THE COMPLETE COSMOS

Chapter 5: Moon

Born of collision, the story of the Moon. Its influence on Earth. Apollo landings and the recent discovery of water.

Outline
The Moon - Earth's partner in space. The Moon's influence on our planet, from mystic links to ancient artifacts such as Stonehenge, in England, to more tangible influences like biological cycles - sea turtles laying eggs according to tidal cycles, and the Moon's effects on tides and timekeeping.

Lunar phases, from new to full and back to new again. As the Moon orbits Earth, we see varying amounts of the half of the Moon that is lit by the Sun. How lunar gravity influences the tides. How tidal drag causes Earth and Moon to move slowly apart. How tidal drag slows Earth's spin, lengthening the day from six hours to 24 hours, and ultimately to 47 days in the far future.

The formation and evolution of the Moon. How, from an impacting planetesimal half the size of Earth, the Moon was formed billions of years ago. The dark lunar "seas" and rugged highlands. The barren, airless, lifeless lunar surface, a landscape scarred by craters, faults and rills - plus huge fluctuations in temperature between day and night. The Apollo 11 Mission - astronauts Armstrong, Aldrin and Collins head for the Moon. A montage of the six Apollo landings, the astronauts' experiences and experiments. The 1998 Lunar Prospector mission, and its confirmation of ice at both poles on the Moon.

Sub-chapters
Our Nearest Neighbor
- The Moon in the night sky above Stonehenge and how the Moon's surface looks from Earth.
- Lunar influences over biological cycles - turtles laying eggs at high and low tide, when incubation periods are best.
- How the Moon's gravitational pull has slowed Earth's spin, lengthening the day from six to 24 hours, and how the process continues.
- Comparisons between Earth and Moon - Earth is nearly four times as wide as the Moon, and 80 times as massive. Traveling ten times around Earth's equator is the same distance as flying to the Moon.

Phases and Tides
- Lunar phases: during the Moon's 27-day orbit of Earth, we see varying amounts of the half of the Moon that is illuminated by the Sun.
- Tidal influences: tides rise and fall twice daily due to the Moon's gravity. Tidal drag slows Earth's spin, increasing the length of the day. The Moon also causes Earth's axis to wobble.

Giant Impacts and the Lunar Surface
- A Mars-sized planetesimal hits early Earth. From the ring of debris, the Moon is formed.
- Surface features: the dark lunar "seas", huge impact basins that filled with lava and solidified; bright, young ray craters, caused by the splash of impacts; faults (valleys) and clefts (rills) which cut through the lunar terrain.
- The airless Moon maintains a pristine record of impacts.
Men on the Moon
- A montage of the six Apollo landings - astronauts working and playing on the Moon. Lunar samples analyzed back on Earth.

Searching for Ice
- 1998's Lunar Prospector sending signals to the Moon's surface and discovering ice at both poles. The promise of further expeditions to the Moon.

Background
The Phases of the Moon
The Sun continually illuminates exactly 50% of the Moon's surface. As the Moon orbits the Earth, however, we see varying amounts of the "lit" half, depending on the relative positions of the Sun and the Moon. As a result, the Moon appears to change shape from night to night: passing from crescent to first quarter, through full moon to last quarter, and back to a thin crescent just before new moon. New moon occurs when the Moon is between the Earth and the Sun, and the illuminated side is facing away from the Earth. Full moon occurs when the Moon is on the opposite side of Earth to the Sun, making the entire illuminated side visible. These apparent changes of shape are known as the "phases of the Moon".

The cycle between successive phases of the Moon, the time from one new moon to the next, is 29.53 days. This is 2.2 days longer than the 27.32 days it takes for the Moon to revolve around the Earth - a period measured relative to the stars. The reason for the difference is that the Earth has moved along its orbit around the Sun. It takes two extra days for the Moon to return to the same position relative to the Sun, producing the same phase.

Tides
Gravitational forces act between all bodies. The gravitational pull of the Moon, and to a lesser extent of the Sun, causes the waters of Earth's oceans to rise and fall. This effect is called a tide. In simple terms, tides are caused by the difference in gravitational pull between parts of the Earth closest to and farthest away from the Moon. This difference causes the oceans to bulge towards the direction of the Moon - two bulges occurring on opposite sides of the Earth. As our planet spins on its axis, each point on the coast passes through two high tides and two low tides every day.

The Sun affects the oceans, but has only 40% of the Moon's influence. Every two weeks, when the Moon and Sun align with Earth, both at new and full moon, their joint gravitational pull creates even higher high tides and even lower low tides. These are called "spring tides". In between, when Earth, Moon and Sun form a right angle, at first and last quarter moon, their gravitational pulls tend to cancel, and high and low tides are less pronounced. These are called "neap tides".

The Surface of the Moon
Casually glancing at the Moon, the light and dark areas of its surface are still strikingly apparent. The dark regions are believed to be volcanic features. Early observers thought these regions were seas, applying the Latin word for sea when describing them - mare (pronounced mah-ray), a term still used today. The very largest impacts created huge basins, and cracked the Moon's crust allowing molten lava to flood the craters. This molten rock eventually cooled, solidifying to form...
the dark mare regions. A relative lack of craters suggests the mare regions are younger than the lighter, rugged lunar highlands.

The lunar surface is entirely covered with craters, although they are more abundant in the rugged highland areas. A small number of craters may be of volcanic origin, but most are believed to be the result of impacts, during an intense bombardment by cosmic projectiles early in the history of the Solar System. Craters vary in size, from craterlets of approximately one meter in diameter, to very large craters spanning over 100 km. Certain larger craters have flat floors and central peaks. Some impact craters are surrounded by light-colored rays of material, ejected by the impacts.

**Links for Further Information**

http://cesp10.phys.utk.edu/astr161/lect/moon/moon.html

Good Moon page, with historical links, links to missions and other moons in the Solar System.
http://www.phy.nau.edu/~danmac/Course_HomePages/A100/Misc/9planets/luna.html

Project Apollo. Detailed history of the Apollo program, including image archive, chronology of events, unmanned and manned missions and links to other pages.
http://www.ksc.nasa.gov/history/apollo/apollo.html

Lunar Prospector Homepage. Comprehensive site, including mission data, results, images and links.
http://lunar.arc.nasa.gov

NSSDC Image Catalog - the Moon. Impressive range of images, plus text, from US lunar missions, including Apollo, Clementine, Galileo and Lunar Orbiter.

Latest theories of Moon formation conducted by the University of Colorado.
http://www.earthsky.com/specials/moonformation.html

**Questions and Activities for the Curious**

1. If the Earth were a football, how big would the Moon be to the same scale? How far from the Earth on this scale would the Moon be?

2. Sketch phases of the Moon, whenever the sky is clear, over a four-week period. Put the date and time underneath your sketch each time you draw it. Using your observations, estimate the dates of new and full moon, and of first and last quarter.

3. Why is the interval between one full moon and the next about 2.2 days longer than the time it takes the Moon to revolve around the Earth?

4. What has been the effect of the Moon on the Earth's rotation? How has this affected the length of our day, and what will happen in the far future?

5. How can you tell the difference between relatively young and relatively old craters on the surface of the Moon? Give three examples of each.
6. Produce a sketch-map of the Moon. Draw the major dark mare areas, and mountain chains, and mark in some of the largest lunar craters.

7. Which Apollo mission nearly ended in disaster? What happened?

8. Select one of the six successful Apollo landings on the Moon and find out what you can about the date of the mission, the activities the astronauts performed, and where on the Moon they landed.