Layers of the Earth

The Earth can be divided into different layers based on various properties.

Composition vs. Physical properties

The diagram below shows two ways to classify Earth's layers. One way, shown on the left, is based on composition (what the layers are made of). The other way, shown on the right, is based on physical properties of the layers (solid vs. liquid, rigid vs. soft, etc.). In most cases, the boundaries between the physical layers do not line up with the boundaries of the compositional layers.

Earth's Compositional Layers

Earth's compositional layers, from the outside to the center, are the crust, the mantle, and the core.

The crust is the outermost, thinnest, least dense layer. Continental crust is made mostly of the rock *granite* and is thicker and less dense than oceanic crust. Oceanic crust is made mostly of the rock *basalt*. Overall, crustal rocks are rich in the elements silicon (Si) and oxygen (O).
This cross section above shows that continental crust (grey area labeled as "1") is thicker than oceanic crust (black area labeled as "2"). The portion of the diagram labeled as "3" is part of the mantle. The blue area is ocean water.

The **mantle** is the hot, middle, thickest layer and accounts for most of the Earth's bulk. It is denser than the crust, but not as dense as the core. The density of the mantle increases with depth due to increasing pressure. Mantle rocks are richer in iron (Fe) and magnesium (Mg) than crustal rocks.

The **core** lies at Earth's center. The core is made mostly of iron and nickel, and it is the densest layer.

**Earth's Physical Layers**

Earth's physical layers, from the outside to the center, are the lithosphere, the asthenosphere, the mesosphere, the outer core, and the inner core.

The **lithosphere** is the cold, brittle layer at Earth's surface. It is a solid layer that contains all of the crust and a very thin part of the mantle's top. Overall, the lithosphere is a stiff, rigid layer that is broken into large pieces called tectonic plates. These plates move around on top of the less rigid layer below them.

The **asthenosphere** is a less rigid layer directly underneath the lithosphere. It consists entirely of mantle rock. Although it is solid, the asthenosphere is able to flow very slowly. This causes the rigid plates of the lithosphere on top to move around.

The **mesosphere** is a solid layer that accounts for the rest of the mantle below the asthenosphere. The mesosphere is stronger and denser than the asthenosphere.
The outer core is the liquid, outer portion of the Earth's core. The slow, gradual flow in the outer core produces the Earth's magnetic field.

The inner core is the solid, inner portion of the Earth's core.

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Landforms & Forces

Landforms can be created by constructive processes, such as deposition. These landforms include deltas, barrier islands, and sand dunes. Landforms can also be created by destructive processes, such as erosion. These landforms include valleys, canyons, caves, arches, and lakes.

Valleys, Canyons, Caves and Arches

Erosion can create new landforms such as valleys, canyons, caves and arches. Erosion is the process by which rock and soil are moved by wind or moving water.

The sea arch above was likely formed by water erosion.

Lakes and Valleys

A glacier is a large, slow moving mass of ice and snow that moves across the Earth's surface, pushing sand and soil, cutting the Earth, forming lakes and valleys, and moving rocks and boulders.
The glacier shown in the picture above is in the process of carving a wide valley between the mountains.

**Deltas, Barrier Islands, and Sand Dunes**

The process of deposition involves the movement of sediment from one area to another and can create new landforms such as river deltas, barrier islands, and sand dunes.

Strong winds can cause sand on beaches to move to new areas and form large mounds, called sand dunes.

Also, flowing water can pick up sediment from its banks and carry it downstream. Near the place where a river empties into the ocean, the water flow becomes very slow. The slow-moving water lays down the rest of the sediment it is carrying. A new landform is created from the sediment. This landform is called a delta.

The deposition of sediment caused the formation of the Mississippi river delta shown above.

Image courtesy of NASA’s Earth Observatory
 Modeling Earth's Surface - Images & Maps

Geologic features on Earth can be identified and visually modeled through the use of aerial photography, satellite imagery, globes, and topographic maps.

**Imagery**

Images of Earth's surface can be made in many ways. Cameras attached to aircraft can photograph areas of interest to create *aerial photos*. Aerial photos can give humans a "bird's eye" view of geologic features such as mountains, valleys, rivers, and coastal features. Aircraft can use other kinds of sensors to study these features as well.

This is an aerial photo of Lava Butte, Oregon. The circular feature at right is a cinder cone volcano. A lava flow can be seen to the left (see the semi-rough texture with sinuous patterns in the large, medium-grey area).

Adapted from image courtesy of USGS/Cascades Volcano Observatory.

**Satellite images** created by cameras on board satellites orbiting the Earth can cover large areas of Earth's surface. Scientists can identify geologic features in satellite images based on combinations of colors and shapes.

Satellite images can be made from different kinds of radiation (visual, infrared, X-ray, etc.) to provide different views of Earth's surface. Scientists can learn more about geologic features by studying them using multiple forms of radiation.
This figure shows two satellite views of Chiliques Volcano in Chile. The left image is shown in nighttime thermal infrared, and the right image is shown in visible light. The thermal image can be used to detect variations in emitted heat. The darker areas are cooler, while the brighter areas are warmer. Note the small warmer spots in the middle of the dark region—these indicate new volcanic activity in the volcano's crater.

Adapted from image courtesy of NASA.

Maps

A globe is like a map of the Earth that is spherical, like the Earth. Unlike flat maps, a globe accurately shows the relative sizes and positions of all the features on it. For example, flat maps may make Greenland appear much larger than it is. Also, many maps of the world give the impression that Alaska and Russia are very far apart. A globe shows just how close they are. A globe can be used to trace ocean currents, air currents, plane routes, or shipping routes across the whole world without a break.
In general, maps are models of the Earth's surface that provide a view of the surface from directly overhead. Maps sometimes are created on top of aerial photos and satellite images, but often maps use only symbols to focus on certain natural or manmade features. Maps also provide information on direction and scale.

**Topographic maps** use *contour lines* to show the elevation of the areas they model. These lines connect points of equal elevation and provide information about *slope*. Contour lines that are close together represent steep slopes (see upper right corner of map below), whereas contour lines that are far apart represent flat or gently sloped areas (see areas "1," "2," and "4" of map below).

The *contour interval* of a topographic map is the change in elevation between adjacent contour lines. For example, if the change in elevation from one contour line to the next is 100 ft, as in the map below, the contour interval is 100 ft.

The *relief* of a topographic map is the difference between the highest and lowest elevation on the map. In the map below, the highest point is a mountain peak at 3,710 ft near the upper right corner. The lowest land elevation on the map is 0 ft, or sea level (ignore the bathymetric contours in the water). This means that the topographic relief for this map is 3,710 ft, which is the same value as the highest elevation. A map whose lowest land elevation is not equal to sea level will have a topographic relief that is not equal to its highest elevation. For example, if the lowest elevation on a map is 1,000 ft (in a valley, for example) and the highest elevation is 8,000 ft (on a mountain peak), the relief would be 7,000 ft.

Topographic map of the area around Tidal Inlet, Glacier Bay National Park

Adapted from image courtesy of USGS.
Earth's Spheres

The Earth has four main interacting systems. The systems are the **atmosphere**, **biosphere**, **geosphere**, and **hydrosphere**.

Atmosphere

The **atmosphere** is composed of a thin layer of gases that surrounds the Earth. Processes in the atmosphere include winds, weather, and the exchange of gases with living organisms.

Composition of the Atmosphere

Nitrogen and oxygen are the two most abundant gases; they make up about 99% of the atmosphere's total volume. However, there are many other gases that are present in smaller amounts. The table below lists the eleven most abundant gases by volume.

Gases in Earth's Atmosphere

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percent of Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>nitrogen</td>
<td>78.08%</td>
</tr>
<tr>
<td>oxygen</td>
<td>20.95%</td>
</tr>
<tr>
<td>water vapor</td>
<td>0-4%</td>
</tr>
<tr>
<td>argon</td>
<td>0.93%</td>
</tr>
<tr>
<td>carbon dioxide</td>
<td>0.036%</td>
</tr>
<tr>
<td>neon</td>
<td>0.0018%</td>
</tr>
<tr>
<td>helium</td>
<td>0.0005%</td>
</tr>
<tr>
<td>methane</td>
<td>0.00017%</td>
</tr>
<tr>
<td>hydrogen</td>
<td>0.00005%</td>
</tr>
<tr>
<td>nitrous oxide</td>
<td>0.00003%</td>
</tr>
<tr>
<td>ozone</td>
<td>0.000004%</td>
</tr>
</tbody>
</table>

Although the exact amount can vary, *water vapor is always present in the atmosphere*. When air has a lot of water vapor, the humidity of the air is high. High humidity makes warm temperatures seem warmer and cool temperatures seem cooler. Water vapor in the atmosphere has a powerful effect on weather.
The atmosphere also plays important roles in warming the Earth and sustaining plant and animal life.

**Biosphere**

The **biosphere** includes any part of the Earth where organisms live. It extends from the crust of the Earth to the atmosphere. All of the living organisms on the Earth are included within the biosphere.

The biosphere includes the wealth and diversity of all living organisms on the Earth.

Processes in the biosphere include life and death, evolution, and extinction.

**Geosphere and Lithosphere**

The **geosphere** includes the physical elements of the Earth's surface, crust, and interior. Processes in the geosphere include continental drift, volcanic eruptions, and earthquakes.

The **lithosphere** is the outermost layer of the geosphere, and it includes the crust and upper mantle. The lithosphere is made up of several different plates, which slowly move across the Earth's surface. Below that lies the asthenosphere, which also includes part of the upper mantle. The core is the inner section of the Earth.

**Hydrosphere and Cryosphere**

The **hydrosphere** includes all of the water on or near the surface of the Earth. This includes water vapor in clouds, solid water in ice caps and glaciers, and liquid water in the oceans, rivers, lakes, and aquifers. Liquid water can be salt water, which is found in the oceans, or it can be fresh water, which is found in lakes, rivers, and streams.

Processes in the hydrosphere include the flow of rivers, evaporation, and rain. These processes represent interactions among the hydrosphere, geosphere, and atmosphere. For example, part of the hydrosphere extends into the geosphere when water infiltrates the ground. When liquid water
evaporates from the Earth's surface and rises as vapor into the air, part of the hydrosphere is
leaving the surface of the geosphere and entering the atmosphere.

Water vapor is also a part of the hydrosphere. Water vapor forms when liquid water evaporates
from the surfaces of ponds, lakes, oceans, rivers, and land. Water vapor also enters the
atmosphere through living processes such as respiration (all organisms), transpiration (plants)
and perspiration (animals).

The cryosphere includes only the frozen portion of the hydrosphere. Processes in the cryosphere
include the buildup and movement of glaciers, ice flow in oceans and rivers, snowfall, and
freezing soil.

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Common Elements of the Earth

There are about 110 known elements, but only a small number make up most of the solid Earth,
living matter, oceans, and the atmosphere on Earth.

The Atmosphere

The Earth's atmosphere is mostly made up of nitrogen and oxygen. The vast majority of the
atmosphere, about 78%, is nitrogen. About 21% of the atmosphere is oxygen. The remaining 1%
is made up of several different gases.
As you can see from the circle graph above, approximately 99% of the atmosphere is composed of nitrogen and oxygen.

**The Oceans**

The Earth's oceans are mostly made up of water, which has a chemical composition of H₂O. About 96.5% of the oceans are made up of this combination of hydrogen and oxygen. The remaining 3.5% is mostly sea salt, which contains the elements chlorine and sodium.

**Living Matter**

The most common elements found in the cells of living organisms include:

- carbon (C)
- hydrogen (H)
- nitrogen (N)
- oxygen (O)
- phosphorus (P)
- sulfur (S)
The elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur (CHNOPS) make up 99% of all living systems.

Water makes up about 75% of most organisms. Carbon is the second most abundant element in the human body, after oxygen. Phosphorus is found in genetic material (DNA and RNA) and energy molecules (ATP). Nitrogen is found in proteins.

**Solid Earth**

Solid Earth is made up of a very small fraction of the known elements. The Earth's crust, for example, is mainly made up of oxygen (47%) and silicon (28%). The Earth's core, however, contains the much denser elements, iron and nickel.

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**Nitrogen Cycle**

The nitrogen cycle describes the movement of nitrogen throughout the atmosphere, lithosphere, and biosphere.

Nitrogen is an essential part of proteins and genetic material. Therefore, all organisms require nitrogen to survive. Even though nitrogen is the most abundant gas in the atmosphere, most organisms are unable to use this form of nitrogen. However, there are a few microscopic organisms and natural processes, such as lightning, that can convert unusable nitrogen in the atmosphere to usable forms of nitrogen in the lithosphere and biosphere.

The video embedded within this lesson describes the nitrogen cycle.

Clip provided by Education Clip Library with permission from ITN Source is only available within the lesson.

**Steps in the Nitrogen Cycle**

During the nitrogen cycle, atmospheric nitrogen (N₂) is fixed, or converted into a usable nitrogen-containing compounds called nitrates, by certain types of microorganisms. Plants can then absorb the nitrogen compounds from the soil and use it to form chlorophyll and other important biological building blocks.
Consumers must obtain nitrogen from the organisms they consume. Herbivores receive their nitrogen from the plants that they eat, and carnivores get their nitrogen from the animals they consume. However, all organisms depend on the ability of nitrogen-fixing microorganisms to convert atmospheric nitrogen into a form of nitrogen that plants can assimilate, or take in and use.

Finally, nitrogen is returned to the atmosphere through the combustion of fossil fuels or when decomposers break down the nitrogen found in fertilizers, urine, and dead plants and animals.

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Human Activity and the Earth’s Processes

Humans have the ability to affect the environment in many different ways. Construction, pollution, resource use, and preservation are just a few of the human actions that affect the environment.

There is a fixed amount of chemical elements in the Earth's system. These elements can be stored in the solid Earth, the oceans, the atmosphere, and organisms. They cycle continuously through and among these four reservoirs as a result of various Earth processes. Human activities can change the balance in Earth's processes, such as the carbon cycle and the water cycle. Careless human activity can also alter or destroy habitats and damage ecosystems.

The Carbon Cycle and Climate Change
The use of fossil fuels has impacted the carbon cycle. When fossil fuels are burned, carbon is transferred from the geosphere to the atmosphere. Greenhouse gases, such as carbon dioxide, methane, and water vapor, are released into the atmosphere in large quantities when fossil fuels are combusted.

The Earth's atmosphere naturally contains greenhouse gases, which trap sunlight energy. The atmosphere has a limited capacity to recycle carbon and other materials naturally. The increasing amount of greenhouse gases released by the growing population of humans is changing the composition of the atmosphere, which may cause average global temperatures to rise, according to climate scientists.

The image on the left represents the natural greenhouse effect. The image on the right shows the effect of extra greenhouse gases on heat retention within Earth's atmosphere.

Image courtesy of NPS

The ocean also plays an important role in the carbon cycle. Carbon compounds from the atmosphere dissolve into the ocean. The ocean's ability to recycle these compounds is limited. When carbon dioxide (CO₂) dissolves in water, it acidifies the water, lowering its pH. If the amount of CO₂ dissolved in the ocean increases too much, certain lifeforms in the ocean will no longer be able to survive in the acidic water.

**Earth's Atmosphere**

Human activities release substances into the air, some of which cause problems for humans, plants, and animals. Some air pollutants return to Earth in the form of acid rain and snow, which corrode statues and buildings, damage crops and forests, and make lakes and streams unsuitable for fish and other plant and animal life.
One type of air pollution, known as particulate matter, consists of the small particles released into the air from burning fuel. These particles are very small pieces of matter, which are easily inhaled deeply into the lungs where they can be absorbed into the bloodstream or remain embedded in the lungs for long periods of time.

Aerosols are suspensions of solid or liquid particles in air. Smoke is an example of an aerosol. Many human activities, such as combustion, release aerosols into the air. Aerosols can lower temperatures by reflecting sunlight back out into space, reducing the amount of sunlight that reaches the Earth. Catastrophic events such as huge volcanic eruptions, meteor impacts, or widespread nuclear war could block enough sunlight to cause global climate change, leading to mass extinctions of animals and even plants.

Burning fossil fuels also releases other pollutants, such as sulfur dioxide and mercury from burning coal and natural gas. Sulfur dioxide and nitrous oxide compounds that are released into the atmosphere contribute to acid rain.

Some substances that are considered air pollution by the U.S. Environmental Protection Agency include:

- Ozone
- Carbon Monoxide
- Carbon Dioxide
- Nitrogen Oxides
- Sulfur Dioxide
- Lead
- Mercury
- Particulate Matter

Ozone is a type of gas in the atmosphere that shields the Earth from the Sun's radiation. Near ground level ozone is considered a pollutant—it is a major component of smog—but in the upper atmosphere it works a bit like sunblock on a global scale.

Chemicals called chlorofluorocarbons, or CFCs, used in air conditioners and pressurized sprays destroy ozone. Scientists believe that these chemicals have caused two holes to develop in the ozone. These gaps in the ozone change both the amount and the type of solar energy that reaches Earth's surface. People worldwide are currently reducing the amount of ozone-destroying chemicals that are used.

**The Nitrogen Cycle**

Human-made fertilizers are produced using nitrogen from the atmosphere. This nitrogen is converted into nitrates, just as would happen in the nitrogen cycle in nature. The creation and use of fertilizers both bypasses the natural nitrogen cycle and cycles nitrogen more rapidly between the atmosphere and plants.
The Water Cycle

Human activity alters the water cycle also. Surface runoff increases where more ground is covered with buildings and concrete. Pollution from these surfaces ends up in the water and changes the chemical balance of water bodies. Pollutants also leach from soils that have been polluted through spills or garbage, increasing the number of pollutants in waterways.

Landfills, which are humankind's most common way of disposing of solid waste, also impact the water cycle. Landfills often contaminate surface and groundwater.

Landfills are collection sites for solid waste materials. Water that is contaminated from the various organic and inorganic substances with which it comes into contact as it migrates through the waste is known as leachate. Water moving through a landfill inevitably becomes contaminated as leachate, which is undrinkable and often toxic. Most modern landfills in the U.S. have leachate collection and monitoring systems. These systems generally involve a layer of durable plastic that is placed beneath the waste to prevent water from seeping into the surrounding soil. But all such systems eventually fail, allowing nearby water sources to become contaminated over time.

The Cycling of Energy: Food Webs

There is a natural energy flow between plants and animals, in which plants use sunlight energy to produce the food that animals use as an energy source. Human activity has impacted the cycling of energy too.

When insecticides are used heavily, they can disrupt the food web in an ecosystem. When too many members near the bottom of a food pyramid die, larger animals do not have enough food, and their populations decline.
The flow of energy is also disrupted by the removal of plants. Deforestation removes the link between solar energy and food for other organisms. Deforestation can greatly limit the energy entering into a food web.

In other cases, human action increases the cycling of energy. Humans can build tools like greenhouses that allow plants to grow all year. Greenhouses increase the energy available to the plants, resulting in more plant growth and more food energy.

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