at high risk for experiencing language losses and given how integral language is to culture, this could prove to be rather culturally damaging and traumatic.

Exercise: Language Loss

View this Story Map of endangered languages. Select a language to examine by choosing one that appears on the top scroll bar or clicking a pin on the map. Read any information associated with the language that appears in the left pane. Then search the language in the UNESCO Atlas of World's Languages in Danger and respond to the following prompts:

- **Summarize key features about the endangered language you chose to examine (ex: where is the language spoken? what level of endangerment does it suffer? how does it relate to the culture and identity? Cite specific statistics when possible (ex: number of speakers).**
- **Conduct a web search to find out what efforts are being made to preserve or revitalize the endangered language. If you cannot find anything about the exact language, research efforts being made to revitalize other languages and/or brainstorm your own ideas on how this could be done. Describe at least 3 ways that the language is being or could be revitalized, being as specific and precise as you can.**

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2.6: Urban Geography

Learning Objectives

- Describe how urban models help explain and predict urban development.
- Explain how urban areas are expanding and why.
- Determine the challenges to urban growth.
- Explain how cities are being build to meet current and future social and environmental demands.

Essential Questions

- Some have argued that how cities are planned and developed is more important than state and federal policies in regards to social and environmental problems. What arguments do you have for or against this idea?

Distribution of Urbanized Areas



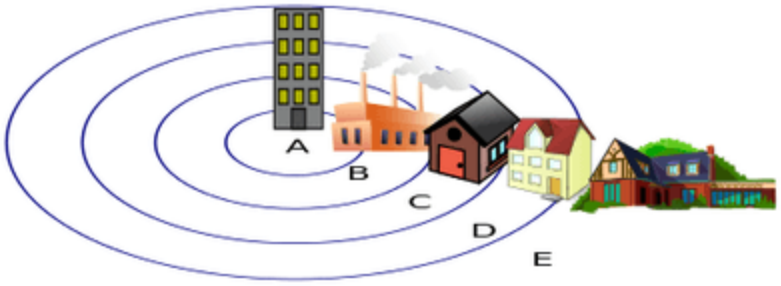
CENTRAL BUSINESS DISTRICT

Most urban centers begin in the downtown region called the **central business district** (CBD). The CBD tends to be the node or of transportation networks along with commercial property, banking, journalism, and judicial departments like City Hall, courts, and libraries. Because of high competition and limited space, property values for commercial and private ownership tend to be at a premium. CBDs also tend to use land above and below ground in the form of subways, underground malls, and high rises. Sports facilities and convention centers also tend to be dominating forces in CBDs.

URBAN GROWTH MODELS

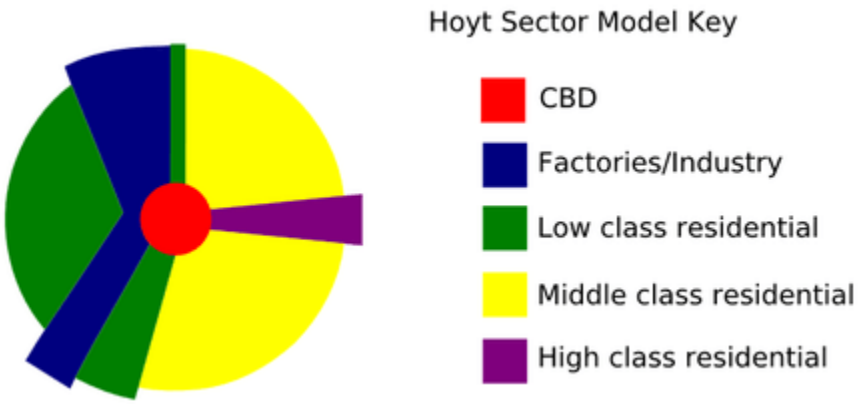
Urban planning is a sub-field of geography and until recently was part of geography departments in academia. An urban planner is someone trained in multiple theories of urban development along with developing ways to minimize traffic, decrease environmental pollution, and build sustainable cities. Urban planners, sociologists, along with geographers have come up with three models to demonstrate and explain how cities grow.

The first model is called the **concentric zone model**,

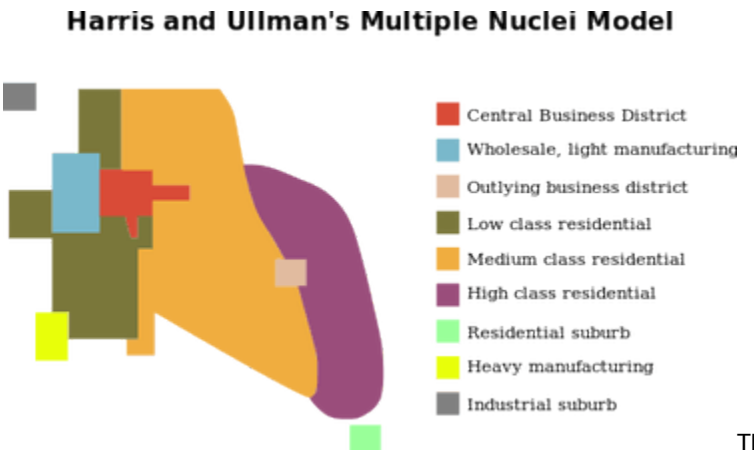


Land Use Rings around a CBD.

which states that cities have the ability to develop in five concentric rings. The inner zone of the cities tends to be the CBD, followed by a second ring that tends to the zone of transition between the first and third rings. In this transition zone, the land tends to be used by industry or low quality housing. The third ring is called the zone of independent workers and tends to be occupied by working-class households. The fourth ring is called the zone of better residences and is dominated by middle-class families. Finally, ring five is called the commuter's zone, where most people living there have to commute to work every day. Land prices are higher in the central rings and lower in the outer rings. Activities which require frequent human interaction and minimal land area such as banking are in the central rings while activities which require lots of land but low profit per acre such as wheat farming are in the outer rings.



The second model for city development and growth is called the **sector model**. This model states that cities tend to grow in sectors rather than concentric rings. The idea behind this model is that "like groups" tend to grow in clusters and expand as a cluster. The center of this model is still the CBD. The next sector is called the transportation and industry sector. The third sector is called the low-class residential sector, where lower income households tend to group. The fourth sector is called the middle-class sector and the fifth is the high-class sector.



The third and final urban design is called the **multiple nuclei model**. In this model, the city is more complex and has more than one CBD. A node could exist for the downtown region, another where a university is situated, and maybe another where an international airport may be. Some clustering does exist in this model

because some sectors tend to stay away from other sectors. For example, industry does not tend to develop next to high-income housing. Determining which urban model fits a particular city is often based on census data.

The U.S. Bureau of the Census divides urban areas into census tracts, where each track contains approximately 5,000 residents. Every 10 years, the bureau does a complete count of the country's individuals and publishes the results. Data includes household incomes, gender, ethnicity, high school completions, and more. This information is not only collected but mapped for spatial analysis. Social scientists use the data and maps to analyze demographic patterns spatially and over time to help understands current and project future social, demographic, and economic trends.

Sociologists, geographers, and urban planners know that no city exactly follows one of the urban models of growth. But the models help us understand broader reason why people live where they do. Higher income households tend to live away from lower income households. Renters and house owners also tend to segregate from each other. In fact, renters tend to live closer to the CBD, whereas home owners tend to live along the outer regions of the city. It should be noted that the three models were developed shortly after World War II and based on U.S. cities; many critics now state that they don't truly represent modern cities.

An excellent website on urban planning using geospatial technology is called the Urban Observatory. The website provides access to spatial data for cities all around the world and allows you to simultaneously view multiple cities at once. Compare and contrast visualized information for a greater understanding of life in the 21st century.

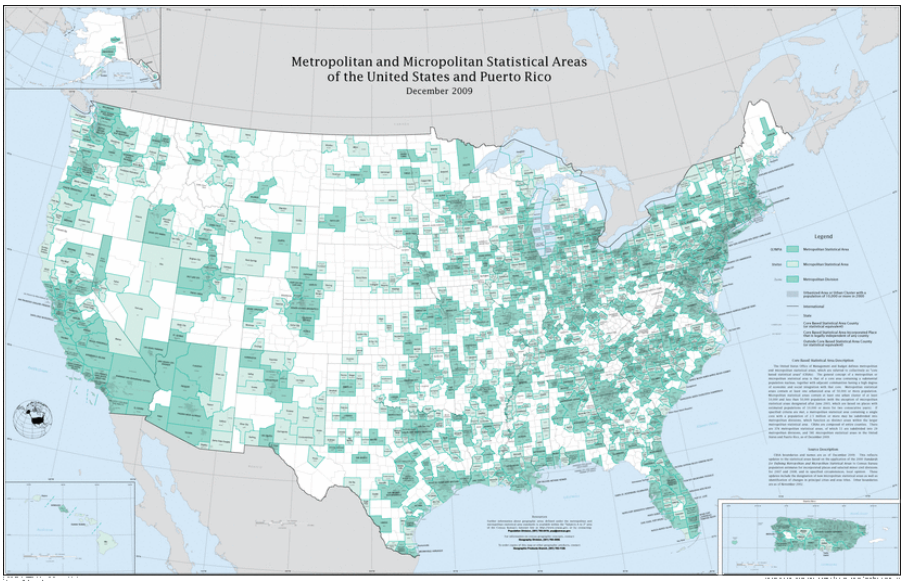
Urban Expansion



METROPOLITAN STATISTICAL AREAS

A **city** is defined as an urban settlement that is legally part of a larger governing entity. Cities have local officials, can raise taxes, and are responsible for providing services to local residents. The central city is a city that is also surrounded by suburbs and together is called an urbanized area. Census counts suggest that 70 percent of Americans live in an urbanized area.

The U.S. Bureau of the Census has created a way of measuring the influence cities have on surrounding regions, called the **metropolitan statistical area** (MSA). An MSA is defined as an urbanized area with at least 50,000 residents, includes the county the city exists within, and any surrounding counties if a high percentage of the residents within those counties work in the central city's county. The federal government has also created smaller designations for urban areas smaller than 50,000 residents and is called a **micropolitan statistical area**. If there is any overlap between these two statistical areas, usually in the form of commuting and transportation patterns, the census has created the term combined statistical area.



FRAGMENTED GOVERNMENTS

There has been an ongoing conflict between cities and peripheral urbanized areas outside of the central city who want to maintain their independence. This becomes problematic for housing, taxes for schooling, transportation, garbage disposal, and law enforcement. If urbanized areas are legally incorporated into an existing city, the process is called **annexation**. In order for annexation to occur, the majority of the residents in the outer regions must vote to approve such an acquisition. The debate over annexation varies throughout the United States and truly is a local issue.

Challenges to Urban Growth



INNER CITIES

One of the major problems that cities face is deteriorating areas, high crime, and homelessness, and poverty. As noted in the urban models, many lower income people live near the city, but lack the job skills to complete for employment within the city. This often results in a variety of social and economic problems. Census data shows that 80 percent of children living in inner cities only have one parent and because child care services are limited in the city; single parents struggle to meet the demands of childcare and employment. Problems associated with lower income areas are often violent crime (assault, murder, rape), prostitution, drug distribution and abuse, and homelessness, and food deserts.

https://youtube.com/watch?v=EzZzZ_qp...ature%3Doembed

SLUMS AND SHANTY TOWNS

Some of these inner city areas are called **slums**, which is a heavily populated urban informal settlement consisting of poor, inadequate living standards. Most slums lack proper sanitation services, access to clean drinking water, law enforcement, or other essential necessities of living in an urban area.A **shanty town**, also known as a **squatter**, is a slum settlement that usually consists of building material made out of plywood sheets of plastic, cardboard boxes, and other cheap material. They are usually found on the periphery of cities or near rivers, lagoons, or city trash dumps.

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Based on reports by UN Habitat, it is currently believed that over 35 percent of the all those living in urbanized areas of the world live in slums and shanty towns. There are a variety of reasons why these types of living conditions develop that include: rapid rapid rural-to-urban migration, economic stagnation and depression, high unemployment, poverty, informal economy, poor planning, politics, natural disasters and social conflicts.



GENTRIFICATION

As a way for city officials to deal with inner city problems, there has been a push recently to renovate cities, a process called **gentrification**. Middle class families are drawn to city life because housing is cheaper, yet can be fixed up and improved, whereas suburb housing prices continue to rise. Some cities also offer tax breaks and cheap loans to families who move into the city to help pay for renovation. Also, city houses tend to have more cultural style and design compared to quickly made suburb homes. Transportation tends to be cheaper and more convenient, so that commuters don't spend hours a day traveling to work. Couples without children are drawn to city living because of the social aspects of theaters, clubs, restaurants, bars, and recreational facilities.

The logic behind gentrification is that it not only reduces crime and homelessness, it also brings tax revenue to cities to improve the city's infrastructure. But there has also been a backlash against gentrification because some view it as a tax break for the middle and upper class rather than spending much needed money on social programs for low income families. It could also be argued that improving lower class households would also increase tax revenue because funding could go toward job skill training, child care services, and reducing drug use and crime.



URBAN SPRAWL

Again referring back to census data, over half of all live in suburbs rather than in the city or rural areas. There was actually an urban sprawl model developed to explain U.S. development called the peripheral model. This model states that urban areas consists of a CBD followed by large suburban are of business and residential developments. The outer regions of the suburbs become transition zones of rural areas.

The attraction to suburbs is low crime rates, lack of social and economic problems, detached single-family housing, access to parks, and usually better schooling. These are nationwide generalizations and not necessarily true everywhere. Suburbs also tend to create economic and social segregation, where tax revenues and social resources provide better funding opportunities than in inner cities. Of course, there is also a cost to urban sprawling. Developers are always looking for cheaper land to build, which usually means developing rural areas and farm land rather than expanding next to existing suburbs. Sprawl also requires more roads and utility lines to be built to reach further away from the urban centers. This often causes local governments to spend more on new infrastructure development than is received through tax revenue. Air pollution and traffic congestion also becomes a problem as working households are required to travel farther to and from work. Suburbs tend to be less commuter friendly to those who walk or bike because the model of development is based around vehicle transportation.

Building Cities for the Future

With a world of 7.3 billion people with the majority of them living in urbanized areas, it is becoming ever more important to design cities to efficiently fit dense populations of people yet in a way that is healthy and sustainable for the people and the environment. This includes more efficient transportation systems, walkable communities, green building projects, and urban gardening.

Many would argue that the future of humanity is not going to be determined by national governments, but by how we develop or local cities and communities.

Click here to listen to NPR's "Cities as Infestations" story (2012) to get a planetary view of the human impact on geographic and biological systems through city building:

"Every geological epoch gets a name. Looking back over millions of years, you have your Eocene, your Pliocene, your Holocene epoch (that was the most recent one). Now folks are suggesting that we are entering a new epoch, the Anthropocene. The Anthropocene means it's our activity which is the main driver changing the planet. But you know what? The Anthropocene is really the epoch of the city. It's our city building — on a massive, planetary scale — that is at work here."



Cities as Infestations

https://youtube.com/watch?v=SM_hPk4r...ature%3Doembed

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2.7: Urban and Suburban Spaces

Why cities?

Cities are a relatively recent part of human culture. The first settlements recognized as cities arose about 10,000 years ago in what is now considered the Middle East. While this region saw the first cities, cities also developed independently around the world in the millennia following, emerging from **hearth areas** of civilization. Why did cities come about during this time period? Different scholars will point to different reasons, but these three are commonly provided:

1. Agriculture became efficient enough to create a productive surplus
2. A growing population created pressure to densify
3. New social organizations of power developed

Agriculture, the process of cultivating plants and/or livestock, is often given as a primary reason for the creation of cities. Once humans began to cultivate crops, humans became less migratory and built permanent structures so that they could tend to and store agricultural products. As humans improved agricultural methods, soon a single farmer or farming family could produce more food than they themselves needed for **sustenance.** The result is that within this permanently-located society, not everyone needed to be an agriculturalist. Instead, the **productive surplus** meant that people in the society could have more specialized, non-agricultural livelihoods; a more complex division of labor emerged. The **specialization** that took place meant that some people would grow and raise food for society, while others would build structures, create tools, defend the settlement as professional soldiers, or become philosophical/religious leaders. As agricultural production improved, more people had access to food leading to population increases. However, agricultural technology did not yet exist to improve marginal lands to productive lands. This meant that the increasing population needed to be more **dense** around productive lands, leading to denser settlements like cities. Lastly, most of these nascent urban societies, in creating a complex division of labor, moved away from **egalitarian** power structures and instead became more **hierarchical**, with a few at the top with much societal power and influence and many at the bottom with little power. Power often came to religious or military leaders. Organized power also enabled the society to collect taxes, pooling resources so that large, permanent structures were built. These structures, such as temples, themselves demonstrated the increased power of the society.

DEEPEN YOUR UNDERSTANDING: This chapter is fairly comprehensive, but if you are looking for more clarification or to complement the knowledge you gain from reading this chapter, consider perusing this linked text.

Spatial structures of cities

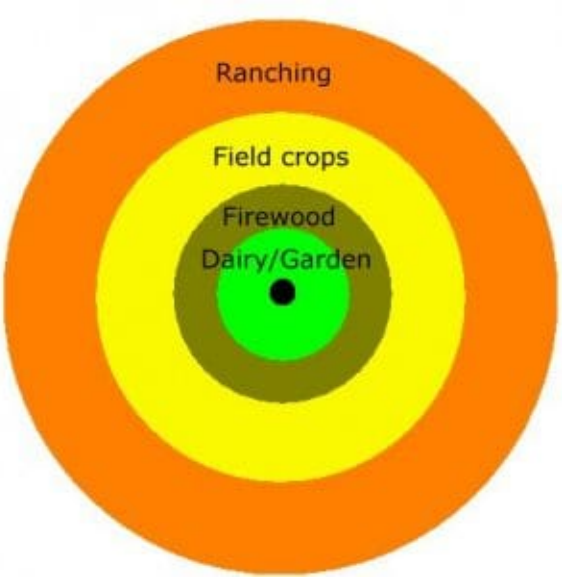


Diagram of the von Thunen model (by author)

Before investigating how cities are internally structured, it is illustrative to view the **von Thunen model** of **hinterland** organization. In 1826, Johann Heinrich von Thunen created an economic model of how the area around the city from which resources are gathered (the hinterland) is organized. Two key points of this economic model become analogous for economic rationale for how cities are theorized to organize. First, this model showed that proximity to the city came with a premium on price due to desirability. This meant that land uses nearest to the city had to be the most profitable in order to afford land rent. Second, the resulting organization of the hinterland is in **concentric rings**, with more profitable products closer and less profitable products further from the center. As an economic model, these outcomes are contingent upon several assumptions, none of which are truly realistic. However, it models an idealized form that is altered and complicated by the complexity of local and regional geographies in all locations. The assumptions are:

- The City is in the center of an isolated State; it is a single market
- The hinterland itself is surrounded by "wilderness"; combined with the prior assumption, it means that there are no connections or products coming to this region or being exported out of the region
- Land is ubiquitous; there are no differences in soil type, topography, or climate, and no water features. All environmental factors are equal everywhere
- Farmers transport their own products to market using an ox cart without roads; roads change the ubiquity of land and therefore don't exist
- Farmers behave rationally in order to maximize profits; farmers seek the most profitable use of their land

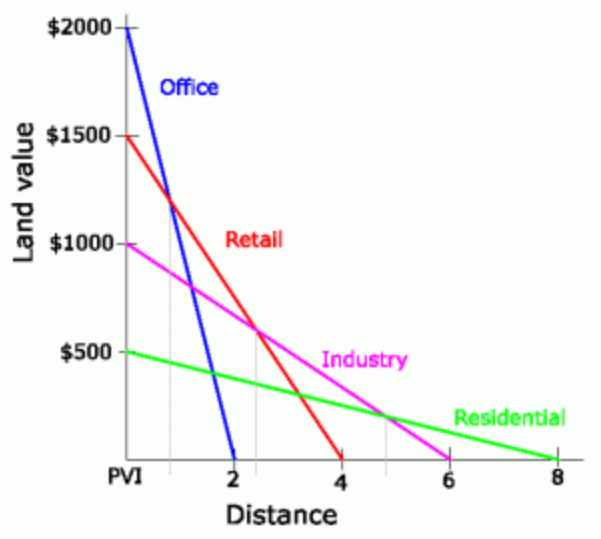
Given these assumptions, von Thunen predicted that certain types of production (or land use) would dominate certain rings. The inner-most ring would be dedicated to dairy production and market gardening. Both categories of agriculture are bulky to transport, can potentially spoil quickly (this is before the invention of refrigeration), and have relatively high productivity per acre in terms of sale price. As such, farmers both can afford the more expensive land, and need proximity in order to get products to market. The next ring is wood for fuel. As with dairy/gardening, it is bulky and hard to transport, but does not produce as much value per acre, therefore it occupies less expensive land. Following fuel wood is a ring of grains and field crops. This produce needs many acres, but cannot merit a large market value per acre planted. Grains however store well and do not need to come to market immediately after ripening. Farmers therefore need larger quantities of cheaper land, and are willing to travel further to market due to a lack of immediate spoilage. The last ring is ranching and livestock. Livestock is transported easily to market, so proximity is not necessary. As well, though an individual cut of meat may be more expensive than the products mention above, meat production is the least profitable per acre. It may take years to raise livestock to the proper age for butchering and it takes vast amounts of grazing land for the larger animals. For these reasons, ranching is furthest from the market and the last agricultural ring before wilderness.

When it comes to cities, similar economic models are used to look at basic spatial structural patterns. A **land value model** of urban land uses is one such example. In this model, land values are estimated based on bid rent. **Bid rent** is the amount of money an individual parcel of land can receive for any land use. While true bid rents are based on a function of **site** and **situation** (attributes of the parcel itself and its location/accessibility), the land value model simplifies reality through these assumptions:

- There exists a **prime value intersection** (PVI); the central point of a city with the highest amount of access
- Access from all other places to the PVI is based solely on distance; no transportation network effects
- All sites are ubiquitous; site advantages like hills, ocean views, and others do not exist
- There is no zoning or planning for particular land uses; land use is based on market forces only

With these assumptions, we get the formula:

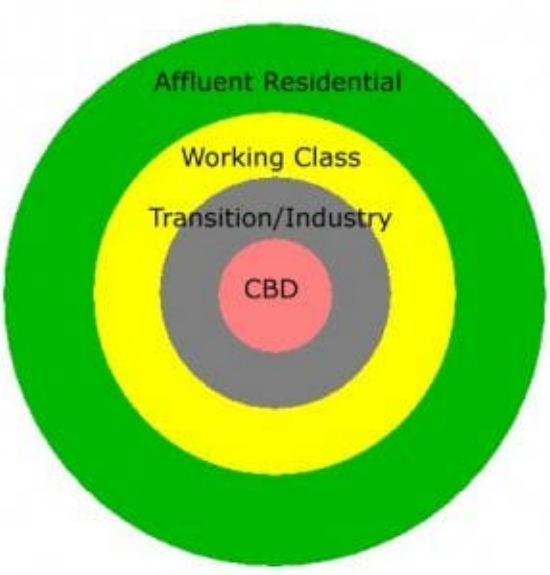
$$\textit{Bid Rent} = \textit{Land Value at PVI} - \textit{Access Costs}$$



By author

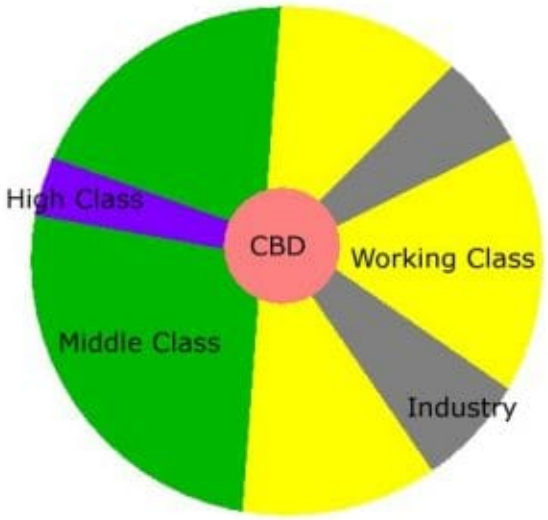
Different land uses have different attenuating effects of distance. In other words, some land uses must have high access, and others can have further distance from the PVI and still be profitable. Land uses have different **bid rent curves**, or different slopes, affected by accessibility. The image to the left is a rough demonstration of this concept. In this simplified model, there are four land uses: office, retail, industry, and residential. Each has a different bid rent curve on the basis of access costs. Office space, where corporate headquarters locate, need access and connectivity, and are also quite profitable. The office bid rent curve then is the steepest; office land uses are willing to pay a premium for the most access, and are unwilling to pay if access decreases too much. Retail likewise wants access, for walk-in shoppers and increased customer traffic, but while profitable are not as profitable as office space. Retail land uses then won't pay the extreme premium of office space, and is willing to have slightly less access. Industry also desires centrality, but generally needs more parcel space than is affordable near the PVI. Industrial land uses are less profitable and need lower rents that have less accessibility. Residential uses have the lowest profitability but also have little stake in needing prime access, and have the shallowest bid rent curve.

As a result, whichever land use is willing to pay the most at each location becomes the land use of that location. This is the "highest and best use" of the land. The result are rings of development based on distance. The gray lines on the image show the distance break points when one dominant land use cedes to another that is willing to pay the highest rent. The center ring is office, then retail, then industry, then residential. At a certain distance, residential land uses too are far from the PVI that rent could be $0 and residences still won't be built. Think of it this way; if someone offered you a free house, but it was 500 miles from your work or school, you probably wouldn't live there! The access costs of commuting would be too great.



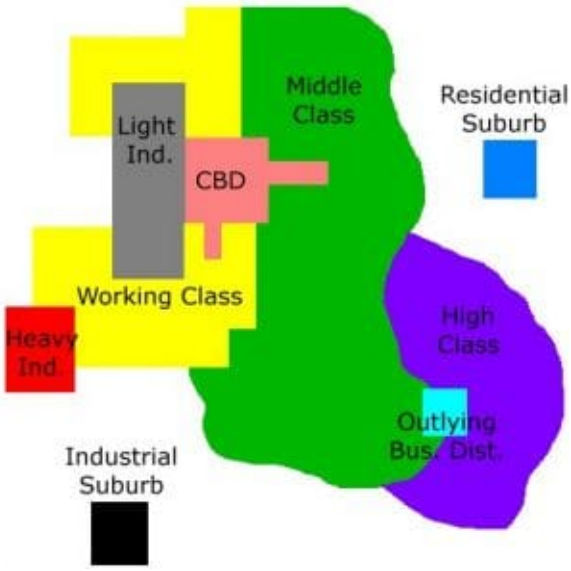
The Burgess Concentric Ring model (by author)

The **Burgess concentric ring model** is, in many ways, seemingly similar to the land value model outlined above, but with one major difference; the land value model is *economic* in nature, and the Burgess model is *social*. The Burgess model outlines rings of zones based on creating social distance between different groups of people. The inner-most ring is the **Central Business District (CBD)**, where offices, public-facing government buildings, major institutions of culture (EG: museums), and retail are situated. Surrounding that core is a zone of transition that includes industry and factories. The last rings are residential, with the working class occupying land closest to factories and the more affluent classes (middle and upper class) living furthest away. While Burgess did see that the residential land uses where stratified by income, the rationale was still social in nature. The wealthy were living further away to avoid the dirt and noise of the city. Their ability to do so was of course due to economic advantages, like being able to afford transportation and larger plots of land, but the Burgess models the choice as being one to create social distance and not the "highest and best use" of land.



The Hoyt Sector model (by author)

The **Hoyt sector model** adapted Burgess to show how cities do not stay in neat circles, but instead have expanding zones of development that often hug transportation corridors. Cities may have sectors of industry that follow a railroad, highway, or body of water, sited so as to lower transportation costs of goods. Small and large cities alike have a 'main drag' of businesses and retail that follow major surface roads. Sometimes the most fashionable neighborhoods of a city generally expand out corridors; these neighborhoods are sometimes nicknamed a "Millionaire Mile" in the city, indicating its sector-based alignment. The Hoyt model still shows that residential uses are largely segregated by socioeconomic class.



Harris and Ullman Multiple Nuclei model (by author)

A third common model discussed is the **Harris and Ullman multiple nuclei model**. This model starts with the central business district of the other models, but shows that a newer and smaller CBD develops on the outskirts of the city. This newer CBD takes advantage of shorter commuting distance for the more affluent people living in the residential areas far from the city center. As well, the multiple nuclei model shows the effect of transportation hubs, like ports or airports, on settlement patterns. Overall, the multiple nuclei model is adapting towards American cities becoming automobile dominant and much more **suburban** in nature.

It is important to note about these models that they are largely based upon cities of the developed world, particularly in North America. Concentric rings was based upon Chicago in the early 20th century, while the multiple nuclei model was based upon Los Angeles at the beginning of the massive suburban exodus that would become dominant in North American cities.

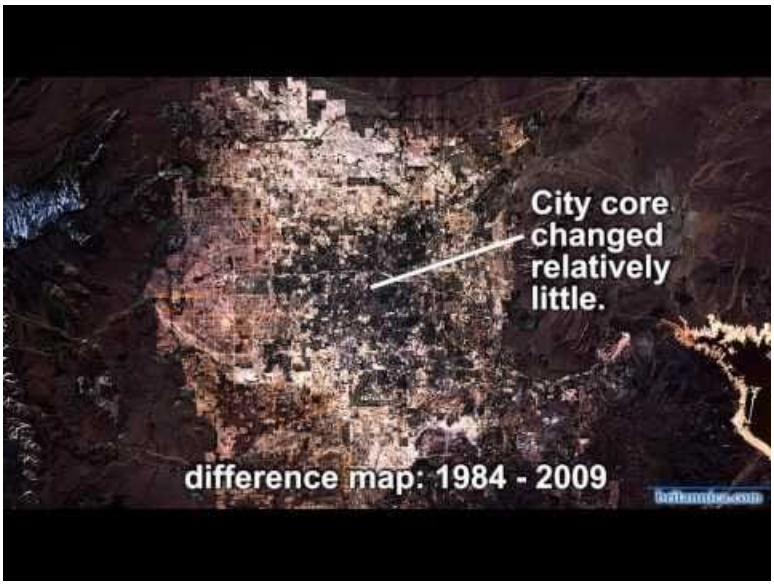
Exercise: Slums

Slums are areas within or adjacent to an urban center occupied by people with no-very low income who live in precarious infrastructure vulnerable to damage or collapse from heavy winds, rains, mudslides, and other hazards. Structures in slums are often not hooked up to public services like running water or electricity. People living in slums often participate in the **informal economy**, which is comprised of jobs without benefits nor subject to labor laws and minimum wages. See below for more information.

- Slums in Latin America are called **favelas** (Brazil) and **barrios** (Venezuela). Check out this video about favela tourism. *What's YOUR take on favela tourism? Who does it benefit, at whose expense, and who does it harm?*
- Makoko is a floating slum in Lagos, Nigeria. *Why is there an effort to map Makoko? What opportunities and/or risks come with being mapped?*

Suburbanization

Between the urban core and the rural hinterland, serving as a kind of buffer and transition zone between the two, are **suburbs** or **suburban spaces**. The suburbs are primarily residential but also have public services like schools and businesses people need to rely on to go about their daily lives. Plenty of people live and work in the suburbs, but commuting to work in or nearer the urban center and living in the suburbs is the predominant pattern. **Sprawl** refers to the expansion of suburbs without a population to match; in other words, infrastructure is built, electrical lines are put up, but the space is not yet occupied with people. If you have ever driven through a neighborhood with brand new houses, usually looking pretty similar to each other (having **standardized** housing allows for it to go up quickly and can be cheaper to purchase) but only a handful seem to be occupied, you've likely witnessed sprawl. An obvious critique of sprawling suburbs is the extreme consumption of land through this development pattern. Regions with modest or even negative population growth are still growing in terms of the footprint of development; a process which often destroys natural landscapes like forests and wetlands, and working landscapes like farms. The **wildland-urban interface** (WUI) refers to where human settlement meets unsettled and undeveloped spaces. Research shows that that expansion of settlement into the WUI, which provides residents with a beautiful residential setting, intermingled with more or less in-tact natural surroundings, increases risk for wildfire exposure because settlement is encroaching in "wild" spaces that experience natural fires. Another geographical critique of sprawl is that this development pattern often lacks a **sense of place**, or a uniqueness of feeling people attach to place. **Remote sensing** helps assess and measure sprawl, as evidenced in the video below.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pb.libretexts.org/sfccintrogeography/?p=162

The 1950s and 1960s in the United States are classically considered major periods of suburban development. This was in part due to changes in transportation which made it possible to more easily commute in and out of the city center, the culture of consumerism, and also because it was during the post-war era when families were reunited and expanding, and the government had programs incentivizing the construction and selling of houses for veterans. The creation of the Interstate system in particular changed the paradigm of commuting over long distances. Interstates not only connected major cities to each other, but cut through many cities themselves. As a result, suburbanites could live dozens of miles from the center of the city, but still commute via personal automobile in a reasonable time frame.

One such effort can be seen in Levittown, a planned community in Pennsylvania which had cookie-cutter houses specifically built for veterans. The video below shows historical footage of a house going up in a day in Levittown. What the video leaves out is the fact that this particular suburban project, and many others, contributed to **residential segregation**, a relic with which suburban spaces of today have to contend and reverse. During the early days of suburbanization, only those that could afford home and auto ownership could live in the suburbs, leading to socioeconomic segregation. While some suburbs maintain this separation of affluence, many suburbs now are places in which those of moderate incomes can live. The link in the grey box above discusses this further.



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Two additional patterns of suburban development are notable. First are new development patterns called **exurbs**. Exurbs are residential, prosperous, but rural areas beyond the suburbs. In the United States, the Census Bureau defines areas as either urban or rural mostly on the basis of population density. There is no definition for suburbs or exurbs at the federal government level. Generally, most suburbs maintain a high enough population density (roughly 1000 people per square mile or more) that the Census Bureau categorizes them as 'urban'. But, there are large swaths of land within commuting distance of cities that are defined as rural; in fact, the majority of land inside metropolitan areas is actually rural. This does not mean agricultural, however; there are many that live lifestyles quite connected to the nearby urban core but live in low population regions in the metropolitan area. These areas are the exurbs and the people are **exurbanites**. A major way of distinguishing between exurban areas and what we colloquially think of as rural is to understand the development pattern and the people occupying the space. Exurbs are generally affluent, shown by statistics on income levels or observing the large footprints of houses. Exurbanites are largely still connected to urban living via commuting and culture.

A second pattern is that of **edge cities**. Edge cities are new concentrations of business, retail, and residences outside of the urban core. They are so named edge cities as they are located on the edge of the traditionally denser development of a major city, but edge cities themselves are starting to be centers in their own right. The classic example of an edge city is Tyson's Corner in Northern Virginia. Edge cities are distinguishable from the surrounding suburbia by possessing development density (as viewed through taller buildings) and the presence of service/retail and office employment. However, edge cities do not have the density of 'traditional' urban cores. Other ways in which edge cities are unique compared to traditional cities are that edge cities:

- Are often **unincorporated**, meaning they lack municipal borders and local government
- Tend to have spread out, car-centric development
- Are often sited at the junctions between highways and expressways

Emphasizing the first point above, most edge cities are not legally-defined cities!

Edge cities developed in three waves. First, there was suburbanization of the population. People moved from the urban core into suburban developments. Second, retail suburbanized in new developments called malls. This 'malling of America' brought retail from the urban core to locations closer to the stores' affluent customer base. Third, companies and industry moved to these areas. White collar employers found cheaper land to build headquarters or to otherwise expand their business footprint within the region. As the third point above details, malls and employers tended to concentrate near junctions of large roads, facilitating the personal automobile as the primary means of transportation into these new centers.

Urban systems

Cities are connected, interrelated, and distributed in knowable ways. Cities organize according to an **urban hierarchy**, which how an **urban system** distributes cities on the basis of size and services. Urban settlements are **central places**; places in which goods and services are available for purchase. The more central a place is, more goods and services are available. Goods and services also have a **range**, which is the distance a customer is willing to travel to consume the good or service.

These interrelated concepts were placed together by Walter Christaller in 1933 as **Central Place Theory**. Small settlements like towns, villages, or hamlets have limited centrality and only provide goods and services with shorter range. These places provide for the people in the immediate area, such as those living in the hinterland. Larger settlements provide more goods and services, and some of those goods and services have a larger range, pulling customers from further away. These longer range goods and services may be those that are more expensive or of infrequent use. The result geographically is an urban system in which there are many smaller-sized places surrounding a few large, somewhat far apart large areas.

You as a reader have likely experienced this concept without knowing the theory behind it! If you are home, and notice that you are out of milk, you are probably going to walk or drive to a shop less than 10 minutes away. Likewise, people do not travel hundreds of miles in order to purchase gasoline for a car. These are goods that have a short range, and therefore we see lots of small settlements, fairly close together, in order to provide people with daily goods. On the other end of the spectrum, major professional sports, operas, and other cultural services are only found, with few exceptions, in the largest of cities. Customers are often willing to travel long spatial and temporal distances for these services. The same pattern is seen when looking at a single good. The types of automobiles available for purchase follow a similar pattern. Small settlements may have used car lots with inexpensive cars. Somewhat larger places will have dealerships for mainline or common makes like Ford and Honda. In even larger/more central places, higher-end brands like BMW and Lexus emerge. And, in only a few major cities are you likely to find

the most luxurious brands like Bentley and Lamborghini. One is unlikely to find a Tesla storefront in a tiny village!

Like the geo-economic models outlined above, Central Place Theory depends on assumptions of ideal conditions. If the ground is featureless and ubiquitous, and if transportation is equal in all places, the hierarchy of central places will be hexagonal in shape. The largest cities will be in a hexagonal pattern, with mid-sized cities arranged around each in a hexagon, with smaller cities around each of those in a hexagon, and so on down to the smallest settlements.

The urban hierarchy goes even higher than a region or a country; there are **global cities**. Global cities are cities that are influential in the worldwide economic system. These cities host a disproportionate amount of the world's most important business, culture, and politics. In other words, these are centers of power that have a strong influence over things that occur around the world. These are often, but not always, the largest cities. In some cases, there are large population cities that do not have a strong global influence; these are common in the Global South or developing world. While global cities are more often discussed for overall economic impact, one can also describe global cities in various economic sectors. For example, Milan is not one of the largest cities, but is globally important as a "fashion capital." The definition for global cities is loose, but commonly cities that have large, important financial sectors are included; think of cities like New York, London, Tokyo, and Shanghai with large stock exchanges.

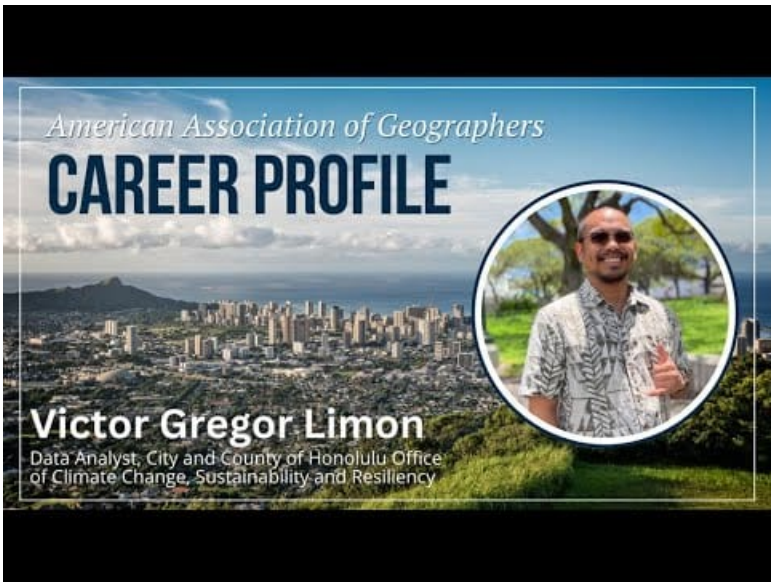
The largest cities are called **megacities**. These are extremely large cities, typically with 10 million people or greater, that are highly centralized and have the highest population in their state. One can also use the term megaregion as these are metropolitan regions that include developed land both inside and outside the city proper.

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2.8: Social and Economic Development

Learning Objectives

- Define economic development through human development and standard of living principles
- Analyze access to social development constructs with a focus on healthcare and education
- Explain gender inequality, what is causing it, and what the world is trying to do to address it
- Explain global extreme poverty and what is being done about it
- Explain how international trade is helping some nations improve their economic and social status

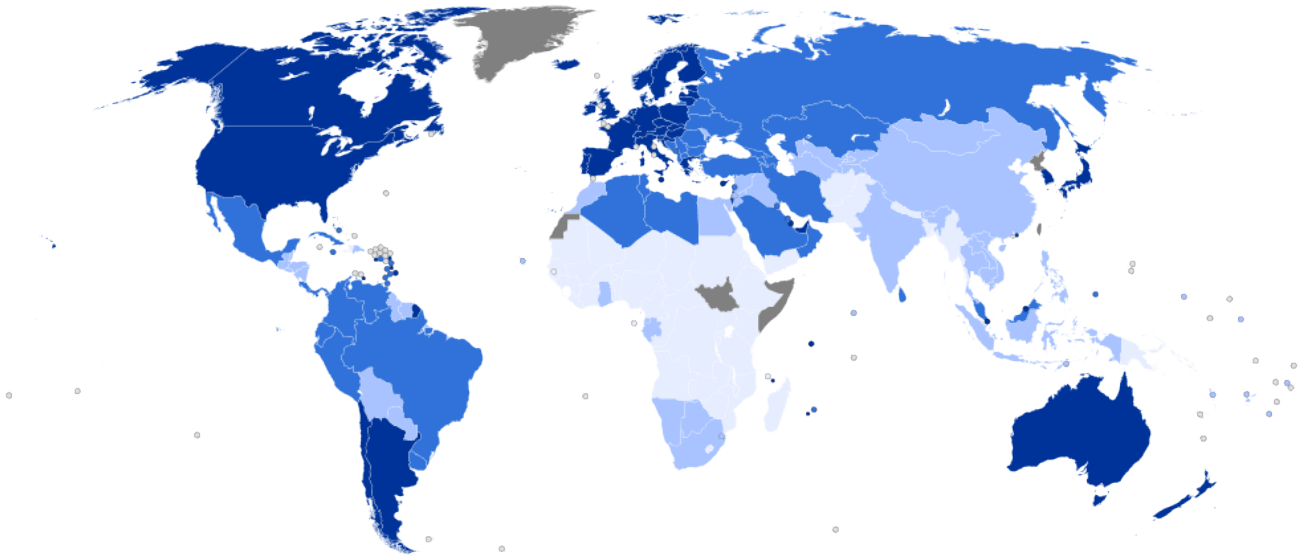


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Defining Human Development

HUMAN DEVELOPMENT INDEX

In order to analyze the world based on various levels of development, the term development must be defined. **Development** is the process of improving the material conditions of people through diffusion of knowledge and technology. All nations lie somewhere in the range of **more developed countries** (MDC) to **less developed countries** (LDC).



Human Development Index shows levels of development. The darker the blue, the greater development that exists within that country.

A nation's development level is based on the **United Nation's Human Development Index** (HDI), which focuses on economic, social, and demographic development. More specifically, the HDI focuses on a nation's *gross domestic product* (GDP) for economics, *literacy rates* and *education* for social factors, and *life expectancy* for demographics. A country's **gross domestic product** is the total market value of all officially recognized final goods and services produced within a country in a year. GDP per capita is often considered an indicator of a country's standard of living.

STANDARD OF LIVING

Standard of living refers to the level of wealth, happiness, comfort, and material goods, necessities available to a certain socioeconomic class in a certain geographic area. The standard of living includes factors such as income, quality and availability of employment, class disparity, poverty rate, quality and affordability of housing, hours of work required to purchase necessities, GDP, inflation rates, affordability to quality heath care, quality and availability of education, life expectancy, incidence of disease, cost of goods and services, infrastructure, national economic growth, economic and political stability, political and religious freedom, environmental quality, to name a few. It's interesting to note that the United States is not the highest on the HDI. The U.S. actually ranks 3rd because it is lower in education standards and life expectancy than most developed nations!

Jobs can be classified into three major types of sectors, which greatly influence the economics, standards of living, trade, and even social classes within a society. The first is called the **primary sector**, which are jobs directly related to the extraction of the Earth's natural resources (e.g. forestry, raw materials, or agriculture). In the **secondary sector,** jobs are focused on manufacturing raw materials from the primary sector to usable products. The **tertiary sector** provides goods and services to people in exchange for payment. These types of jobs include lawyers, doctors, educators, banking, retail, athletes, and others.

It's probably apparent that the majority of the jobs in developed countries (MDCs) are tertiary. There are primary and secondary sector jobs in countries like the United States, but the driving economic force is in the tertiary sector. MDCs are also more productive than LDCs, not because they work harder, but because of access and use of technology. In economics, **productivity** is the value of a particular product compared to the amount of labor needed to make it. **Value added** is the gross value of the product minus the cost of raw materials and energy.

Access to Social and Economic Development



ACCESS TO QUALITY EDUCATION

MDCs have the ability to invest more money and resources because of their economies, thus their people tend to be more educated, healthier, children are more likely to survive, and adults tend to live longer than those in LDCs. Probably the two most important or basic components to have a nation's developmental status to begin to rise is through *education* and *heath care*. There is a direct correlation to development and education. The more developed a nation, the more educated the population. In fact, one of the best indicators of a nation's level of development is it's **literacy rate**, the percent of people who can read or write. In MDCs, the literacy rate is usually around 98 percent, whereas in LDCs the literacy rate is around 60 percent. It impact of this is that books are written for people in MDCs and scientific advances tend to occur in these countries. Compared to LDCs, MDCs spend less of their GDP on education because their GDP's are so high. A small amount of a developed nation's GDP can have a higher monetary value than large amounts coming from the GDP of a less developed nation. In terms of percentage, LDCs spend more of their GDP on education than MDCs need to. In LDCs, the children going to school often have outdated books and not written in their primary language. Often times in LDCs, more schools are private than public because the government lacks the ability to fund them. Many of these schools are funded by outside religious groups and nonprofit organizations.

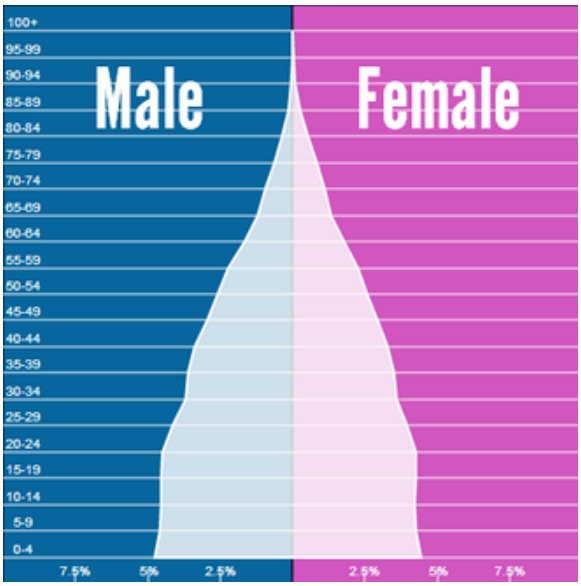
ACCESS TO HEALTH CARE

People are often healthier in MDCs than LDCs because of diet and healthcare. With diet, people in MDCs tend to have more access to calories, nutrients, and protein. But there is a dark side to this as well. Many developed countries are now experiencing epic obesity issues. In fact, more people in the world are obese than are hungry. It's not just about consuming too much food; many nutrition experts would also question the quality of the protein and nutrients from this food that more and more is in the form of trans fats.

With access to healthcare, MDCs tend to spend more infesting in public health than possible in LDCs. This is done at the governmental, private business, and individual level. In MDCs, there is a much lower ratio of nurses or doctors to patients than in LDCs. Because of this investment in health, the life expectancy in MDCs is much higher. Men tend to live 10 years longer than those compared to LDCs; women can expect to live 13 years longer in MDCs than in LDCs. There is a gender issue related to this too. In MDCs, men tend to live 10 years longer than women LDCs. But higher life expectancy comes with a price too. People tend to work longer into their life, preventing advancement of younger generations. The longer life expectancy through retirement also means that social programs must support an aging population.

Children also tend to have a higher survival rate, called infant mortality rates, in MDCs than in LDCs. In MDCs, the survival rate of children is near 99 percent, whereas in LDCs the rate is around 94 percent. Children tend to have higher mortality rates in LDCs because of malnutrition, starvation, dehydration, disease, and lack of access to health services and professionals.

Gender Inequality



Do you think there are more men or women on the planet? Well if you look at the population pyramid on the left, you'll see that women just outweigh men in population size. But what if the "data" doesn't really meet the realities on the ground? It is believed that between 60-100 million females were born in the current population, but have now disappeared of the planet, a concept called **gendercide**.

Currently no social scientist or governmental agency like the United Nations has found a country where women are treated equal to men. To determine the equality, or inequality, of women in nations, the **Gender Inequality Index** (GII) is used. The index uses a variety of measures to determine the inequality of females compared to males including: labor, reproductive health, and empowerment. The higher the number that a region receives demonstrates the greater the inequality in that region.

Some nations have severe gender inequalities, meaning that women have nearly no legal, social, or economic rights even when they are head of their household. Many argue that if the world focused on gender equality of females, most of our social, economic, and environmental problems would be greatly minimized.

In the 21st Century, gender inequity as Sheryl WuDunn states in her TED Talk "Our Century's Greatest Injustice? : is the moral and ethical issue of our time. Why have so many females disappeared out of the human population?

That's the point of the organization Half the Sky. The title is a Chinese proverb that means women hold up half the sky, so women need to be part of the solution.

In terms of reproductive health, maternal mortality ratio and adolescent fertility rates are determined. The **maternal mortality ratio** is a measure of the number of women who die giving birth per 100,000 births. The **adolescent fertility rate** is a measurement of the number of births per 1,000 women between the ages of 15 through 19. In LDCs, women are more likely to die during labor and have children during their adolescent years. Reproductive health is an important indicator of gender inequality because women tend to have fewer rights, including access to health care, where the gender-related development index is high.

There are several organizations around the world that are working on empowering females from young to old through a range of social and economic policies. The ultimate goal of these organizations like Half the Sky, CARE, and The Girl Effect to name a few, is to empower women so that they might have legal, economic, social, and health rights. **Empowerment** is something that can be tracked and monitored because it's a focus on two critical indicators in relation to gender inequality. One is to measure the percentage of seats held by women in a nation's federal government. This is a basically a measurement of political and economic power women have or don't have in a country.

Just take for example the United States Congress in 2013. Currently there are 20 women and 80 men serving in the Senate; there are 78 women and 357 men serving in the House of Representatives. How do you think that might influence policies to women, about women, and for women in the United States? How about the fact that no woman has ever served as President or Vice President and only one has served as the Speaker of the House, which is the third most powerful position in our federal

government. The other is a measurement of the percent of women who have completed high school.

Ending Global Poverty



Shantytown in Soweto, South Africa

It can be said that issues such as literacy rates, life expectancy, natural increase, and infant mortality rates have improved in LDC. But the gap between development and income is only getting wider. Only one-fifth of the world's population lives in MDC, but those same nations consume five-sixths of the world's resources. In fact, if all 7 billion people on the planet lived the lifestyle of the average American, it would require three planets! Currently there are over 1 billion people on the planet living in what's called extreme poverty.

James Rubenstein wrote in *Cultural Landscape: An Introduction to Human Geography* (2010), "The United Nations recently placed the contrast in spending between MDCs and LDCs in picturesque terms: Americans spend more per year on cosmetics ($8 billion) than the cost of providing schools for the 2 billion in the world in need of them ($6 billion), and Europeans spend more on ice cream ($11 billion) than the cost of providing a working toilet to the 2 billion people currently without one at home ($9 billion)." To put U.S. consumer spending in context with the cost of providing basic needs for those in the developing world, Americans spent $20 billion in 2007 on Black Friday–the day after Thanksgiving and the biggest shopping day of the year in the United States. Consider how redirecting the funds used for one day of shopping in the U.S. could do much to eradicate extreme poverty.

Currently over $1 billion people live in extreme poverty, a term used to define people who live on less than $1.25 a day for food, water, and shelter. In order for LDCs to develop, they first need to dramatically improve their gross national product (GNP). Once income starts flowing, that money needs to be invested into other HDI factors such social and other economic factors. The goal of the self-sufficiency model is to focus on reducing poverty than increasing wealth and creating wealth classes. Investment in a state's infrastructure and economic structure is spread equally so that all benefit. The idea of "local first" outweighs globalization. The problem with this model is that it can quickly become inefficient because local industries are protected by the government from outside forces. Also, it requires a large governmental fingerprint to administer the controls and conditions to equally distribute the wealth.

International Development

SELF-EFFICIENCY MODEL OF DEVELOPMENT

There are two models of economic development that play off each other as a way to. The first model is called the Self-Efficiency Model of Development, which encourages domestic development of goods and resources and discourages foreign influence and investment. Between 1990 to 2000, this was the main form of economic development until globalization became the dominate force. What makes this model of development competitive to international trade models is that governments create barriers through the form of tariffs on imports, which makes them more expensive and less economically competitive with their local

businesses. New businesses are nurtured until they and economically sustainable and competitive enough to compete with businesses abroad.This model of development prides itself in more equal distribution of resources to a nation's people and businesses over foreign entities and investments. But there are several critics of this form of development because they argue that this model protects inefficient businesses and does not reward competitive and highly efficient ones, requires a large bureaucratic government to administer this model of development and limit abuse and corruption, and does not receive the benefits of rewarding foreign corporations that could provide goods and services to countries with limited resources.

MODERNIZATION MODEL OF DEVELOPMENT

The other model for economic development is through international trade. W.W. Rostow proposed in the 1950s the idea of five-stage model of development that competes with the self-sufficiency model. In a report by Peter Kasanda, Rostow's Modernization Theory of Development implies that nations should use local resources and industries to sell scarce or needed resources globally through international trade. The money that comes back to the country would increase the nation's GDP, which could then be used to improve the development of infrastructure, invest in education and healthcare, and ultimately improve a country's standard of living. The following is the 5-stage model of how progress and development might occur for a country:

- **Traditional Society** – This primary sector is determined for societies that have little economic development and a high percentage of people active in family-scale subsistence agriculture. Most of the money for development goes toward religious or military activities.
- **Economic Growth** – Key investments in core structures of the existing economy to expand it's development. Structured invests in mining and larger-scale agriculture and with technology to enhance the efficiency of existing infrastructure. The goal is to invest in the overall structure of the nation's economy so the production of goods can begin to occur.
- **Economic Takeoff** – Investment and development leads to expanded, but limited activity in mining, textile, and food production along with continued improvements and investment in modern technology. A key indicator of the "takeoff" stage is when the people in the country become more driven by economic development rather than traditional activities. Is should also be noted that this is often times when concerning issues of slavery and sweatshops begin to surface if not handled properly.
- **Drive to Economic Maturity** – During this period, society is driven by modern technological advances over most other areas of the economy. Technology drives production and efficiency throughout all parts of the economy. It is at this time when a local economy becomes an international economic player. This stage is often times said to be an extension of the "takeoff" stage, but more expansive than limited in scope.
- **Age of Mass Consumption** – This final stage of economic development occurs when an economy shifts from a secondary sector of manufacturing toward the tertiary sector of services. The economic status of the nation's society also becomes driven by mass consumption of disposable goods.

The theory of international trade has become the preferred way to improve economic development. The reason is because most nations cannot produce all the goods and resources they require. So if nations can focus on specific goods and services to export, they can return purchase the goods and services they need.

In 1995, the World Trade Organization (WTO) was created to represent 97 percent of the world-trading establishment. It is through the WTO that nations can negotiate with each other international trade restrictions, governmental subsidies and tariffs on exports. The WTO also has the power to act like an international court to enforce international agreements.

The WTO has been highly attacked by liberals and conservatives. Liberals believe that too many actions or rulings are done undemocratically and behind close doors. They also believe the organization focuses more on the rights of corporations rather than poorer nations. Conservatives believe that no international organization has the right to dictate the choices of sovereign nations. Learn more about the World Trade Organization.

ECONOMIC SLAVERY

There's also a darker side to international trade and that exists in the black market. On the poaching side, animals ranging from mountain gorillas, rhinoceroses, and African elephants are being slaughtered for parts to be sold. There are also natural resources such as diamonds, gold, stonery, textiles, and more that are either mined or assembled using mass slavery. The products are sold to MDCs to fund local and regional civil wars like the in Uganda, Angola, Sierra Leon, and the Democratic Republic of Congo. Many times, people of all age groups who try to escape slavery are often times raped, have body parts amputated alive and with no medicine, or killed all to fear, power, and control. The TED Talk "Photos that Bear Witness to Modern Slavery" and National Geographic Society's documentary "Diamonds of War: Africa's Blood Diamonds" are both powerful, but disturbing witnesses of

how slavery is used all around the world to fund political conflicts and wars.

UNITED NATIONS MILLENNIUM DEVELOPMENT GOALS

There is broad global support for addressing extreme poverty because of it's implications in regards to global and local economics, environmental protection, geopolitical stability of governments, and humanitarian efforts. In 2002, the United Nations created the Millennium Development Goals (MDGs) to proactively reduce extreme poverty in half by 2015. The MDGs are broken down into eight smaller goals, each with a specific target or mission to accomplish.

The MDGs have been updated and are now called the Sustainable Development Goals. These are overarching guidelines that all major policies and programs run in cooperation with the UN strive to achieve.



Here is more information on each goal.

In Bono's TED Talk on global poverty, he said "Human beings have been campaigning against inequality and poverty for 3,000 years, but this journey is accelerating. Bono 'embraces his inner nerd' and shares inspiring data that shows the end of poverty is in sight ... if we can harness the momentum. Bono, the lead singer of U2, uses his celebrity to fight for social justice worldwide: to end hunger, poverty and disease, especially in Africa. His nonprofit ONE raises awareness via media, policy and calls to action." Some may ask, why Bono? He's just a millionaire "rock star" who doesn't know a thing about poverty issues. It turns out that Bono is extremely active in humanitarian issues and one of the largest philanthropists in the world. He started the ONE Campaign to help inform, educate, and advocate about extreme poverty. He has also studied under one of the economic leaders on global poverty, Dr. Jeffrey Sachs, the Director of the Earth Institute at Columbia University and one of the original leaders of the MDGs.

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2.9: Economy and Development

The etymology of the word **Economy** reveals that its first meaning was "household management" but has since grown to signify the presence and use of "wealth and resources of a country." Colloquially, economy is often used to mean how a person or a country makes money and supports a livelihood.

The field of **economic geography** concerns itself with the often unevenly distributed spatial dimensions of economic structure and type, resources, and general activities of production and consumption. Economic geography is often oriented around issues and questions of **development**, which refers to the processes of increasing the wealth and quality of life within a country.

But before we talk about development, let's pause and learn some ways to describe economy and economic development.

Economic Type

One way to describe the economy of a place–a city, a country, or an entire world region–is by classifying its economy into types:

1. **Primary (aka. extractive)** examples: agriculture, mining
2. **Secondary (aka. manufacturing)** examples: automobile assembly, textile manufacturing
3. **Tertiary (aka. service)** examples: tourism, banking
4. **Quaternary (aka. knowledge)** examples: education, information-technology, research and development

In addition to these 4 types, there is also the **informal economy**, which refers to activities that happen outside of any formal regulations. For instance, shoe shining, street performances, and window washing at stop lights are examples of economic activities that tend to fall with in the informal economy–rarely do people who engage in these activities get protections employees do (in theory) in the formal economy, nor is their compensation for services subject to taxes. Other terms for the informal economic sector is under-the-table or the black market. Those of you reading this that have earned money babysitting or housesitting have likely participated in the informal economy.

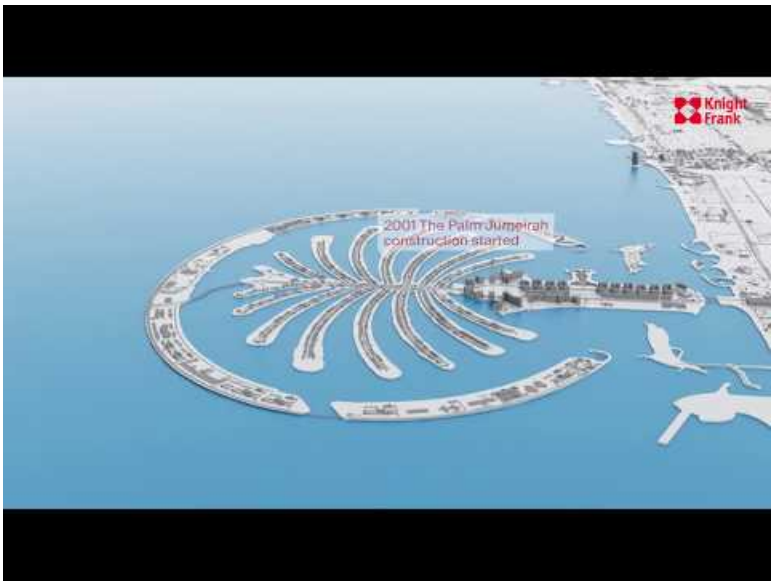
Nearly all economies have elements of each of the types above, albeit in vastly different proportions. In fact, there is a geography to how economic type is distributed across the world, which we will talk about below.

Just as a financial planner would tell you that a diversified financial portfolio is a stronger than a undiversified one, so too is a diversified economy generally stronger than an undiversified one. This means that economies that are nearly all made up of one of the sectors or types above is more vulnerable to damage than one that has economic activity in multiple sectors. Why and how is this the case? Let's look at an example.

The Arab states have a huge proportion of the world's oil and gas reserves; as such, the primary economic sector of their economy has historically and still is in large part very robust in comparison to other sectors. As long as oil and gas are present, extractable, and in demand, this allows the region to easily amass wealth, BUT, what happens when the oil and gas reserves are depleted and/or demand for alternative forms of energy overtake demands for oil and gas? If the Arab states' economy were overly reliant on the primary sector of the economy, they may face economic turmoil.

One way countries in the Middle East are working to diversify their economy and ramp up the tertiary and quaternary sectors is through developing various tourism industries (even building islands off the coast with extravagant hotel experiences) and educational facilities, such as attracting major universities to open branch campuses in places like Qatar and the United Arab Emirates (UAE). Building the infrastructure to support these expanding sectors takes a huge amount of labor.

Check out this time-lapse of infrastructural development in Dubai, UAE (speed it up to get an idea of how the landscape has changed).



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To learn more about issues surrounding the labor conditions facing typically migrant workers from South Asia who come to Arab States for construction-related jobs, including those surrounding building stadiums for the 2022 Wold Cup in Qatar, see here.

Exercise: Tree Maps

Check out the Atlas of Economic Complexity hosted by Harvard to view various countries' economic tree maps, representations of how the economies of a country break down. Type in or select the country you want to view by clicking the Country box in the right hand navigation panel. Hover over the boxes on the tree map to learn more.

- View the export tree maps for Vietnam, Mauritania, and Poland
- Compare and contrast the tree maps. Why are the economies different? What aspects–geographical, historical, cultural–can you think of that would explain the differences?
- Practice classifying the economy by applying the correct economic type to various product sectors depicted in the tree maps

Development & Measuring Development

Development is a broad term referring to processes of increasing the wealth and quality of life within a country.

It is common practice to conceptually break the world into different categories based on each country's or region's level of development. The result is a geography of development that codes regions like North America and Europe as **developed**, and regions like South Asia and East Asia as **developing. MDC** refers to more developed countries and **LDC** refers to least developed country. Other terms used to describe these distinctions are **core** and **periphery**, or core, **semi-periphery**, and periphery, which were foregrounded as part of sociologist and historian Immanual Wallerstein's **world-systems theory**.

Check out the video below to learn about other terms used to describe the developing-developed spectrum.

https://www.youtube.com/watch?v=X1xB...ature=youtu.be

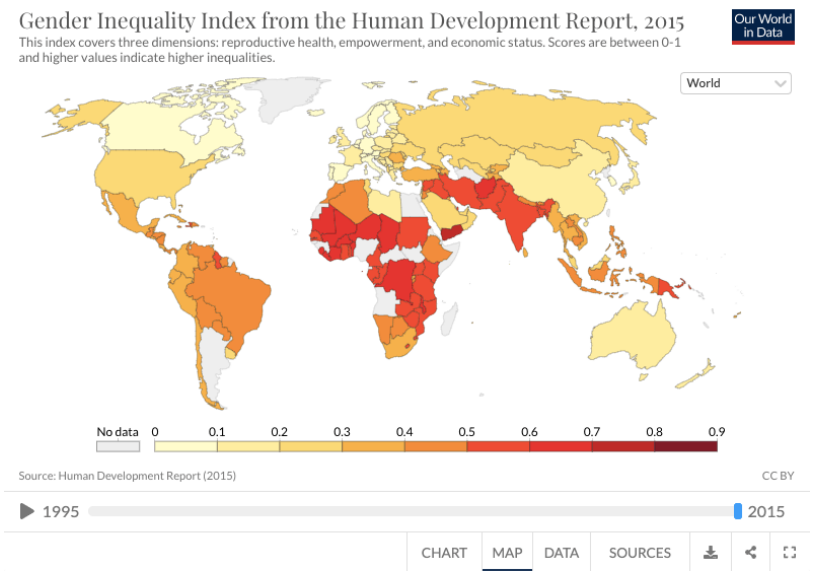
So, how do we assess and measure development?

Common metrics include the following:

- **HDI**, Human Development Index
- **GII***, Gender Inequality Index
- **GDP**, Gross Domestic Product
- **GNI per capita**, Gross National Income per person
- **Gini coefficient**, which measures income inequality

DEEPEN YOUR UNDERSTANDING: Learn what these terms mean and about more ways to describe the world in terms of development by clicking here and reading the following sections: A Mission to Help the World, Measuring Development, and The Geography of Development.

*View map below and click here for interactive map.



Source: https://ourworldindata.org/grapher/g...lopment-report

Exercise: HDI

Examine this map of HDI using UN data from Our World in Data. Hover over and/or click on countries to learn more.

- What patterns do you notice regarding the spatial distribution of HDI across the world?
- On the top right of the map, click the drop down menu labeled “world” and click to view a particular world region that hast countries with varied HDIs. Select a country in that region to explore more.
- Learn more about your selected country by viewing its country profile in the CIA World Factbook (select relevant country in drop down menu on top right). What information did you learn that helps contextualize why the HDI is relatively high or low in this country?

Paths to & Funding of Development

There are many different approaches a country may take towards developing. These may include **top-down** or **bottom-up development**, and may strive more towards **self-sufficiency** or **international trade**.

Top-down development may include projects initiated and funded at the federal level, whereas bottom-up development may include projects (infrastructural development, social aid programs, educational initiatives) that emerge from a group of people at the local level and are carried out from there.

Taking a self-sufficiency path towards development means that a country places primacy on limiting/eliminating foreign influence in the domestic economy. Two ways this is typically done is by limiting the ownership of business by foreign companies and

increasing tariffs (taxes) on imported foreign goods and services. **Import substitution** refers to when domestically produced items come to replace foreign imports.

Countries that take the international trade path towards development, in contrast, focus on amplifying their production of a few key resources, products, or services, and competing on the international market. Foreign business presence in the country is not limited and the goal is not to eliminate foreign imports.

DEEPEN YOUR UNDERSTANDING: Read more about the paths to development here. *NOTE: you ONLY need to read the section labeled Strategies for Development.

All paths and approaches to development require funding, which often comes through any combination of the following:

- **Foreign Direct Investment (FDI)**: when a foreign country or company provides funds for a domestic project
- **International Monetary Fund (IMF):** provides loans to countries specifically to expand their presence within international trade
- **World Bank:** provides loans to countries for development purposes
- **Microcredit/microfinancing:** when banks provide tiny loans to individuals who would otherwise not qualify for traditional loans

Check out this video which has clips from the documentary Life & Debt, which documents the on-the-ground impacts on everyday life of the IMF and World Bank loans to and programs in Jamaica.



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Globalization & Economic Geography

In the current iteration of **globalization**, which can be understood as increasingly intensified interconnectedness among people and places across economic and socio-cultural dimensions, the way that national economies work has vastly changed.

One way to understand how is to borrow the term **space-time compression,** foregrounded by geographer David Harvey. Space-time compression refers to the idea that the world is getting smaller due to the reduced time it takes to travel (in reality and virtually) through space.

As space-time compresses, what happens to the uniqueness of place? As the world gets ‘smaller’, is the world becoming a single place? To some degree, yes. There are places separated by vast distance that have similar looks and feels. If you are traveling the world, there is a decent chance you can still encounter Americanized fast food, with its familiar packaging. You likely might hear the same songs popular back home. But this is far from the full picture; in many ways, place differentiation is being heightened

by globalization. Regional and ethnic differences can become more valuable as cultural diffusion eases. The further transnational corporations (see below) reach, the more they may respond to place-to-place differences.

Some factors that have led to the current landscape of globalization include **Transnational Corporations (TNCs**), which operate in multiple countries, and the associated **outsourcing** of labor to areas where labor is less regulated and cheaper to obtain. Examples of this include how Apple outsources labor to China to produce the iPhone, as exemplified by the Foxconn factory in Zhengzhou, China and **maquiladoras**, or foreign-owned factories in Mexico that produce tax-free products for US export. For considerations about what it's like to work in the maquiladora industry, which overwhelmingly employs women, read this synopsis for the movie Maquilapolis. Some see globalization as **neocolonialism**; a process in which former colonies, now as new independent countries, are still controlled economically and politically by core countries. This is an informal rule, rather than the formal and direct rule of core countries over colonies. Informal rule is enforced via international financial regulations, commercial relations, and covert intelligence operations. At the same time, corporations in core countries grew larger and became transnational, themselves being able to exert financial pressure on peripheral countries.

In order to illustrate the truly global scope of international economic integration and contemporary globalization, it is common practice among economic geographers to chart **commodity chains,** which show from where all the component parts of a fabricate product come. Products of everyday use may travel tens if not hundreds of thousands of miles to reach their final destination. This is made possible by the effects of **consumption**. Wealthy people and regions can consume more, and corporations are able to reduce prices through outsourcing. Not only are products and components **outsourced**, but so too are labor and pollution. Look at cotton; the United States ranks first in cotton production around the world by far. However, most cotton-based apparel sold in the United States was imported from abroad. How does that make sense? While the US produces the raw product (with the help of government subsidies), but corporations that need the raw product to create finished clothes ship it overseas. The corporation saves on labor costs through international outsourcing, plus the United States saves locally on greenhouse gases and other pollution associated with the manufacture of clothing. The final product is then shipped and bought back to the US, in some cases at a low cost for end consumers.

Click here to view an interactive map charting the commodity chain of Nike shoes.

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2.10: Political Geography

Learning Objectives

- Describe what determines a location as a state.
- Explain the physical shape of states and the environmental factors that influence those shapes.
- Describe the main international organizations that exist to help states interact with each other so that war can be minimized.
- Determine what constitutes as terror and give examples of current global conflicts.
- The politics of electoral geography

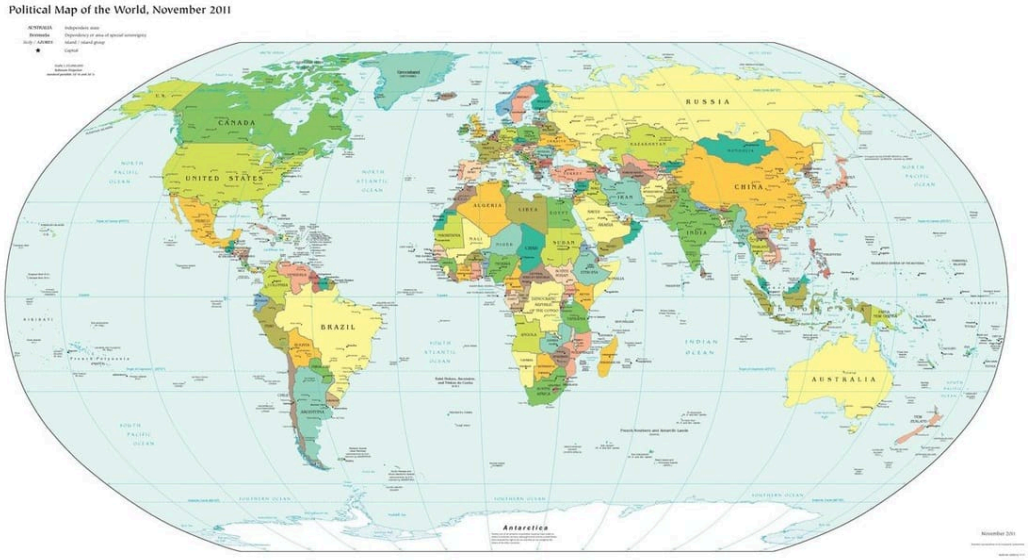
Introduction



In the chapter on population, we discussed how and why population growth exploded in the 20th century. Recall that as nations evolve from Stage 1 to Stage 2, death rates plummet, but birth rates are maintained at their existing levels causing an explosion in population. Europe and America were the first nations to enter Stage 2, but today no nation is in Stage 1. Most nations are still in Stage 2 and the result of this is the human population is now over 6.6 billion. Our numbers are expected to peak at 9 billion by 2100.

The 20th century was also the deadliest century, in terms of war, in human history. This century experienced two world wars, multiple civil wars, genocides in Rwanda (Tutsis and moderate Hutus), Sudan, Yugoslavia, and the Holocaust that decimated the Jewish population in Europe during WWII. In addition to WWI and WWII, this century experienced the Korean War, Vietnam War, the Cold War, and the first Gulf War. Additionally, this century saw regional and civil conflicts such as those experienced in the Congo (6 million people died), as well as an upsurge in child soldiers and modern **slavery**.

Defining States



STATES

A **state** (also called a **nation** or **country**) is an area with defined boundaries organized into a political unit and ruled by an established government that has control over its internal and foreign affairs. When a state has total control over its internal and foreign affairs, it is called a **sovereign state**. A location claimed by a sovereign state is called a **territory**. According to the United Nations, in 2012 the world had 193 nations; however, many of those nations dispute their borders.

The idea or concept of a state originated in the Fertile Crescent between the Persian Gulf and Mediterranean Sea. The first ancient states that formed during this time were called city-states. A **city-state** is a sovereign state that encompasses a town and the surrounding landscape. Often, city-states secured the town by surrounding it with walls and farmlands were located outside of the city walls. Later, **empires** formed when several city-states were militarily controlled by a single city-state.

COLONIES

A **colony** is a territory that is controlled by a sovereign state. European powers focused on establishing settlements and political power around the world by imposing their military, economic, political, and cultural influence through **colonialism**. Colonialism is control of previously uninhabited or sparsely inhabited land. Europeans used colonialism to promote political control over religion, extract natural resources, increase economic influence, and to expand political and military power. The European states first colonized the New World of the Americas, but later redirected their focus to Africa and Asia. This colonial expansion across the globe is called **imperialism**. Imperialism is the control of territory already occupied and organized by an indigenous society.



European colonial regions after the Berlin Conference of 1884.

Shape and Boundaries of States

SHAPE OF STATES

The shape of a state is important because it helps determine potential communication internally, military protection, access to resources, and more. The following is a list of the six types of state shapes and can be viewed in Google Maps by clicking on the links provided.

- **Compact states** have relatively equal distances from their center to any boundary, much like a circle. They are often regarded as efficient states. An example of a compact state would be Kenya, Rwanda, Uganda, and Burundi.
- **Elongated states** have a long and narrow shape. The major problem with these states is with internal communication, which causes isolation of towns from the capital city. Malawi is an example of this.(Also Chile and Vietnam. Chile is 2,653 long and averages 110 miles east/west in width.)
- **Prorupted states** occur when a compact state has a portion of its boundary extending outward exceedingly more than the other portions of the boundary. Some of these types of states exist so that the citizens can have access to a specific resource such as a large body of water. In other circumstances, the extended boundary was created to separate two other nations from having a common boundary. An example of a prorupted state would be Namibia.
- **Perforated states** have other state territories or states within them. A great example of this is Lesotho, which is a sovereign state within South Africa.
- **Fragmented states** exist when a state is separated. Sometimes large bodies of water can fragment a state. Indonesia is an example of a fragmented state. Fragmentation also occurs when a state is separated by another state. An example in the U.S. would be Michigan.
- **Landlocked states** lack a direct outlet to a major body of water such as a sea or ocean. This becomes problematic specifically for exporting trade and can hinder a state's economy. Landlocked states are mostly common in Africa, where the European powers divided up Africa into territories during the Berlin Conference of 1884. After these African territories gained their independence and broke into sovereign states, many became landlocked from the surrounding ocean. An example here would be the Austria.

TYPES OF STATE BOUNDARIES

State **boundaries** are determined either by *physical features* such as rivers, mountains, deserts, or glaciers or by *cultural features* such as religion, culture, or ethnicity. Boundaries are actually dynamic features that vary with space and time. Throughout most of human history, boundaries were determined by **frontiers** where no political entity controlled the area. These were often large, uninhabitable regions such as deserts, oceans, and glaciers. But technological and communication advancements have allowed nations to protect there regions without the need of frontiers. Today, most frontiers have been replaced by boundaries.

- **Desert boundaries** can be quite large barriers for states and can serve for protection. Deserts are common along 30 degrees north or south of the equator where permanent high pressure creates sunny, dry conditions year-round.
- **Mountainous boundaries** can also provide protection over large areas if they are difficult to climb through. But they can also isolate societies from each other by means of transportation, trade and export, and culture. Like desert boundaries, they can also make geopolitics difficult when determining the boundary of a state since it's not a distinct boundary or line.
- Often times, **water boundaries** like rivers, lakes, and oceans create state boundaries. If the body of water is large enough, it can be protective. Invading armies would need to use boats and limited resources to attack a state from its water boundary. But boundaries that use rivers and lakes can be problematic with changing climates. If a river meanders to a new location, does the boundary of that country also change?
- **Geometric boundaries** are basically straight lines drawn on a map.
- **Cultural boundaries** are used to separate people with differences in both of these cultural traits. Often times, cultural and ethnic conflicts occur between people with different languages or religions. Religious differences often coincide with boundaries between states, but in only a few cases has religion been used to select the actual boundary line. The most notable example was in South Asia, when the British partitioned India into two states on the basis of religion. The predominantly Muslim portions were allocated to Pakistan, whereas the predominantly Hindu portions became the independent state India. Language is an important cultural characteristic for drawing boundaries, especially in Europe. By global standards, European languages have substantial literacy traditions and formal rules of grammar and spelling. Language has long been a significant means of distinguishing distinctive nationalities in Europe. In 2011, the state of Sudan separated into Sudan and South Sudan along a language boundary.

UNITARY AND FEDERAL STATES

Most governments are placed into two categories: federal states or unitary states. **Unitary states** place most of the political power in the hands of a central government. The unitary state model works best with states that have little cultural or ethnic diversity and strong national unity. The United Kingdom is an example of a unitary state. **Federal states** – like the United States – works best with nations that have greater diversity. Size also determines if a government tends to be unitary or federal. Large states like the United States, Russia, or Canada tend to be federal because having the entire country controlled by one city (i.e. capital) becomes impractical. Many states around the world have been pressured to decentralize their governments and provide more political power to smaller ethnic groups.

International Relationships



The UN headquarters in New York city.

THE UNITED NATIONS

In the early twentieth century, international relations became a high priority as the world move from an isolationist point of view. The world had just experienced two world wars and the question of the day was, "Can the world survive a third world war?"

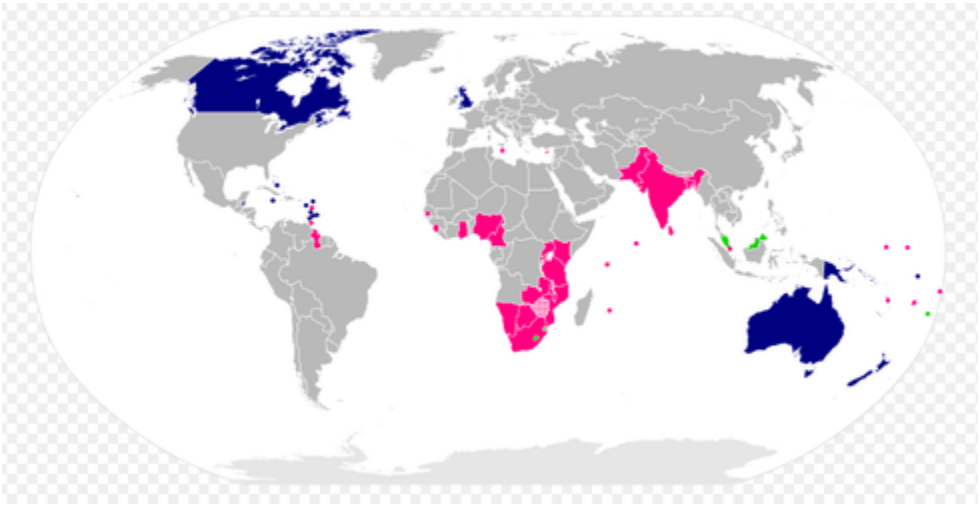
Shortly after World War I, the United States first helped organize the first international peace organization called the **League of Nations.** The American Senate never ratified membership to the organization, which ultimately lead to its demise. Following World War II, the **United Nations** was formed. In 2014, the U.N. is comprised of 193 nations. (A list of members can be found here http://www.un.org/en/members/.) The sole purpose of the United Nations is to provide a forum for nations to state their grievances with other nations in a civil manner rather than through open warfare. One of the important documents that came from the United Nations is called the **Declaration of Human Rights** (http://www.un.org/en/documents/udhr/). Based on the United States Bill of Rights, this declaration declares what rights humans have throughout the world no matter what nation they are a citizen of.

The most powerful council in the UN is the **Security Council.** The United States, the Russian Federation (formerly the Soviet Union), France, China, and the United Kingdom make up the permanent members of the council. Permanent members have veto powers for any Security Council resolution. Additionally, ten non-permanent members are elected for two-year terms. (http://www.un.org/en/sc/members/). This council has the power to determine if peacekeeping or military intervention by the United Nations is necessary. Often, these nations have differences of opinion and philosophies on various security and human rights issues. Thus, there is often conflict about what should be done. Three recent examples of such disagreements are Iraq, Darfur in Sudan, and Syria.

In 2003, the United States and United Kingdom's international military took action against Iraq because of concern of "weapons of mass destruction." The other permanent members of the Security Council – Russia, France, and China – disagreed with this action, thus the United States and United Kingdom invaded Iraq with very little international support. Another recent conflict pitting the United States against the other Security Council members was the conflict in Darfur, Sudan. Former Secretary of State Colin Powell declared that the conflict in the eastern Sudan region amounted to genocide which under United Nations rules requires military, political, and economic action. However, again Russia and China disagreed with the United States and vetoed any military action in Sudan. Currently, the Security Council is having problems coming together to decide what to do with the human rights abuses and mass murders of citizens in Syria.

After the dissolution of the Soviet Union in 1991, the world made a dramatic shift from military power to economic power. Today, the world's economic superpowers are the United States, China, the European Union (the largest economic entity in the world), and Japan. The recent global recession of 2007 lasted several years and has shown the world that an economic ripple in one part of the world could cause the entire world to go into a recession. The United States is not immune from what happens to even small countries around the world because of globalization. For example, the Greek debt crisis, which began in 2009 had an impact both inside Greece and worldwide. Currently, Greece has the potential to economically collapse. A collapse of the Greek economy would cause turmoil for the European Union and could ultimately cause the United States to go into a deep recession.

Russia has lost economic power since the fall of the Soviet Union. As the price of oil increases, Russia has begun to rebound economically. This rebound has provided vast amounts of money to rebuild their infrastructure, military, and economy and has thus dramatically improved their influence in the world.



British Commonwealth members.

REGIONAL ORGANIZATIONS

There are a few other noteworthy international organizations that must be recognized. First is the **African Union** (AU), which was founded in 2001 and is comprised of members from most of the nations in Africa. When conflicts occur in Africa, the AU is usually the first organization to handle the situation. The organization was founded to help Africa deal with its brutally historic past of colonialism, slavery, and apartheid, but now includes promoting economic development.

Another important intergovernmental organization the **Commonwealth of Nations.** The Commonwealth consists of 53 member states that include most of the colonies of the former British Empire (Bangladesh, Canada, India, Pakistan, etc.). Click on the image above to see a breakdown of the status of each Commonwealth member.

Terrorism and Civil Conflict

TERRORISM

The term terrorist (Latin for "to frighten") has become a mainstream term since the attacks of September 11, 2001, in New York, Virginia, and Pennsylvania. **Terrorism** is the systematic use of violence by a group in order to intimidate ordinary citizens as a way to coerce a government into granting the group's demands. Violence is considered necessary by terrorists to bring widespread publicity to goals and grievances that they believe cannot be addressed through peaceful means. Belief in the cause is so strong that terrorists do not hesitate to strike in spite of knowing they will probably die in the act. **State-sponsored terrorism** exists when a state provides sanctuary for terrorists that are wanted by other countries; provides weapons, money, and intelligence to terrorist groups; or helps in planning a terrorist attack.

Geospatial technology is used heavily in geopolitical conflicts within the National Geospatial-Intelligence Agency, National Security Agency, and the Department of Homeland Security to name a few. The video on the right is a section of the Geospatial Revolution, Episode 3 that focuses on war and conflict. Click here to read an interesting article from WIRED Magazine titled How Geospatial Analytics is Helping Hunt the LRA and al-Shabaab.
Geospatial technology can also be used for humanitarian efforts as a way to end conflict or monitor situations before they escalate. One organization, called the Satellite Sentinel Project, was created by The Enough Project and the largest private satellite imagery corporation called Digital Globe. The organization was first used satellite imagery from Digital Globe and Google Earth to monitor potential humanitarian conflicts along the border of Sudan and the newly created South Sudan. Now it is using satellite imagery to track poachers who use the money from the black market to fund civil wars like the Lord's Resistance Army (LRA).

ISRAEL AND PALESTINE



The story of the conflict between Israel and Palestine goes back thousands of years and is rooted in religious and cultural

differences. Today's modern conflict is more than just about religion; it's about water, natural resources, land use, infrastructure, and economic development. Many would argue that the state of Israel began after World War II, when the United Nations partitioned Palestine into Israeli and Palestinian states. Others, especially Jews, believe the story goes back further to early biblical times. They claim that they were given the land by god thousands of years ago.

There is growing debate around the world about needs to be done to end the conflict between the people of Israel and Palestine. Basically there are three options: 1) create a "two-state solution" where basically the Israeli people keep most of Israel, but give the Palestinians the West Bank and possibly Gaza Strip, 2) integrate Palestinians into Israel and legal citizens which would make them the majority within Israel, 3) keep segregation between Israelis and Palestinians as it currently exists and be considered an apartheid by the global community. Is there a case to be made that Israel's very survival depends on the creation of a stable and viable Palestinian state?

ISRAEL AND IRAN

Ronny Edry, a graphic design educator and activist believes that peace doesn't need to be so complicated and that all that is required is reaching out to the "enemies" you've been indoctrinated to hate. Web 2.0 and social media have become a new force in grassroots geopolitical change. Ronny Edry's movement can be viewed on The Peace Factory Facebook page. Items to consider are:

- Do you really think a grassroots movement like this could help bring peace to the Middle East or is it something that can be solely done by governments?
- Is this an effective way to get citizens involved geopolitical movements?
- What other ways could citizens become more involved beyond social media?
- Does social media help democratic movements like the Arab Spring and what are there downsides of using this technology?

ELECTORAL GEOGRAPHY

Electoral geographer investigate the patterns of voters, and their ability to votes. Gerrymandering is a deliberate attempt to set boundaries of voting regions to capture or exclude specific types of voters.

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2.11: Power, Politics, and Place

Power & Politics

One common misconception people have about geography is that it's all about states and capitals. Geographers certainly do care about place, but memorizing a list of states and capitals is not at all what geographers do, nor how geography is taught, particularly in a world where this information is much more readily accessible than times past due to technology.

Political geography is a subfield of human geography that examines how politics influences place and how place and its distinctiveness shapes the kind of politics that operate there. Geographers always have an eye open towards noticing and evaluating the spatial distribution of phenomenon and possible resulting unevenness. In the case of political geography, this translates to examining how political structures are distributed across the world, understanding the context of why political structures operate where they do, and the impact this has on peoples' everyday lives and the global world order, or how power is distributed internationally.

Politics is first and foremost about power.

Check out the video below to learn about two key types of power: **hard power**, which operates by force and coercion and **soft power**, which operates by fostering consent and attraction.



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Politics can be understood in three senses:

- **High Politics**: essential to state survival (examples: elections, war and peace, diplomacy)
- **Low Politics**: non-essential to state survival; mundane; about welfare of the state (examples: department of education, environmental protection agency)
- **politics with a lower case p**: challenging existing structures of power (examples: Black Lives Matter movement, gun right's advocacy groups)

Political geography examines how all three aspects of politics intersect in place and impact peoples' livelihoods.

States, Nations, & Borders

DEEPEN YOUR UNDERSTANDING: Learn more about **states**, **nations**, **sovereignty**, **state shape**, **types of governance**,

and **borders** by reading this (you may stop reading once you reach the Theories of a State section): https://humangeography.pressbooks.com/chapter/4-1/

Exercise: Distribution of Governance Structures

Geographers examine the spatial distribution of phenomena, including governance structures. Use the link below to complete the following tasks: https://education.maps.arcgis.com/home/webmap/viewer.html?webmap=a4712b8499994842a6a34a8c8803e62c

- What spatial patterns do you notice in terms of how and where government types are distributed? What factors do you know of that may help explain these patterns?
- Choose 3 government types to analyze further and do a quick web search to learn what exactly each government type means and compare and contrast the 3 types.

Challenges to State Sovereignty

DEEPEN YOUR UNDERSTANDING: Learn more about challenges to state sovereignty including **separatism** often driven by differences in **identity** here (you may stop reading once you reach the Terrorism section): https://humangeography.pressbooks.com/chapter/4-2/ Border disputes and conflicts also pose challenges to state sovereignty. Check out the video about Kashmir below to learn more.



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Exercise: Border Disputes

Visit this link and click on countries and yellow dots along borders to learn more about major ongoing border disputes: http://metrocosm.com/disputed-territories-map.html

Sometimes conflict within states, often rooted in (at least perceived) cultural differences, can lead to a humanitarian crisis involving **internally displaced persons or refugees, where people are either uprooted from their home and move internally within a country, or cross borders to gain protection. Check out the video below to hear from the voice of a refugee from Myanmar fleeing to Bangladesh, as part of the Rohingya crisis.**

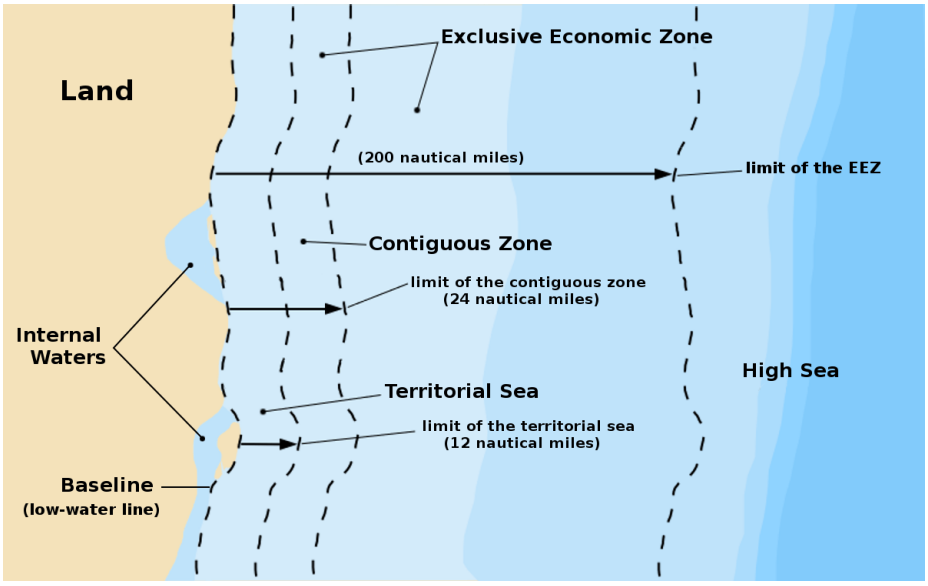


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Sovereignty in Maritime Spaces

The world is about 70% water and you may have wondered at some point: who owns the oceans? It's a fair question, but not an entirely easy one to answer.

UNCLOS, which stands for the **United Nations** (**an international organization**) Convention for the Law of the Sea, is the current governing agreement by which the majority of countries in theory abide. Below is a chart explaining how sovereignty extends from a territory's land borders into the sea. Of special note are the powers afforded to countries within **territorial sea,** which include air, surface, and subsurface rights, and **exclusive economic zones (EEZ)**, which include surface and subsurface rights.



Source: https://commons.wikimedia.org/wiki/File:UNCLOS-en.png

The videos below profile two hotspot maritime battlegrounds: the Arctic, where waterways are opening up because of the retreat of sea ice due to climate change, and the South China Sea, where countries in East Asia and Southeast Asia are vying for rights and human-made islands are being constructed to help assert sovereignty. Note how UNCLOS does and does not guide the actions of countries in these areas.



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Closer to Home: Electoral Geography

A substantial branch of political geography is devoted to **electoral geography**, which examines how geography influences political representation and even prescribe best practices to ensure fairness.

If you've ever heard of **gerrymandering**, or wonder why the **census** becomes a hot-button political issue every ten years, you already know a thing or two about electoral geography.

Check out the video below for a crash course on how geometry and geography intersect with politics, and can affect the weight of your vote in state and national elections.



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Questions

After working through this chapter, you should have something to say in response to each of these questions:

- What is the difference between a state and a nation?
- What is the function of borders?
- What factors (natural, socio-cultural, etc) influence the location, character, and impact of borders?
- What are the effects of border disputes (and for whom)?
- How does the shape of a state affect its internal operations and international actions?
- How does sovereignty operate in marine spaces?
- How have events like the Cold War and European and American colonialism shaped the distribution of government types and international diplomatic relations globally?
- On what grounds are countries making claims in the Arctic?

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2.12: Economic Geography

The Economics of Geography

The economy is a system of redistributing goods and services from where they are found to where people want to use them. The components of production in the economy are labor, land (natural resources), and capital. You need to mix those three ingredients to get your product. There's not an infinite supply of everything. Someone will want something they don't yet have, and are willing to give up something they do have. Methods for getting those desired goods and servicesinclude barter, the exchange of goods and services of perceived equal value; and purchasing with cash or cash equivalent; and use of force. In economic geography, the questions include where are the components of the economy located, how do they vary from place to place, and how do they move? Fundamentally, the economy assumes a scarcity of goods and services.

We often talk about four, sometimes five sectors of the economy. The simple direct use or extraction of natural goods such as farming, mining, fishing form the **primary** sector. There's minimal skill and technology required for these activities in their basic form. Once products from the primary are combined into new goods through manufacturing processes, you are into the **secondary** economic sector. Controlling, using, and combining natural resources, agriculture, and manufacturing is the traditional method to increase national income. Many manufacturers are good at making things, but aren't focused on selling them to the end consumer. That retail sales job falls in the **tertiary** sector. As the economy becomes more complicated and interconnected it's sometimes difficult to determine the best options for wealth creation. In this case you use the service sector, the **quaternary**, and **quinary** economic activities, to get and interpret information.

Places around the world have sometimes been named after the methods used to gain wealth. For example, the Gold Coast of western Africa received its label because of the abundance of gold in the region. The term breadbasket often refers to a region with abundant agricultural surpluses. Another example is the Champagne region of France, which has become synonymous with the beverage made from the grapes grown there. The Banana Republics in Central America earned their name because their large fruit plantations were the primary income source for the large corporations that operated them.

Countries with few opportunities to gain wealth to support their governments often borrow money to provide services for their people. The national debt is a significant problem for national governments. National income can be consolidated into the hands of a small group of powerful people at the top of the socioeconomic strata. These social elites can dominate the politics of their countries or regions. The elites may hold most of a country's wealth, while at the same time, their government might not always have enough revenues to pay for public services. To pay for public services, the government might need to borrow money, which then increases that country's national debt. The government could have a high national debt even when the country is home to many wealthy citizens or a growing economy. Taxes are a standard method for governments to collect revenue. If economic conditions decline, the amount of taxes collected can also decline, which could leave the government with a shortfall. Again, the government might borrow money to continue operating and to provide the same level of services. Political corruption and the mismanagement of funds can also cause a country's government to lack revenues to pay for the services it needs to provide its citizens. The National debt, defined as the total amount of money a government owes, is a growing concern across the globe.

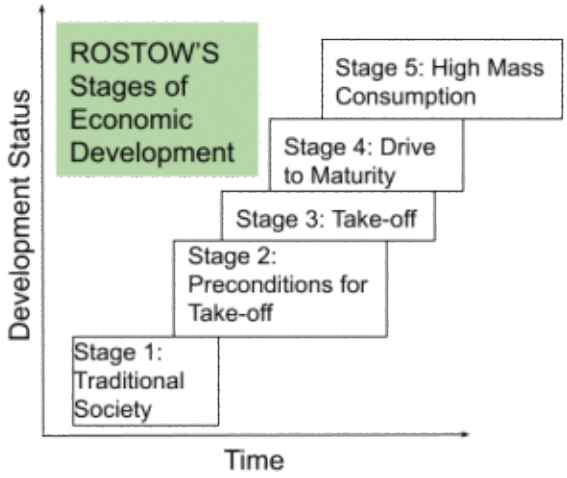
Many governments have problems paying their national debt or even the interest on their national debt. Governments whose debt has surpassed their ability to pay have often inflated their currency to increase the amount of money in circulation, a practice that can lead to hyperinflation and, eventually, the collapse of the government's currency, which could have serious adverse effects on the country's economy. In contrast to the national debt, the term budget deficit refers to the annual cycle of accounting of a government's excess spending over the number of revenues it takes enduring a given fiscal year.

The Geography of Economics

The Industrial Revolution, which prompted the shift in population from rural to urban, also encouraged market economies, which have evolved into modern consumer societies. Various theories and models have been developed over the years to help explain these changes. For example, in 1929, the American demographer Warren Thompson developed the demographic transition model (DTM) to explain population growth based on an interpretation of demographic history.

In the 1960s, economist Walt Rostow adapted Warren Thompson's **demographic transition model (see chapter on population)** to outline a pattern of economic development that has become one model for growth in a global economy. Rostow's model

described the five stages of growth in the economic modernization of a country:



Rostow's Stages of Economic Development

The **human development index** (HDI) was developed in 1990 and is used by the **United Nations Development Program** to measure a standard of human development, which refers to the widening opportunities available to individuals for education, health care, income, and employment. The HDI incorporates variables such as standards of living, literacy rate, and life expectancy to indicate a measure of well-being or the quality of life for a specific country.

The human development approach, developed by the economist Mahbub Ul Haq, is anchored in the Nobel laureate Amartya Sen's work on human capabilities, often framed regarding whether people can "be" and "do" desirable things in life.

Examples include:

- Beings: well-fed, sheltered, healthy
- Doings: work, education, voting, participating in community life.

Freedom of choice is central to the approach: someone choosing to be hungry (during a religious fast say) is quite different to someone hungry because they cannot afford to buy food.

Ideas on the links between economic growth and development during the second half of the 20th Century also had a formative influence. Gross Domestic Product (GDP) and economic growth emerged as leading indicators of national progress in many countries, yet GDP was never intended to be used as a measure of wellbeing. In the 1970s and 80s, development debate considered using alternative focuses on going beyond GDP, including putting greater emphasis on employment, followed by redistribution with growth, and then whether people had their basic needs met. These ideas helped pave the way for human development (both the approach and its measurement).

One of the more notable achievements of the human development approach has been to ensure a growing acceptance of the fact that monetary measures, such as GDP per capita, are inadequate representations of development. This measure of human development remains a simple unweighted average of a nation's longevity, education, and income and is widely accepted in development discourse. Over the years, however, some modifications and refinements have been made to the index. Indeed, the critics of the HDI and their concerns have stimulated, and continue to stimulate, adjustments to the index and the development of companion indices, which help paint a broader picture of global human development.

The HDI emphasizes that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone. The HDI can also be used to question national policy choices, asking how two countries with the same level of GNI per capita can end up with different human development outcomes. These contrasts can stimulate debate about government policy priorities.

Jobs can be classified into three major types of sectors, which greatly influence the economics, standards of living, trade, and

even social classes within a society. The first is called the primary sector, which are jobs directly related to the extraction of the Earth's natural resources (e.g., forestry, raw materials, or agriculture). In the secondary sector, jobs are focused on manufacturing raw materials from the primary sector to usable products. The tertiary sector provides goods and services to people in exchange for payment. These types of jobs include lawyers, doctors, educators, banking, retail, athletes, and others.

It is probably apparent that the majority of the jobs in more developed countries (MDCs) are tertiary. There are primary and secondary sector jobs in countries like the United States, but the driving economic force is in the tertiary sector. MDCs are also more productive than LDCs, not because they work harder, but because of access and use of technology. In economics, productivity is the value of a product compared to the amount of labor.

MDCs also can invest more money and resources because of their economies. Thus their people tend to be more educated and healthier; children are more likely to survive, and adults tend to live longer than those in LDCs. Probably the two most important or essential components to have a nation's developmental status begin to rise is through education and health care. There is a direct correlation to development and education: the more developed a nation, the more educated the population. One of the best indicators of a nation's level of development is its literacy rate, the percent of people who can read or write.

In most developed countries, the literacy rate is usually around 98 percent, whereas, in emerging countries, the literacy rate is roughly 60 percent. The impact of this is that books are written for people in MDCs, and scientific advances tend to occur in these countries. Regarding percentage, least developed countries spend more of their GDP on education than most developed countries need to. In LDCs, the children going to school often have outdated books and not written in their primary language. Often in LDCs, more schools are private than public because the government cannot fund them. Outside religious groups and nonprofit organizations fund many of these schools.

Access to health care mirrors literacy statistics globally. However, geographers always want to look at these issues from different scales to understand if the patterns at a global scale hold at a regional or national level.

Other measures of development can be utilized to help geographers understand patterns of social and economic differences at a variety of scales. For example, looking at Gross Domestic Income (GDI) per capita gives a global view of the economic status of nations. North America, Northern Europe, Australia, and Japan have relatively stable economies and tend to be political world leaders. Interestingly, Saudi Arabia has a high GDI but is surrounded by countries with weaker economies. What confluence of factors might account for this phenomenon?

At this scale, a geographer might think that a country like Spain, with a strong GDI, also has a healthy economy. However, Spain has struggled to recover from the worldwide recession of 2008 and continues to have large pockets of the population who are chronically unemployed.

At this regional level, we can make some conclusions about the location of the unemployed, which create other questions that can be answered from a geographical spatial perspective, such as:

- Are unemployed people who are living in cities also in poverty?
- What kinds of education levels exist among people in those areas?
- What kinds of social services, if any, are needed in those areas?

As you can see, this type of questioning can help us understand different patterns of social and economic development, as well as influence public policy.

Source:

Largely based on the chapter "Economic Geography" in Human Geography by Dastrup at Pressbooks.

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GLOSSARY

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Sample Word 1 | Sample Definition 1

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