63 moons have been found orbiting Jupiter (May 9, 2005), but most are very small.

The four largest are the Galilean moons, so called because they were first observed by Galileo:

- **Io**: 3,64 km, Density 3.55 g/cm³, Revolution & Rotation 1.77 days
- **Europa**: 3,14 km, Density 3.01 g/cm³, Revolution & Rotation 3.55 days
- **Ganymede**: 5,26 km, Density 1.94 g/cm³, Revolution & Rotation 7.15 days
- **Callisto**: 4,81 km, Density 1.86 g/cm³, Revolution & Rotation 16.7 days

Io is the most similar to our own Moon (rocky crust, molten mantle, iron core)
Europa similar but has a layer of icy crust and a buried ocean
Europa, Ganymede & Callisto have magnetic fields – induced from Jupiter
Ganymede has small iron core (relative to others) but is a mix of ice & rock
Callisto does not have iron core, and is most likely mixed ice-rock

**Lunar**

- **R**: 3,476 km
- **Den**: 3.34
- **Rotation/Rev**: 27.3 days

**Interiors**

- **Io**: Icy crust, Icy mantle (and ocean?), Rocky mantle, Molten mantle, Rocky crust, Iron core
- **Europa**: Icy crust, Ocean?, Mixed ice-rock interior
- **Ganymede**: Icy crust, Icy mantel (and ocean?), Rocky mantle, Molten mantle, Rocky crust, Iron core
- **Callisto**: Icy crust, Ocean?, Mixed ice-rock interior
Io

- No craters; they fill in too fast
- Very cold $T = -143$ C
- A thin atmosphere composed of sulfur dioxide
- Io is the most geologically active object in the Solar System.

In 1979 an engineer responsible for navigation of the Voyager I spacecraft noticed a strange mushroom-like object on the limb of Io.

The camera had captured a volcano erupting on the surface of Io—the first live volcano found in the Solar System beyond the Earth.

Subsequent spacecraft (Voyager II and Galileo) have documented extensive volcanism.

Io's plume eruptions release 100,000 tons of material every second: enough to cover 1000s of km² in a matter of weeks.

Io has a very thin atmosphere composed of sulfur dioxide from the volcanoes.

Io's colors are a consequence volcanic activity that spews various sulfur compounds onto the surface.

- Eruptions occur when hot liquid sulfur dioxide rushes to the surface creating geysers.
- Plumes of liquid sulfur dioxide rise more 200 miles above Io's surface.
- The sulfur solidifies when it reaches the cold of space, becoming 'snow'.
- Sulfur gas lands on the surface and arranges its chemical structure into red molecules.
- Later, the Sulfur atoms re-arrange into the most stable configuration, yellow.

The red areas are associated with places where hot lava is erupting onto the surface.

The red material appears to follow the base of a mountain, which may indicate that sulfurous gases are escaping along a fault.

Some volcanoes seen by Voyager are no longer erupting, but new have begun erupting in the 17 years between Voyager and Galileo.
Io's heat source
Orbital period for Io: 1.77 days
Orbital period for Europa: 3.55 days

3.55/1.77 --- 2/1 resonance

Io sees Europa at the same place every 2 orbits of Io since their period have a ratio of 1 to 2
The orbit of Io becomes eccentric since outer moon will "see" the inner moon in the same place every 2 orbits of Io

Europa
density: 3 g/cm³
composition: mostly rock and metal;
icy surface
Metallic core, rocky mantle,
The reddish brown color has been painted by mineral contaminants carried and spread by water vapor released from below the crust when it was disrupted. The original color of the icy surface was probably a deep blue color seen in large areas elsewhere on the moon.

crust made of H₂O ice:
- few impact craters seen
- cracks
- jumbled icebergs
- evidence of a subsurface ocean.

Long, dark lines are ridges and fractures in the crust, some of which are more than 3,000 kilometers long.

has a magnetic field.
- implies liquid salt water beneath the icy crust

Orbital resonances and Heating

• Like pushing a pendulum in time with its natural swing
• A small push, repeated many times, can add a lot of energy to the pendulum
Europa Surface Features

Dark spots-- upwelling

The domes and spots, termed "lenticulae" (Latin for "freckles") are commonly about 10 km (6 miles) in diameter, often appear in clusters, and are thought to be places where blobs of warm ice have risen and pressed against or broken through the surface.

A Possible example of a recent local melting

Europa an ice-covered moon with a thin, cracked ice shell, probably moving slowly over the surface of an ocean that is 100 kilometers or more deep.

Life?

Europa is too small to retain its internal heat — Heating mostly from tidal interactions.

Orbital period for Europa: 3.55 days
Orbital period for Ganymede: 7.16 days

(≈ 2x 3.55 --- 2/1 resonance)

Distance from massive planet changes because the outer moon pulls the inner moon out of a circular orbit.

Ganymede

- largest moon in Solar System (larger than our Moon, Mercury or Pluto)
- Av. density = 1.9 g/cm³
- Rocky core Ice-rich mantle Crust of ice
- It has a magnetic field.

Dark patches of ancient terrain are broken up by swaths of brighter, younger material, and the entire icy surface is peppered by more recent impact craters that have splashed fresh, bright ice across the surface.

Tidal Heating of Europa

Outer moon will "see" the inner moon in the same place every 2 orbits of the inner moon.

An exaggerated view of the "kneading" of a planet undergoing tidal heating due to changes in the tidal force.

Europa's surface is estimated to distort by ~50 meters per orbital period from tidal interactions. This is one explanation for Europa's cracked ice surface.
Galileo Regio

Galileo Regio is a region of ancient dark material that has been broken apart by tectonics. The dark material may be accumulated dark fragments from many meteorites.

The craters testify to the great age of the terrain, dating back several billion years. It is thought to be some 4 billion years old and is heavily cratered.

Callisto

Second largest moon of Jupiter; about the size of Mercury measurements show an interior of rock mixed with ice it has a magnetic field.

heavily cratered ancient surface, ~4 billion years cratering reveals clean, white ice No large mountains

Ganymede Grooved terrain

Grooved terrain on Ganymede may have been caused by a process similar to plate tectonics on Earth.

The area shown in (b) is about 50 km across and reveals a multitude of ever-smaller ridges, valleys, and craters, right down to the resolution about 300 m, or about three times the length of a football field.

Part (c) shows the grooves at even higher resolution, suggesting erosion of some sort, possibly even caused by water

Valhalla

The large series of concentric ridges visible on the left of the image is known as Valhalla. Extending nearly 1500 km from center of the basin, the ridges formed when "ripples" from a large meteoritic impact froze before they could disperse completely.
### Inner Moons of Jupiter

- **Metis & Adrastea**
  - Small (40 & 20 km) and irregular,
  - They orbit Jupiter in 7 hours and are in almost identical orbits

- **Amalthea**
  - 262 x134 km (163x83 mi), orbits Jupiter in 12 hours
  - Reddest object in the solar system, maybe due to sulfur emitted by Io and deposited on its surface

- **Thebe**
  - 110 x 90 km
  - Orbits Jupiter in 16 hours

### Three Rings: Gossamer Rings, Main Ring, Halo

- Jupiter’s four inner most moons and the three rings
  1. Metis (Halo)
  2. Adrastea (Main)
  3. Amalthea (Gossamer)
  4. Thebe (Gossamer)

  - The rings are made from dust and debris kicked off of the small moons when these moons were struck by interplanetary meteoroids, comets or asteroids.

### Total number of moons for Jupiter is 63

- **Outer Moons: Captured Asteroids**
  - Retrograde satellites
  - Prograde satellites
  - Callisto's orbit

**END OF CHAPTER 11B JUPITER**