Moons: Natural satellites

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The moons (natural satellites) of the solar system are especially interesting in their incredible range of diversity. It is perhaps the variety of features among the moons that make them so interesting to study. The moons in the solar system are typically either rocky or a mixture of rock and ice. Most are airless, however, some of them have an atmosphere. Some are even volcanically active, with eruptions or fissure flows of molten rocky material or slushy ice. Some moons are very hot, while others are very cold—extreme conditions compared to Earth.

Based on their location of origin, the moons of the solar system can be divided into two groups—*regular moons* and *irregular moons*. Regular moons have a nearly circular or slightly elliptical orbit around their host planet. It is thought that these moons formed during the early history of the solar system as their host planet formed. Regular moons follow orbits that are in the direction of their planet's rotation. Irregular moons, on the other hand, have an orbit that is highly elliptical, which has them orbiting their planet at a distance of many millions of kilometers. Many of the irregular moons orbit their planet *retrograde*, or the opposite direction of the regular moons and the planet's rotation. These irregular moons are believed to have originally orbited the Sun and, over time, have been subsequently "captured" by the planet they now orbit.

With recent advances in both observational and imaging technologies, and through the camera eyes of robotic missions, additional moons have been discovered. The number of new moons has increased tremendously, doubling in just the past four years (see Figure 1). As of June 2003 there were 128 known moons in our solar system with the constant possibility for more discoveries. This continuously growing list includes our own moon, the two that orbit Mars, Pluto's moon Charon, as well as the 21 new Jupiter moons, the new Saturn moon, and the three new Neptunian moons discovered this year.

While one might think of a moon in terms of what we have seen of our own moon, that thinking would not be consistent with what we have learned about the others moons in our solar system. One thing we have learned is that diversity is the norm. The first thing noticed is the incredible range in size. Interestingly, the newly discovered moons are irregular both in orbit and shape and they all share something in common with most of the other moons—they are relatively small and, with two exceptions (Luna and Charon), considerably smaller than their host planet. Moon sizes range from about 1 km in diameter to the largest moon, planet-sized Ganymede, with a diameter of nearly 5,300 km. Joining Ganymede is the 5,100-km-diameter moon Titan, and more than a dozen other moons with diameters greater than 1,000 km. While there is quite a size range, on the average most moons are only a few kilometers in size.

Surface features vary tremendously as well, but it is those that are close to their host planet that exhibit the most interesting features. These moon surfaces are exposed to the *tidal forces*, or gravitational pull, of the larger and more massive host planet. Tidal forces are very significant in terms of the interaction between a planet and its natural satellites. Consider, for example, Jupiter's two moons, Io and Europa. Both of these moons are continually stretched and re-stretched by tidal forces. This produces friction within Io that results in heating, which keeps the volcanoes fired up. With Europa, the stretching and friction produces enough heat to keep water in its liquid state below the frozen surface.

Io has more active volcanoes than any other object in the solar system (more than Earth and Venus combined!). It is less than 500,000 km from Jupiter and is close enough that the tremendous tidal forces from Jupiter actually cause a tidal bulge in the solid crust of the moon, much as our moon cre-

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FIGURE 1 **Moons discovered in last 25 years**

Planet	Known moons	1978	1979	1980	1986	1989	1990	1997	1999	2000	2001	2002	2003
Mercury	0												
Venus	0												
Earth	1												
Mars	2												
Jupiter	61		3							11	11	1	21
Saturn	31			6			1			12			1
Uranus	21				9			2	4				
Neptune	11					6							3
Pluto	1	1											

ates a tidal bulge in the oceans here on Earth. As Io revolves around Jupiter it is in a constant tug-of-war not only with Jupiter but also with three larger moons, Ganymede, Europa, and Callisto.

Europa, the next large moon out from Jupiter, at about double the distance as Io, has a surface like a ball showing cracks in its icy crust caused by the tidal stress from the host planet. It is distant enough that, while it is still under the intense tidal force from Jupiter, it is far enough away to only have a "cracked" surface. There are almost no craters on this moon because the icy crater walls formed by impact eventually slump down under their own weight.

Life as a moon is not as safe and stable as one might think. In fact, the surfaces of most moons display the effects of numerous impacts with rocky objects. All are cratered to some degree, and some exhibit other types of damage. Uranus's moon Miranda appears to have suffered a tremendous impact, broken apart, and then over time slowly drifted back together—but not exactly along the lines where it originally broke. Several moons, Mars' Phobos and Saturn's Mimas for example, are among the many moons displaying craters large enough to make scientists wonder what prevented these moons from shattering into several pieces.

Internet resources

Moons in our solar system—*www.windows.ucar.edu/tour/link=/our_solar_system/moons_table.html*
The Jupiter Satellite Page—*www.ifa.hawaii.edu/~sheppard/satellites*
Saturn's known satellites—*www.ifa.hawaii.edu/~sheppard/satellites/satsatdata.html*
The Nine Planets—*www.seds.org/nineplanets/nineplanets/nineplanets.html#toc*
World Space Week—*www.spaceweek.org*
Daylight saving time—*scienceworld.wolfram.com/astronomy/DaylightSavingTime.html*

Visible planets

- Mercury is visible low over the eastern horizon at sunrise during the first half of the month.
- Venus is very low over the southwestern horizon at sunset.
- Mars is visible over the southeastern horizon at sunset and sets before sunrise.
- Jupiter is over the eastern horizon at sunrise.
- Saturn rises before midnight and is high over the eastern horizon at sunrise.

Moon phases

First quarter	10/02
Full Moon	10/10
Last quarter	10/18
New Moon	10/25

Celestial events

10/01 NASA's 45th Birthday
10/04–10 World Space Week
10/06 Mars near Moon
10/21 Jupiter near Moon
10/25 Mercury at superior conjunction
10/26 Venus near Moon
10/26 Daylight savings