SPASH ASTRONOMY
CHAPTER 11: JUPITER, SATURN, AND THEIR MOONS
OVERHEAD LECTURE NOTES

1. What is considered the outer solar system: Jupiter, Saturn, Uranus, Neptune, and Pluto.

2. How does the outer four planets compare to the inner four planets. List **at least two** comparisons.

Jupiter was named for the monarch of the Roman gods. It contains 71% of the total planetary mass. Jupiter is a little over 10 times Earth's diameter and Saturn is just under 10 times. Uranus and Neptune have diameters about four times the Earth's. Earth would be like a dime on a Jupiter dinner plate.

All four giant planets together have at least 76 satellites (95% of all known satellites) and contain 99.5% of the total planetary mass.

The four giant planets have much lower mean densities than the inner planets, 700 to 1600 kg/m^3 (Saturn at 700 kg/m^3 would float as water is 1000 kg/m^3).

Because the outer solar system is so much farther from the sun it contains more ice than the inner solar system (about 50-50 mixtures of rock and ice).

3. Name **at least three** general features of Jupiter and Saturn:

1. They are the largest and most colorful of the giant planets, with similar cloud patterns and atmospheric compositions.

2. Through a telescope one can but merely see the tops of the thick cloud decks that cover both planets. But one can also see the belts of each planet, the Galileo moons of Jupiter, Saturn's largest moon Titan, and the rings of Saturn.

3. The clouds on both planets maintain their general features for many years, but details of these features change from month to month and year to year because of turbulent movements of the clouds. The clouds of both are organized in systems of dark belts and bright zones running parallel to the equators. Generally, the zones are whitish or yellowish, and the belts are darker, with gray-brown and reddish tinges. When you are looking at the lighter colored belts you are seeing the higher clouds and thus the darker belts are deeper in the atmosphere of each.

4. At the equatorial and temperate zones on Jupiter the smaller clouds are going 338 miles faster than the movements of the clouds in the dark equatorial belts, where Saturn's clouds move at 1,010 mph faster than the neighboring belts.

5. On both J&S, the clouds are believed to be composed primarily of ice crystals of ammonia, ammonium hydrosulfide, and frozen water.

6. Jupiter's Great Red Spot has existed for at least 300 years, since it was first reported by G.D. Cassini in 1665, and other smaller transient spots are oval storms (probably hurricanes). The Great Red Spot averages three times the width of the entire planet Earth!

7. Voyagers' photos of the night side of J revealed might blasts of lightning playing among the clouds and enormous auroral displays flickering high above the clouds in Jupiter's polar regions. Saturn's atmosphere is less active in these regards.

Why does Jupiter have more colorful clouds (not the rings) and more storms than Saturn?

Saturn's clouds are less active and less colorful than Jupiter's because Saturn is colder (further om Sun, and radiates less internal heat). The daytime and nighttime cloud top temperatures of J. ıd Sat. average about -207°F to -173°F because this is the temp. at which ammonia NH_3 and certain nmonia-based compounds condense and form clouds. Because of Jupiter's greater heat, it has ıore energy to drive storm systems (the Red Spot and more upwelling of colorful clouds from the 'armer regions below). The farther down we go in these atmospheres, the warmer they become. cientists believe that lower regions, about 60 km below the cloud tops, may reach room temperature t pressures nearly ten times greater than on |Earth - relatively benign conditions except that the gas /ould be poisonous to Earth's organisms!

. How fast does J. and S. rotate? (earth is 24 hours)

All four giant planets rotate faster than Earth. The best estimate of the rotation speed of the nderlying planetary body, based on radio radiations from deep-atmosphere electrical storms for J. is $^h55.5^m$ and for S. $10^h39.4^m$ for the planet itself. Because the equatorial belts and zones rotate a bit aster their average period is J. 9^h50^m and Sat. 10^h14^m.

5. Are the giant planets luminous or illuminated?

The four giant planets have thermal infrared radiation from the heat of the planets themselves. They radiate considerably more heat than they receive from the Sun. J. radiates 2.5 times as much ıeat and Sat. 2.3 times as much as they receive from the Sun. On Earth and the other three terrestrial planets, the internal heat generated by radioactivity is only 0.005 percent of the heat received from he Sun.

Theorists believe J. and S. are slowly contracting, which generates heat in their interiors, causing a flow of infrared radiation outward.

Although J. and S. radiate their own energy, they are not true stars, because the energy is not coming from thermonuclear fusion reactions the way a star's is produced..

7. How does Jupiter's and Saturn's magnetic fields compare to Earth's? List **at least two.**

Jupiter's magnetic field was first observed directly in 1973 and 1974 when Pioneers 10 and 11 flew through it and measured it. Jupiter's field reaches strengths 10 to 20 times stronger than Earth's, Saturn's, or Uranus'.

The angles of the planets magnetic fields with the rotation axis is 10° for Jupiter, 11° for Earth, and less than 1° off for Saturn.

Jupiter's polarity is opposite Earth's but even Earth's field has alternated during Earth's history, reversing polarity sporadically several times per million years.

Another similarity to Earth is that charged atomic particles emitted by the Sun have been trapped by Jupiter's magnetic field and concentrated into doughnut shaped rings around the planet, like Earth's Van Allen belts. The particles are 100,000 to a million times more concentrated than they are near Earth, making a zone of quite hazardous, energetic atomic particles near Jupiter's inner satellites.

Saturn shares many of these features but with weaker strength. The charged particles zipping through Saturn's magnetic field get absorbed when they collide with particles in Saturn's rings (which are much denser than Jupiter's rings). The region from Saturn's rings inward toward the top of the atmosphere is the best-shielded region of space in the solar system, in terms of its low density of energetic particles.

The strange magnetic fields of planets are believed to be generated by circulation currents in an electrically conductive hot material deep inside some planets.

8. What are these planets like under their clouds? Note the 3rd paragraph summaries this question.

Strangely enough, there is probably no well-defined surface on which we could land, contrary to our experience on terrestrial planets. If we descended far below the visible clouds, we would find the atmosphere growing thicker and thicker, at higher and higher pressure. There is no ocean surface of liquid hydrogen because the temperature is too high, and so the gas simply gets denser at lower depths, turning into a mush resembling a thick, hot liquid, but with no well-defined surface. Just as well that there is no surface on which to land as a 150 pound person from Earth would weigh 400 pounds on Jupiter. It would be hard to walk around.

The deeper internal structures of Jupiter and Saturn are still stranger. The interiors of these planets are roughly 66% hydrogen, with the rest being helium mixed with small amounts of silicates and other impurities. Near the small rock/ice core is a region of liquid metallic hydrogen formed when electrons are stripped away from the atoms, so that we have protons surrounded by loose electrons.

In short, J. and S. can be visualized as cold, buried super-Earth's, surrounded by vast oceans of liquid hydrogen and deep hydrogen atmospheres full of clouds, stretching to about ten times Earth's diameter.

9. OK, are all the outer giant planets married or something because they all have rings?

Today we know all four giant planets have ring systems. Saturn's rings present a changing appearance from year to year in a 29 year cycle; this is because of the change in the ring plane orientation relative to Earth as Saturn orbits around the Sun every 29 years.

Modern spacecraft photos confirm that the rings are not solid because we can see through parts of them. All the rings are made of countless tiny particles orbiting each giant planet over its equator.

10. Name at least two ways in which Jupiter's rings differ from Saturn's rings:

You can only see Jupiter's rings by looking back toward the Sun from the far side of the planet thus we cannot see Jupiter's rings from Earth.

Saturn's rings are not made of dust particles, like Jupiter's, but of chunks of ice! A visitor to the ring system of Saturn would be surrounded by an amazing swarm of floating hailstone-like bodies. Even though from tip to tip Saturn's rings span 171,000 miles (274,000 km) the rings are less than 100 meters thick.

11. Why don't the ring particles come together to form another satellite around each planet?

Recall that inside Roche's limit the difference in force is enough to pull the bodies apart. hus, if two ring particles inside Roche's limit began to clump together due to their mutual gravity, ıey would soon find that the tidal force would pull them apart again. Thus all we find all ring ystems inside Roche's limit for their planets.

2. What caused the ring systems of Jupiter and Saturn?

Jupiter's rings are dark microscopic particles that have been "sandblasted" off the ınermost small moons by meteorites. In a sense, the Jupiter ring system is like a river: It is not a ixed object but is composed of material flowing through it toward the planet.

Saturn's rings are thought to be fragments of a moderate-sized icy moon (like some of Saturn's ther inner moons) that was blown apart eons ago by a meteorite impact.

3. Why is it not fair to say our solar system has nine planets and their moons?

Planets are not more important since two of the moons are larger than the smaller planets it s fairer to say that the solar system is composed of two dozen world-class objects some of which are ılanets and some are moons – with individual geologic and astronomical personalities.. After all we tand a better chance of finding life on the outer moons than on the planets.

14. How many moons do Jupiter and Saturn have?

Voyagers 1 and 2 discovered many new moons bringing the total for Jupiter to 16 and the total for Saturn to 18. ***New Data:*** **The discovery of 11 small moons orbiting Jupiter leapfrogs the number of that planet's moons to 39, nine more than the record of the previous champ, Saturn.**

J. & S.'s MOONS

15. Each giant planet's family of moons can be divided into four groups: Name them:

1. Countless minimoonlets and dust particles involved in the ring systems.
2. Small moons close to the planet, on the outskits of the rings systems (or in some cases inside the ring system) These are sources of the ring material.
3. Large moons at intermediate distance from the planet. These have the most distinctive geology.
4. Small moons on the outskirts of the planet's sphere of gravitational influence. These moons seem not to be native to the planet, but rather passing interplanetary bodies that were captured by the planet's gravity.

16. In the "salt and pepper" model of satellite materials what is the "salt" and what is the "pepper"? The salt is the ices which include familiar H_2O at very low temperatures, along with frozen carbon dioxide (CO_2, also called dry ice), frozen methane (CH_4), and other frozen material. The "pepper" is black carbon-rich dirt called carbonaceous material, which probably resembles black, sooty dust and gravel.

17. Name at least two properties of each of the following moons' Jupiter and Saturn:

Jupiter I

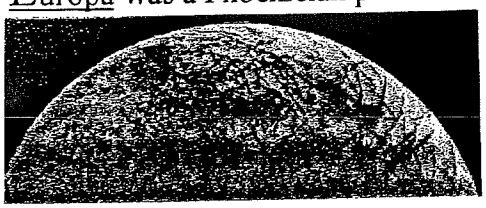
Io (EYE oh) is the fifth of Jupiter's known satellites and the third largest; it is the innermost of the Galilean moons. Io is slightly larger than Earth's Moon. orbit: 422,000 km from Jupiter diameter: 3630 km mass: 8.93e22 kg The pronunciation "EE oh" is also acceptable. Io was a maiden who was loved by Zeus (Jupiter) and transformed into a heifer in a vain attempt to hide her from the jealous Hera. Discovered by Galileo and Marius in 1610. In contrast to most of the moons in the outer solar system, Io and Europa may be somewhat similar in bulk composition to the terrestrial planets, primarily composed of molten silicate rock. Recent data from Galileo indicates that Io has a core of iron (perhaps mixed with iron sulfide) with a radius of at least 900 km. Io's surface is radically different from any other body in the solar system. It came as a very big surprise to the Voyager scientists on the first encounter. They had expected to see impact craters like those on the other terrestrial bodies and from their number per unit area to estimate the age of Io's surface. But there are very few, if any, impact craters on Io (left). Therefore, the surface is very young. Instead of craters, Voyager 1 found hundreds of volcanic calderas. Some of the volcanoes are **active**! Striking photos of actual eruptions with plumes 300 km high were sent back by both Voyagers (right) and by Galileo (bottom left image on this page) This may have been the most important single discovery of the Voyager missions; it was the first real proof that the interiors of other "terrestrial" bodies are actually hot and active. The material erupting from Io's vents appears to be some form of sulfur or sulfur dioxide. The volcanic eruptions change rapidly. In just four months between the arrivals of Voyager 1 and Voyager 2 some of them stopped and others started up. The deposits surrounding the vents also changed visibly. Recent images taken with NASA's Infrared Telescope Facility on Mauna Kea, Hawaii show a new and very large eruption (right). A large new feature near Ra Patera has also been seen by HST. Images from Galileo also show many changes from the time of Voyager's encounter. These observations confirm that Io's surface is very active indeed. Io has an amazing variety of terrains: calderas up to several kilometers deep, lakes of molten sulfur (below right), mountains which are apparently NOT volcanoes (left), extensive flows hundreds of kilometers long of some low viscosity fluid (some form of sulfur?), and volcanic vents. Sulfur and its compounds take on a wide range of colors which are responsible for Io's variegated appearance. Analysis of the Voyager images led scientists to believe that the lava flows on Io's surface were composed mostly of various compounds of molten sulfur. However, subsequent ground-based infra-red studies indicate that they are too hot for liquid sulfur. One current idea is that Io's lavas are molten silicate rock. Recent HST observations indicate that the material may be rich in sodium. Or there may be a variety of different materials in different locations. Some of the hottest spots on Io may reach temperatures as high as 2000 K though the average is much lower, about 130 K. These hot spots are the principal mechanism by which Io loses its heat. The energy for all this activity probably derives from tidal interactions between Io, Europa, Ganymede and Jupiter. These three moons are locked into resonant orbits such that Io orbits twice for each orbit of Europa which in turn orbits twice for each orbit of Ganymede. Though Io, like Earth's Moon always faces the same side toward its planet, the effects of Europa and Ganymede cause it to wobble a bit. This wobbling stretches and bends Io by as much as 100 meters (a 100 meter tide!) and generates heat the same way a coat hanger heats up when bent back and forth. (Lacking another body to perturb it, the Moon is not heated by Earth in this way.) Io also cuts across Jupiter's magnetic field lines, generating an electric current. Though small compared to the tidal heating, this current may carry more than 1 trillion watts. It also strips some material away from Io which forms a torus of intense radiation around Jupiter. Particles escaping from this torus are partially responsible for Jupiter's unusually large magnetosphere. Recent data from Galileo indicate that Io may have its own magnetic field as does Ganymede. Io has a thin atmosphere composed of sulfur dioxide and perhaps some other gases. Unlike the other Galilean satellites, Io has little or no water.

Jupiter II

Europa ("yoo ROH puh") is the sixth of Jupiter's known satellites and the fourth largest; it is the second of the Galilean moons. Europa slightly smaller than the Earth's Moon.

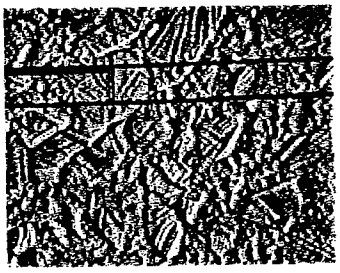
orbit: 670,900 km from Jupiter
diameter: 3138 km
mass: 4.80e22 kg

Europa was a Phoenician princess abducted to Crete by Zeus, who had assumed the form of a white bull, and by



him the mother of Minos. Discovered by Galileo and Marius in 1610.

Europa and Io are somewhat similar in bulk composition to the terrestrial planets: primarily composed of silicate rock. Unlike Io, however, Europa has a thin outer layer of ice. Recent data from Galileo indicate that Europa has a layered internal structure perhaps with a small metallic core. But Europa's surface is not at all like anything in the inner solar system. It is exceedingly **smooth**: few features more than a few hundred meters high have been seen. The prominent markings seem to be only albedo features with very low relief. There are very few craters on Europa; only three craters larger than 5 km in diameter have been found. This would seem to indicate a young and active surface. However, the Voyagers mapped only a fraction of the surface at high resolution. The precise age of Europa's surface is an open question. The images of Europa's surface strongly resemble images of sea ice on Earth. It is possible that beneath Europa's surface ice there is a layer of liquid **water**, perhaps as much as 50 km deep, kept liquid by tidally generated heat. If so, it would be the only place in the solar system besides Earth where liquid water exists in significant quantities. Europa's most striking aspect is a series of dark streaks crisscrossing the entire globe. The larger ones are roughly 20 km across with diffuse outer edges and a central band of lighter material. The latest theory of their origin is that they are produced by a series of volcanic eruptions or geysers. Recent observations with HST reveal that Europa has a very tenuous atmosphere (1e-11 bar) composed of oxygen. Of the 61 moons in the solar system only four others (Io, Ganymede, Titan and Triton) are known to have atmospheres. Unlike the oxygen in Earth's atmosphere, Europa's is almost certainly not of biologic origin. It is most likely generated by sunlight and charged particles hitting Europa's icy surface producing water vapor which is subsequently split into hydrogen and oxygen. The hydrogen escapes leaving the oxygen.



The Voyagers didn't get a very good look at Europa. But it is a principal focus of the Galileo mission. Images from Galileo's first two close encounters with Europa seem to confirm earlier theories that Europa's surface is very young: very few craters are seen, some sort of activity is obviously occurring. There are regions that look very much like pack-ice on polar seas during spring thaws on Earth. The exact nature of Europa's surface and interior is not yet clear but the evidence is now strong for a subsurface 'ocean'.

Galileo has found that Europa has a weak magnetic field (perhaps 1/4 of the strength of Ganymede's). And most interestingly, it varies periodically as it passes thru Jupiter's massive magnetic field. This is very strong evidence that there is a conducting material beneath Europa's surface, most likely a salty ocean.

Jupiter III

Ganymede ("GAN uh meed") is the seventh and largest of Jupiter's known satellites. Ganymede is the third of the Galilean moons.

orbit: 1,070,000 km from Jupiter
diameter: 5262 km
mass: 1.48e23 kg

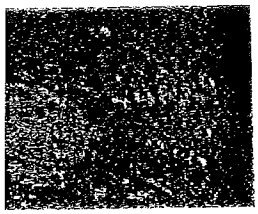
Ganymede was a Trojan boy of great beauty whom Zeus carried away to be cup bearer to the gods.

Discovered by Galileo and Marius in 1610.

Ganymede is the largest satellite in the solar system. It is larger in diameter than Mercury but only about half its mass. Ganymede is much larger than Pluto.

Before the Galileo encounters with Ganymede it was thought that Ganymede and Callisto were composed of a rocky core surrounded by a large mantle of water or water ice with an ice surface (and that Titan and Triton were similar). Preliminary indications from the Galileo data now suggest that Callisto has a uniform composition while Ganymede is differentiated into a three layer structure: a small molten iron or iron/sulfur core surrounded by a rocky silicate mantle with a icy shell on top. In fact, Ganymede may be similar to Io with an additional outer layer of ice.

Ganymede's surface is a roughly equal mix of two types of terrain: very old, highly cratered dark regions (left), and somewhat younger (but still ancient) lighter regions marked with an extensive array of **grooves and ridges** (right). Their origin is clearly of a tectonic nature, but the details are unknown. In this respect, Ganymede may more similar to the Earth than either Venus or Mars (though there is no evidence of recent tectonic activity). Evidence for a tenuous oxygen atmosphere on Ganymede, very similar to the one found on Europa, has been found recently by HST (note that this is definitely NOT evidence of life). Similar ridge and groove terrain is seen on Enceladus, Miranda and Ariel. The dark regions are similar to the surface of Callisto.



Extensive cratering is seen on both types of terrain. The density of cratering indicates an age of 3 to 3.5 billion years, similar to the Moon. Craters both overlay and are cross cut by the groove systems indicating the the grooves are quite ancient, too. Relatively young craters with rays of ejecta are also visible (left).

Unlike the Moon, however, the craters are quite flat, lacking the ring mountains and central depressions common to craters on the Moon and Mercury. This is probably due to the relatively weak nature of Ganymede's icy crust which can flow over geologic time and thereby soften the relief. Ancient craters whose relief has disappeared leaving only a "ghost" of a crater are known as **palimpsests** (right).

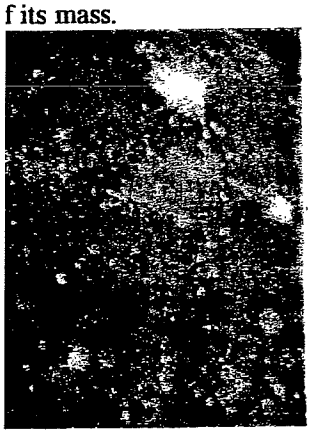
Galileo's first flyby of Ganymede discovered that Ganymede has its own magnetosphere field embedded inside Jupiter's huge one. This is probably generated in a similar fashion to the Earth's: as a result of motion of conducting material in the interior.

Jupiter IV

Callisto ("ka LIS toh") is the eighth of Jupiter's known satellites and the second largest. It is the outermost of the Galilean moons.

orbit: 1,883,000 km from Jupiter
diameter: 4800 km
mass: 1.08e23 kg

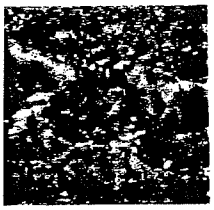
Callisto was a nymph, beloved of Zeus and hated by Hera. Hera changed her into a bear and Zeus then placed her in the sky as the onstellation Ursa Major. Discovered by Galileo and Marius in 1610. Callisto is only slightly smaller than Mercury but only a third f its mass.



Unlike Ganymede, Callisto seems to have little internal structure; however there are signs from recent Galileo data that the interior materials have settled partially, with the percentage of rock increasing toward the center. Callisto is about 40% ice and 60% rock/iron. Titan and Triton are probably similar.

Callisto's surface is covered entirely with craters. The surface is very old, like the highlands of the Moon and Mars. Callisto has the oldest, most cratered surface of any body yet observed in the solar system; having undergone little change other than the occasional impact for 4 billion years.

The largest craters are surrounded by a series of concentric rings which look like huge cracks but which have been smoothed out by eons of slow movement of the ice. The largest of these has been named **Valhalla** (right). Nearly 3000 km in diameter, Valhalla is a dramatic example of a **multi-ring basin**, the result of a massive impact. Other examples are Callisto's Asgard (left), Mare Orientale on the Moon and Caloris Basin on Mercury.



Like Ganymede, Callisto's ancient craters have collapsed. They lack the high ring mountains, radial rays and central depressions common to craters on the Moon and Mercury. Detailed images from Galileo (left) show that, in some areas at least, small craters have mostly been obliterated. This suggests that some processes have been at work more recently, even if its just slumping.

Another interesting feature is **Gipul Catena**, a long series of impact craters lined up in a straight line (right). This was probably caused by an object that was tidally disrupted as it passed close to Jupiter (much like Comet SL 9) and then impacted on Callisto.

Callisto has a very tenuous atmosphere composed of carbon dioxide.

Galileo has detected evidence of a weak magnetic field which may indicate some sort of salty fluid below the surface.

Unlike Ganymede, with its complex terrains, there is little evidence of tectonic activity on Callisto. While Callisto is very similar in bulk properties to Ganymede, it apparently has a much simpler geologic history. The different geologic histories of the two has been an important problem for planetary scientists; (it may be related to the orbital and tidal evolution of Ganymede). "Simple" Callisto is a good reference for comparison with other more complex worlds and it may represent what the other Galilean moons were like early in their history.

Saturn VI

Titan is the fifteenth of Saturn's known satellites and the largest:
orbit: 1,221,830 km from Saturn diameter: 5150 km mass: 1.35e23 kg.

In Greek mythology the Titans were a family of giants, the children of Uranus and Gaia, who sought to rule the heavens but were overthrown and supplanted by the family of Zeus. Discovered by Huygens in 1655. It was long thought that Titan was the largest satellite in the solar system but recent observations have shown that Titan's atmosphere is so thick that its solid surface is slightly smaller than Ganymede's. Titan is nevertheless larger in diameter than Mercury and larger and more massive than Pluto. One of the principal objectives of the Voyager 1 mission was the study of Titan. Voyager 1 came within 4000 km of the surface. We learned more in the few minutes of that encounter than in the previous 300 years. And yet our knowledge is frustratingly incomplete. Titan is surrounded by a thick, opaque **atmosphere**; the surface cannot be seen at all in visible light (below left). (The Cassini mission will map Titan's surface with radar as Magellan did at Venus.) All that the Voyager images show is a slight variation in color between the northern and southern hemispheres. Some surface detail is visible in the infrared with HST. Titan is similar in bulk properties to Ganymede, Callisto, Triton and (probably) Pluto. It is not known whether it has any internal structure like Ganymede or is uniform like Callisto. Titan is about half water ice and half rocky material. It is probably differentiated into several layers with a 3400 km rocky center surrounded by several layers composed of different crystal forms of ice. Its interior may still be hot. Though similar in composition to Rhea and the rest of Saturn's moons, it is denser because it is so large that its gravity compresses its interior. Alone of all the satellites in the solar system, Titan has a significant **atmosphere**. At the surface, its pressure is more than 1.5 bar (50% higher than Earth's). It is composed primarily of molecular nitrogen (as is Earth's) with no more than 6% argon and a few percent methane. Interestingly, there are also trace amounts of at least a dozen other organic compounds (i.e. ethane, hydrogen cyanide, carbon dioxide) and water. The organics are formed as methane, which dominates in Titan's upper atmosphere, is destroyed by sunlight. The result is similar to the smog found over large cities, but much thicker. In many ways, this is similar to the conditions on Earth early in its history when life was first getting started. Titan has no magnetic field and sometimes orbits outside Saturn's magnetosphere. It is therefore directly exposed to the solar wind. This may ionize and carry away some molecules from the top of the atmosphere. At the surface, Titan's temperature is about 94 K (-290 F). At this temperature water ice does not sublimate and thus there is little water vapor in the atmosphere. Nevertheless, there appears to be a lot of chemistry going on; the end result seems to be a lot like a very thick smog.

There are scattered variable clouds in Titan's atmosphere in addition to the overall deep haze. These clouds are probably composed of methane, ethane or other simple organics. Other more complex chemicals in small quantities must be responsible for the orange color as seen from space. It seems likely that the ethane clouds would produce a rain of liquid ethane onto the surface perhaps producing an "**ocean**" of ethane (or an ethane/methane mixture) up to 1000 meters deep. Recent ground-based radar observations have cast this into doubt, however. Recent observations with the Hubble Space Telescope show remarkable near infrared views of Titan's surface (right and top). Voyager's camera couldn't see through Titan's atmosphere but in the near infrared the haze becomes more transparent, and HST's pictures suggest that a huge bright "continent" exists on the hemisphere of Titan that faces forward in its orbit. These Hubble results don't prove that liquid "seas" exist, however, only that Titan has large bright and dark regions on its surface. The landing site for the Huygens probe has been chosen in part by examining these images. It will be just "offshore" of the largest "continent" at 18.1 degrees North, 208.7 degrees longitude. The observations by HST also indicate that Titan's rotation is in fact synchronous like most of Saturn's other moons.

Saturn I

Mimas ("MY mas") is the seventh of Saturn's known satellites:
orbit: 185,520 km from Saturn diameter: 392 km mass: 3.80e19 kg

The pronunciation "MEE mas" is also acceptable. Mimas was one of the Titans slain by Hercules. Discovered in 789 by Herschel. Mimas' low density (1.17) indicates that it is composed mostly of water ice with only a small amount of rock. The surface of Mimas is dominated by an impact crater 130 km across, known as **Herschel**; it's almost 1/3 of the diameter of the entire moon. Herschel's walls are approximately 5 km high, parts of its floor measure 10 km deep, and its central peak rises 6 km above the crater floor. The impact that made this crater must have nearly disrupted Mimas. Fractures can be seen on the opposite side of Mimas that may be due to the same impact. The surface is saturated with impact craters. But no others are nearly as large as Herschel. This suggests that early in its history, Mimas was probably impacted by even larger bodies than the one that created Herschel which completely disrupted the new moon (wiping out the evidence of earlier large impacts) but that the impact debris then coalesced again to form present-day Mimas.

Saturn VIII

Iapetus ("eye AP i tus") is the seventeenth of Saturn's known satellites and the third largest:
orbit: 3,561,300 km from Saturn diameter: 1460 km mass: 1.88e21 kg

In Greek mythology Iapetus was a Titan, the son of Uranus, the father of Prometheus and Atlas and an ancestor of the human race. Discovered by Cassini in 1671. With a density of only 1.1, Iapetus must be composed almost entirely of water ice. The leading and trailing hemispheres of Iapetus are radically different. The albedo of the leading hemisphere is between .03 and .05, as dark as lampblack, whereas the trailing hemisphere's albedo is .5, almost as bright as Europa. This difference is so striking that Cassini noted that he could see Iapetus only on one side of Saturn and not on the other. One explanation of this is that the leading hemisphere is dusted with a coating of material knocked off of Phoebe. However, the color of the leading half of Iapetus and that of Phoebe don't quite match. Another possibility is that some active process within Iapetus is responsible. The puzzle is compounded by the fact that the dividing line between the two sides is inexplicably sharp. All of Saturn's moons except for Iapetus and Phoebe are very nearly in the plane of Saturn's equator. Iapetus is inclined almost 15 degrees.

Saturn IX

Phoebe ("FEE bee") is the outermost of Saturn's known satellites. Phoebe is almost 4 times more distant from Saturn than its nearest neighbor (Iapetus). orbit: 12,952,000 km from Saturn diameter: 220 km mass: 4.0e18 kg Phoebe is the daughter of Uranus and Gaia; grandmother of Apollo and Artemis.

Discovered by Pickering in 1898. Most of Saturn's moons are bright but Phoebe's albedo is very low (.05), as dark as lampblack. All of Saturn's moons except for Phoebe and Iapetus orbit very nearly in the plane of Saturn's equator. Phoebe's orbit is inclined almost 175° (its north pole is in the opposite direction to Saturn's). Phoebe's eccentric, retrograde orbit and unusual albedo indicates that it may be a captured asteroid or Kuiper Belt object. Phoebe is also unusual in that it does not rotate synchronously as do all the other moons of Saturn except Hyperion. Material knocked off of Phoebe's surface by microscopic meteor impacts may be responsible for the dark surfaces of Hyperion and the leading hemisphere of Iapetus.