Cosmic Journey: A Solar System Adventure
General Information

Imagine it … a huge spiral galaxy containing hundreds of billions of stars, spiraling out from a galactic center. Nestled deep within one of the great galactic arms is a star. It's a yellow star, average in size and temperature. Yet there is something extraordinary about this star. It lies in the center of a great collection of bodies, all attracted to it by its sheer gravity. This average star is our sun, and the very contributor for the energy that we need to sustain life here on Earth, the third planet in the solar system.

What makes up the solar system?

At the center of it all is the sun, our nearest star and the brightest object in the sky. It's a ball of gas held together and heated by its own self-gravity. At its center, heat and pressure are so high that nuclear fusion reactions are ignited, releasing even more heat. The energy released at its core takes hundreds of thousands of years to filter out to the sun's surface, where it is then released into space. By comparison, it takes only eight minutes for light from the sun's surface to reach Earth!

It's the only star we know of that shelters life among its family of planets. These planets and their moons, and thousands of smaller bodies—such as asteroids, comets, meteoroids, and interplanetary dust—comprise the remainder of the solar system. The objects in the solar system differ widely from one another but can be sorted into five types.

	Terrestrial planets	Asteroid belt objects	Jovian planets	Kuiper Belt objects	Oort Cloud objects
Object	Mercury, Venus, Earth, Mars	Asteroids	Jupiter, Saturn, Neptune, Uranus	Pluto, comets	Comets
Description	Rocky Small Few or no moons No rings	Rocky	Gas and ice Big Lots of moons Rings	Ice and rock	Ice and rock

What are terrestrial planets?

Terrestrial planets are the inner planets of the solar system, those that lie closest to the sun. They are small, hard-surfaced planets made of rock and metal with few or no moons and no ring systems. With the exception of Mercury, whose atmosphere is very thin, the terrestrial planets have atmospheres composed of a variety of gaseous chemicals, including carbon dioxide, nitrogen,

oxygen, and even sulfuric acid. Each of the terrestrial planets has a similar structure and density, and is composed of a central metallic core and a surrounding mantle. When compared to their larger, gaseous counterparts, terrestrial planets rotate slowly, which makes for longer days, but orbit fairly quickly due to their close proximity to the sun.

How are Jovian planets different?

The Jovian planets are known as the gas giants, large planets whose composition is largely gaseous hydrogen and helium. These planets—Jupiter, Saturn, Uranus, and Neptune—are home to turbulent atmospheres and no solid surface. They have compressed cores and thick atmospheres mottled by fierce storms and powerful winds. The gas giants lie beyond the asteroid belt, at distances far greater than the inner planets. In comparison to their inner planetary cousins, the gas giants rotate at fast speeds, leading to short days. Elaborate rings of debris circle each of the four Jovian planets, though Saturn's are the most spectacular. More than 100 moons orbit these large planets, two of which are larger than Mercury, and several larger than Pluto.

What else can be found in the solar system?

What remains in the solar system can be grouped into three categories. First are asteroid belt objects, a group of rocky objects that orbit the sun but are small like moons. They are simply chunks of rock that never quite pulled it together to become planets and are probably left over from the time of the solar system's formation. The asteroid belt can be found between the orbits of Mars and Jupiter and is home to millions of objects ranging in size from 60 miles to 20 feet in diameter.

Beyond the orbit of Neptune are Kuiper Belt objects. These objects, including Pluto and many short period comets, are composed mainly of rock and ices such as methane, ammonia, and water. The Kuiper Belt is very similar to the asteroid belt, though it is much larger, at least 20 times as wide. Much like the asteroid belt, the Kuiper Belt is home to objects probably left over from the time of solar system formation, pieces of material that didn't form into a planet.

Beyond the Kuiper Belt lies the Oort Cloud, home to comets made of ice and rock. Considered to be the outer edge of the solar system, the Oort Cloud extends 18 trillion miles from the sun. The most famous of the Oort Cloud objects is Sedna, a reddish object estimated to be three-fourths the size of Pluto.

How many planets are in the solar system?

Since 1930 when Clyde Tombaugh discovered Pluto, it has been widely accepted that there are nine planets in the solar system. Recently, scientific discoveries in the outer solar system have lead to confusion among the members of the scientific community about the definition of a planet. Some astronomers believe that Pluto is not a planet and should be considered a "dwarf planet."

The general definition of a planet is any celestial body (besides comets or satellites) that orbits around a star. Pluto, like the other planets, is round and orbits around the sun. It even has a satellite of its own. However, it is much farther out from the sun and has a strange, tilted, oval-shape orbit. It is also much smaller than the other planets in the solar system.

New discoveries have shown many more of these small, distant, icy objects similar to Pluto beyond its orbit. If Pluto is considered a planet, then these other objects would also qualify for planet status. These factors have contributed to the confusion among astronomers about Pluto's status as a planet. Yet the debate remains and probably will for some time to come. Is Pluto a planet or a dwarf planet?

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Average distance from sun (in miles)	36 million	67 million	93 million	142 million	483 million	888 million	1, 784 million	2, 794 million	3, 647 million
Average distance from sun (in km)	58 million	108 million	150 million	228 million	778.4 million	1, 426 million	2, 871 million	4, 498 million	5,906 million
Diameter (miles)	3, 030	7, 523	7,926	4,222	88,846	74,898	31,763	30,775	1,485
Diameter (km)	4,876	12, 107	12, 755	6,794	142,983	120,536	51,117	49,527	2,390
Number of moons	0	0	1	2	61	31	21	11	1
Ring system present	No	No	No	No	Yes	Yes	Yes	Yes	No
Length of orbit (based on Earth day)	88 days	224.7 days	365 days	687 days	4332.6 days	10,759 days	30,684 days	60,190 days	90,465 days
Length of rotation	59 days	243 days	24 hours	24.5 hours	10 hours	10.2 hours	17.2 hours	16.3 hours	6.4 days

Why is Earth the only planet with life?

Life as we know it needs three things: chemicals based on carbon, liquid water, and energy. Earth's position in the solar system is the perfect location to provide for these three things. Its distance from the sun allows just the right amount of heat to maintain the liquid state of water. This distance allows for just the right amount of heat and light from the sun for a pleasant climate. The sun's energy warms the planet, creates our weather, and circulates ocean currents.

Are there other places in the solar system that might harbor life?

There are many other locations in the solar system where scientists are now looking for life or conditions that may have supported life in the past. Though scientists have studied the possibility of life's existence on gas giants in the outer solar system, most have concluded that the conditions of the atmospheres of these planets are much too unstable to support life, despite their having the ingredients possible to form it.

However, scientists have not given up on their search for life within the solar system. Most of the locations of interest now are on moons of other planets. For instance, Neptune's moon Triton is known to have organic material, but all of its water is frozen and it is too far away from the sun to receive the energy needed to support life.

Saturn's moon Titan is also a hot spot for scientists who search for life. Titan is home to a thick nitrogen atmosphere made hazy by chemicals called hydrocarbons. Underneath this thick atmosphere is a hard, icy landscape where chemicals rain from the sky carving the landscape with gullies and liquid lakes of methane. Scientists think that this moon is a lot like Earth was in the beginning with lots of organic material. Yet the surface is still much too cold for liquid water or for the conditions necessary for life.

Another of Saturn's moons, Enceladus, was recently discovered to be releasing water into space from cracks in its crust, in much the same way as geysers on Earth spout water into the air. The strong gravitation pull of Saturn or some radioactive elements are keeping things warm enough inside to melt ice into liquid water. This liquid water could possibly make a home for simple forms of life.

Jupiter's moon Europa is another source of study for scientists. Much like Enceladus, Jupiter's gravitational pulls on Europa creates a warm interior that may be warm enough to harbor an ocean of liquid water beneath its icy crust. If the moon does have liquid water, a source of heat, and organic materials, it could possibly be home again to simple forms of life.

What are moons?

A moon or satellite is a body that orbits a planet or another body larger than itself. There are about 240 known moons in the solar system. Jovian planets possess extensive moon systems, where terrestrial planets have few or no moons. The largest moons in our solar system include Earth's moon, Jupiter's four Galilean moons (Io, Europa, Callisto, and Ganymede), Saturn's moon Titan, and Neptune's moon Triton. Moons are as diverse as the planets in which they orbit. Some have atmospheres, others are dead, crater-pocked wastelands. Others are home to active volcanoes while still others contain geysers that spout water into space.

How old is the solar system?

Just more than 4.5 billion years ago, an incredible event happened that has shaped life as we know it. This event, the formation of the solar system, is a mystery about which scientists can only speculate. Using radiometric dating of meteorites, scientists have hypothesized that the sun was born in a nebula about 4.6 billion years ago. Based on the trends in the nature of the planets compared to their distance from the sun, we now believe the planets were also formed at the same time as the sun.

What does the future look like for the solar system?

Scientists have estimated that the sun is about halfway through its life. In another 5 billion years or so, the sun will run out of nuclear fuel in its core, and it will become unstable, evolving to a red giant and eventually puffing off its outer layers as a planetary nebula, leaving only a white-dwarf core behind. The inner planets may be completely destroyed and conditions will change on the outer planets. Perhaps some of the now-frozen icy moons will even become warmer places where life can thrive in this distant future.

National Science Education Standards
(compiled by McREL)

Earth and Space Sciences

Benchmark 3: Understands the composition and structure of the universe and Earth's place in it

Level II (Grades 3–5)

1. Knows that night and day are caused by Earth's rotation on its axis
2. Knows that Earth is one of several planets that orbits the sun and that the moon orbits Earth
3. Knows that the patterns of stars in the sky stay the same, although they appear to slowly move east to west across the sky nightly and different stars can be seen in different seasons
4. Knows that planets look like stars but over time they appear to wander among the constellations
5. Knows that astronomical objects in space are massive in size and are separated from one another by vast distances (e.g., many stars are more massive than our sun but so distant they look like points of light)
6. Knows that telescopes magnify distant objects in the sky (e.g., the moon, planets) and dramatically increase the number of stars we can see

Level III (Grades 6–8)

1. Knows characteristics and movement patterns of the nine (eight) planets in the solar system (e.g., planets differ in size, composition, and surface features; planets move around the sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them)
2. Knows how the regular and predictable motions of Earth and moon explain phenomena on Earth (e.g., the day, the year, phases of the moon, eclipses, tides, shadows)
3. Knows characteristics of the sun and its position in the universe (e.g., the sun is a medium-size star; it is the closest star to Earth; it is the central and largest body in the solar system; it is located at the edge of a disk-shape galaxy)
4. Knows that gravitational force keeps planets in orbit around the sun and moons in orbit around the planets
5. Knows characteristics and movement patterns of asteroids, comets, and meteors
6. Knows that Earth and the solar system appear to be somewhat unique (e.g., Earth is the only celestial body known to support life), although similar systems might yet be discovered in the universe

Colorado State Standards and CSAP Assessment Objectives
Grades 3–5
Available at
http://www.cde.state.co.us/cdeassess/documents/csap/csap_frameworks.html

Standard 4	**Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.** ***(Focus: Geology, Meteorology, Astronomy, Oceanography)***	
Benchmark 4.7	There are basic components of the solar system (for example, sun, planets, moons).	
Assessment Objective 5th grade CSAP	4.7.a	Compare and contrast the solar system's components (the sun, planets, moons).
Benchmark 4.8	Earth and the sun provide a diversity of resources (for example, soils, fuel, minerals, medicines, and food).	
Assessment Objective 5th grade CSAP	4.8.a	Describe types of natural energy resources (renewable, nonrenewable) and their uses on Earth.
	4.8.b	Identify Earth's different natural resources and their uses on Earth.
Benchmark 4.9	The rotation of Earth on its axis, in relation to the sun, produces the day-and-night cycle, and the orbit of Earth around the sun completes one year.	
Assessment Objective 5th grade CSAP	4.9.a	Describe the events that occur as a result of the motions of Earth (day/night, year, revolution vs. rotation, orbit).

Colorado State Standards and CSAP Assessment Objectives
Grades 6-8
Available at:
http://www.cde.state.co.us/cdeassess/documents/csap/csap_frameworks.html

Standard 4	**Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.** ***(Focus: Geology, Meteorology, Astronomy, Oceanography)***	
Benchmark 4.13	There are characteristics (components, composition, size) and scientific theories of the origin of the solar system.	
Assessment Objectives 8th grade CSAP	4.13.a	Describes the parts (planets, Sun, moons, asteroids, comets) of the solar system and their motions.
	4.13.b	Compare and contrast the characteristics of the Sun, Moon, and Earth.
	4.13.c	Examine and explain the scientific theories on the formation of our Solar System, Earth, and Moon.
Benchmark 4.14	Relative motion, axes, tilt, and positions of the Sun, Earth, and Moon have observable effects (for example: seasons, eclipses, moon phases).	
Assessment Objectives 8th grade CSAP	4.14.a	Understand how the location of the Moon affects the phases of the Moon, eclipses, and the tides.
	4.14.b	Understand how the tilt and motions of the Earth result in days, years, and seasons.
Benchmark 4.15	The universe consists of many billions of galaxies (each containing man billions of stars) and that vast differences separate these galaxies and stars from one another and from Earth.	
Assessment Objectives 8th grade CSAP	4.15.a	Describe the components of the Universe in terms of galaxies, stars, and solar systems.
Benchmark 4.16	Technology is needed to explore space (for example: telescopes, spectroscopes, spacecraft, life support systems).	
Assessment Objectives 8th grade CSAP	4.16.a	Understand the technologies needed to explore space and evaluate their effectiveness and challenges.

GLOSSARY OF TERMS

apparent motion—the motion of celestial objects as observed from Earth

asteroid—a large rocky body in orbit around the sun; most asteroids are found in orbit in the asteroid belt between Mars and Jupiter

asteroid belt—a large group of asteroids in orbit around the sun between Mars and Jupiter

axis—an imaginary line around which an object (such as a planet or moon) turns

core—the innermost layer of a planet, moon, or star

full moon—a moon that appears as a whole circle in the sky; a full moon occurs once each lunar month, when the moon is on the opposite side of Earth from the sun

gas giants—the large, gaseous outer planets of the solar system, including Jupiter, Saturn, Uranus, and Neptune; these planets are sometimes referred to as the Jovian planets

gibbous moon—the shape the moon takes when it is between a full moon and a half moon or between a half moon and a full moon

gravity—a physical force that attracts objects to each other; the more massive an object, the stronger its gravitational force

half moon—the shape of the moon when it looks like half a circle; sometimes called a quarter moon

heliocentric—a system in which the sun is at the center

inner planets—the four planets orbiting closest to the sun, Mercury, Venus, Earth, and Mars; these planets are relatively small, rocky planets with few or no moons

Jovian planets—a term used to describe the large, gaseous planets of Jupiter, Saturn, Uranus, and Neptune

Kuiper Belt—an area beyond Neptune containing thousands of small objects, including short-period comets

meteor—a meteoroid that has entered Earth's atmosphere; often called shooting stars

meteorite—a meteor that has fallen to Earth

meteoroid—small rocks or pieces of metal that travel through space

moon—a natural satellite that orbits a planet or other object

nebula—a cloud of gas and dust found in space; stars are born in nebulae

new moon—the moon phase in which the moon is not visible because the side of the moon facing Earth is not lit by the sun

Oort Cloud—a cloud of rocks and dust that surrounds our solar system beyond the Kuiper Belt; believed to be the source of most of the comets in the solar system

outer planets—the planets orbiting farthest from the sun, including Jupiter, Saturn, Uranus, and Neptune; also called the gas giant planets as they are large, gaseous, ringed, and have many moons

planet—a large body orbiting a star that does not shine on its own

seasons—periods of time on Earth—winter, spring, summer, and autumn—caused by the tilt of Earth's axis; seasons can occur on other planets as well

waning—shrinking in size; used to describe the phases of the moon

Waxing—growing in size; used to describe the phases of the moon

RECOMMENDED WEBSITES FOR TEACHERS AND STUDENTS

DMNS Space Odyssey Online Guide-Solar System Pathway
http://www.dmns.org/main/minisites/spaceOdyssey/teachersGuide/index.html

Kinesthetic Astronomy
http://www.spacescience.org/education/instructional_materials.html

NASA Space Place
http://spaceplace.nasa.gov/en/kids/

Astroventure
http://astroventure.arc.nasa.gov/

NASA Kids
http://www.nasa.gov/audience/forkids/home/index.html

NASA Quest
http://quest.nasa.gov/

JPL Student and Educator Resources
http://education.jpl.nasa.gov/k12/indexBackpack.html

NASA Solar System Exploration
http://solarsystem.nasa.gov/kids/index.cfm

NASA New Frontiers Program
http://newfrontiers.nasa.gov/teacher_zone.html