Characteristics of the Solar System

Reflect

Our *solar system* is made up of thousands of objects, at the center of which is a star, the Sun. The objects beyond the Sun include 8 planets, at least 5 dwarf planets, and more than 170 moons. Our solar system also contains thousands of chunks of dust and ice called *comets* and hundreds of thousands of rocks called *asteroids*. Some of these asteroids are tiny; others are larger than Earth's largest mountains.

The "blue planet," Earth, is the only place in the solar system—and possibly the universe—known to support life.

Of all these objects, however, only one is known to support life. That object is the planet on which we live: Earth! What makes Earth able to support life? What are the conditions that must be met for life as we know it to develop and flourish?

One factor that allows Earth to support life is its distance from the Sun.

As far as we know, life can survive and develop only where temperatures fall within a narrow range. That range must allow water to exist in the liquid state at least part of the time. On Earth, liquid water covers about 70% of the planet's surface. Therefore, the bottom of the range must be near 0˚C, the freezing point of water. The top of the range must be near 100˚C, the boiling point of water. The right amount of energy is needed to maintain such a range of temperatures. One source of this energy is our Sun, a star at the center of our solar system.

Any person who has been exposed to sunlight has experienced two forms of the Sun's energy: heat and light. Let's focus on heat energy because it is what produces the temperature conditions needed to keep water in the liquid state. The Sun radiates a tremendous amount of heat. An object too close to the Sun receives so much heat that water cannot exist in the liquid state; it boils away. Scientists think this happened to the liquid water that may once have existed on the planet Venus. An object too far from the Sun receives so little heat that water cannot exist in the liquid state; it freezes. Scientists think this happened to the liquid water that may once have existed on the planet Mars.

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The part of space in our solar system where the Sun's energy provides the conditions for liquid water to exist is called the habitable zone. It begins beyond the orbit of Venus. Earth's orbit lies within the zone. At least part of the orbit of Mars also lies inside the zone. Therefore, Venus is too hot to support life. Earth's temperatures are just right to support life. And Mars may be able to support life, or it may once have supported life.

What Do You Think?

Take a look at this illustration. It shows the Sun and the eight planets of the solar system. It also shows the dwarf planet Pluto (lower-right corner). Which planets are likely too cold to support life as we know it? Which planets are likely too hot?

A factor that allows Earth to support life is its atmosphere. Although it is invisible, Earth's atmosphere is essential to life on our planet. However, the presence of an atmosphere does not necessarily provide conditions that support life. In addition to Earth, six of our solar system's planets (Venus, Mars, Jupiter, Saturn, Uranus, and Neptune) possess atmospheres. However, with the possible exception of Mars, life as we know it could not exist on these planets. (The remaining planet, Mercury, does not have an atmosphere.)

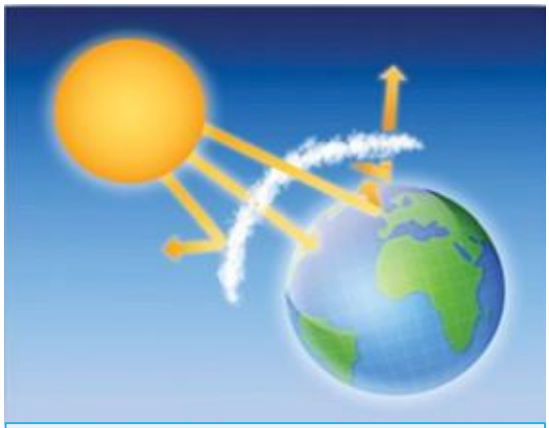
In fact, certain atmospheres may be harmful to life. The atmospheres of some planets contain poisonous gases or produce conditions that are deadly to living things. Again, Mars is an exception. The chart below compares the major components of the atmospheres of the solar system's eight planets.

Planet	Atmosphere contains …?	Planet	Atmosphere contains …?
Mercury	none	Jupiter	hydrogen, helium
Venus	carbon dioxide, nitrogen	Saturn	hydrogen, helium
Earth	nitrogen, oxygen	Uranus	hydrogen, helium, methane
Mars	carbon dioxide, nitrogen, argon	Neptune	hydrogen, helium, methane

Note that only the atmosphere of Earth contains oxygen as a major component. Earth's atmosphere is approximately 78% nitrogen and 21% oxygen. Almost all forms of life on Earth, and certainly its most complex forms, require oxygen to produce the energy needed to survive. Because the other planets of our solar system have so little oxygen, scientists have concluded that complex forms of life similar to those on Earth cannot exist on those planets.

What Do You Think?

A planet's atmosphere contributes to its other properties, especially its surface temperature. As discussed above, a planet's temperature range affects its ability to support life. The components of an atmosphere, especially carbon dioxide, affect a planet's surface temperature.



Earth's atmosphere traps some of the Sun's energy at the planet's surface.

Carbon dioxide gas allows heat from the Sun to pass through the atmosphere. However, carbon dioxide gas also prevents heat from passing out of the atmosphere. Thus, atmospheric carbon dioxide tends to keep the surface of a planet warm.

Earth's atmosphere contains a relatively low concentration of carbon dioxide. This helps to keep surface temperatures moderate. The atmosphere of Venus contains a relatively high concentration of carbon dioxide. This traps great amounts of heat near the planet's surface. As a result, surface temperatures on Venus are about 462˚C (864˚F).

The atmosphere of Mars also contains carbon dioxide. However, Mars has a very thin atmosphere. This—combined with the planet's great distance from the Sun—produces very cool surface temperatures. Surface temperatures on Mars range between –87˚C (–125˚F) and –5˚C (23˚F). Keep in mind that these figures may have been significantly higher in the past. Scientists think that the atmosphere on Mars used to be denser than it now is.

The Curiosity rover collected data, including photographs, as it rolled over the Martian surface in 2012.

How do scientists on Earth know the surface temperatures on other planets? Data have been collected by space probes that have landed on, orbited, or passed by the other planets of our solar system. Special telescopes on Earth have also gathered data on the atmospheres and surface temperatures of other planets.

Look Out!

Most organisms on Earth could not survive without oxygen. However, some organisms, including certain bacteria, obtain energy in the absence of oxygen. As a matter of fact, for some of these organisms, oxygen is actually a poison. Such organisms can survive only in the absence of oxygen. An example is the bacterium *Clostridium botulinum*, which may grow in canned or jarred food. This bacterium can cause deadly food poisoning in humans. To prevent its growth, people jarring or canning food should leave oxygen in the jars. People can also kill the bacteria by heating the food.

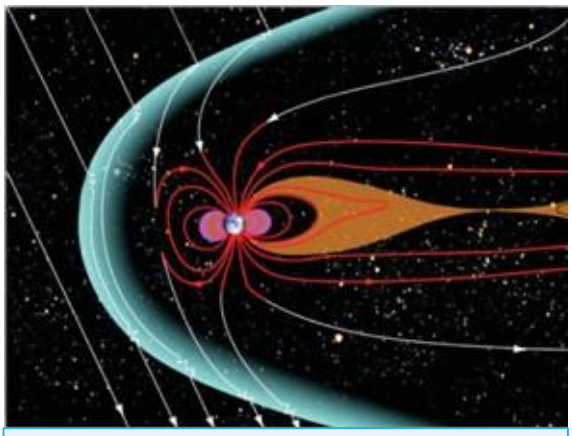
A factor that allows Earth to support life is the planet's ozone layer.
Although heat and light from the Sun make life possible on Earth, other forms of energy from the Sun threaten life on Earth. These include charged particles: positively charged protons and negatively charged electrons. They also include ultraviolet (UV) radiation.

Two characteristics of Earth help protect its living things from the Sun's harmful radiation. These characteristics are Earth's magnetic field and its ozone layer. *Ozone* is a molecule of oxygen made up of three atoms of the gas (O_3). Most molecules of oxygen found in Earth's atmosphere consist of two atoms of oxygen (O_2). The *ozone layer* is a thin concentration of ozone high in Earth's atmosphere. The ozone layer is most concentrated about 23 km above Earth's surface.

Ozone protects life on Earth by absorbing ultraviolet radiation, especially a form called UVB. UVB causes sunburn, skin cancer, and **cataracts** in humans. UVB can also harm some crops and forms of ocean life. As anyone who has suffered from sunburn knows, a lot of UVB radiation does get through the ozone layer. Without the ozone layer, however, even more harmful radiation would reach Earth's surface.

cataracts: dark spots on the lens of an eye that reduce vision

A factor that allows Earth to support life is the planet's magnetosphere.
If you have used a compass, you know that Earth acts as if it had a bar magnet thrust through its center. The magnetized "needle" of a compass is attracted to Earth's magnetic north pole and points toward it. What you cannot see is the magnetic force produced by Earth's magnetism. This force forms a kind of magnetic blanket around the planet called the *magnetosphere*.



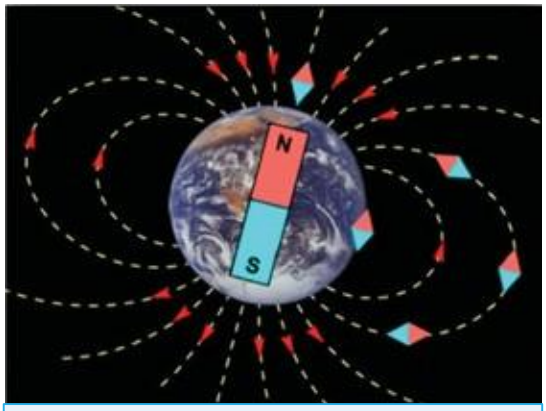
This diagram shows Earth's magnetosphere. It protects Earth from charged particles from the Sun.

Look Out!

The magnetosphere begins about 1000 km above Earth's surface. On the side of Earth that faces the Sun, the magnetosphere reaches about 4000 km above Earth's surface. On the opposite side, the magnetosphere extends even farther out into space.

The magnetic force of an ordinary magnet captures iron filings. Similarly, Earth's magnetosphere captures some of the harmful charged particles that pour down on Earth from the Sun. The magnetosphere protects life on Earth by preventing these particles from reaching the planet's surface. The magnetosphere also protects life by preserving the oxygen in Earth's atmosphere.

This was discovered recently when scientists compared the effects of the Sun's radiation on the atmospheres of Earth and Mars. Oxygen was being lost at a far greater rate from the atmosphere of Mars than from the atmosphere of Earth. Mars has a much weaker magnetosphere than Earth has. The scientists concluded that the difference in the magnetic fields accounted for the differences in oxygen loss. The stronger the magnetic field, the less oxygen is lost.



Earth's magnetic north pole is slowly moving away from the North Pole. In a few thousand years, the magnetic north pole might be located at the South Pole!

Looking to the Future: Earth's Changing Magnetic Field

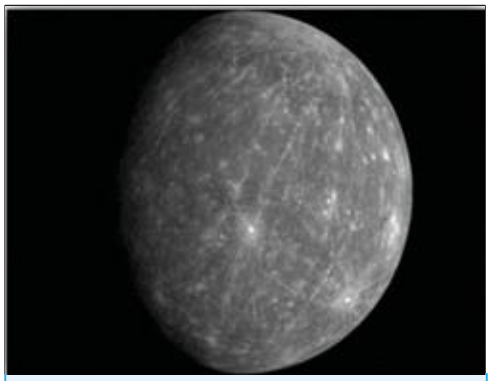
Earth has two north poles and two south poles. Earth's geographic north and south poles are points around which Earth *rotates*, or spins. Earth's magnetic north and south poles are points where Earth's magnetic lines of force are most concentrated. You might think of these points as where the lines of force enter or leave the surface of Earth.

Earth's geographic and magnetic poles do not share the same locations. Today, they are hundreds of kilometers apart. Although the geographic poles are pretty fixed in their positions, the magnetic poles wander considerably over time. In fact, the north and south magnetic poles have switched positions in the past, and they will do so again in the future. Scientists have found evidence that, on average, the magnetic poles switch position every 300,000 years. The last switch happened 780,000 years ago. So the next one is overdue. Such a switch in position takes a few thousand years.

Look Out!

What happens to Earth's magnetic field during such a switch? Scientists don't think that it disappears. However, the magnetic poles might turn up in some seemingly unlikely places. For example, the north magnetic pole might wander to Florida or Brazil. Would this endanger living things? No. The magnetosphere would still protect living things from the Sun's radiation.

Water exists elsewhere in the solar system.
Earth is the only known planet in the universe that supports life. However, Earth is not the only reservoir of water. Comets are made partly of water in the form of ice. Jupiter's moon Europa holds a vast sea of liquid water under a crust of ice. Evidence gathered by a space probe suggests that Saturn's moon Titan probably possesses an underground layer of liquid water. Water ice geysers have been detected by a space probe on Enceladus, another moon of Saturn.



The *MESSENGER* probe has been orbiting Mercury since March 2011.

In 2012, the Mars rover *Curiosity* discovered what looks like an ancient streambed on the red planet's surface. Although liquid water has not yet been found on Mars, the evidence indicates that water once flowed over its surface. Scientists wonder whether some of that water has formed pools that exist today under the surface of Mars. The *MESSENGER* space probe has also discovered ice in craters near Mercury's poles.

If other objects in the solar system hold water in one state or another, might some of these objects also harbor living things? It's possible. Living things as we know them require water to grow and function. Remember, however, that water is not the only condition that supports life on Earth.

Characteristics of the Solar System

Try Now

What do you know?

Various conditions must be met for life to develop on an object in the solar system. The chart lists a number of these objects in the first column. In the second column, write one or more conditions that prevent life from developing on each object. Consider the following eliminating conditions: temperatures too extreme; no liquid water; too far from Sun; too close to Sun; atmosphere does not support life; no atmosphere; poisonous atmosphere. You may add other eliminating conditions if you can think of them.

Object in the Solar System	Eliminating Condition(s)
Mercury	
Venus	
Mars	
Neptune	
Comet	
Earth's moon	

Connecting With Your Child

The Magnetosphere and Life on Earth

You can help your child model the effects of Earth's magnetosphere on the Sun's radiation. To do this, you will need the following materials:

- a bar magnet shaped like a rectangle
- a sheet of paper
- tape
- metric ruler
- iron filings or metal paper clips

Follow this procedure to create your model:

1. Tape the magnet widthwise to the center of the sheet of paper, magnetized side down. Turn the sheet of paper over and lay it on a flat surface.
2. Place the iron filings or paper clips in a row about 3 cm above the magnet.
3. Gently tilt the sheet of paper so the iron filings or paper clips slide downward. Observe what happens.
4. Ask your child the following questions:
    - How far from the magnet does its force act on the filings or paper clips?
    - In what ways is this investigation a model for the effect of Earth's magnetosphere on the Sun's radiation?

The magnetosphere is crucial to supporting life on Earth. To help your child review additional characteristics that support life, take your child on a field trip to a location such as a park or a nearby field. Point out a variety of living things, or have your child do so. Make sure to include examples of plants, animals, and perhaps fungi such as mushrooms. For each organism identified, ask the following questions:

- What role does water play in the life of this organism?
- What role does the Sun play in the life of this organism?
- How does Earth's position in the solar system affect the life of this organism?
- Would this organism have difficulty surviving on Mars? On Mercury? Why or why not?