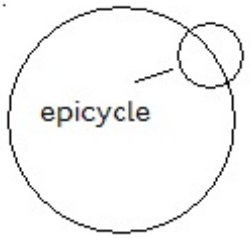
Newton and Gravity

First, there was **Aristarchus of Samos,** an ancient Greek, who lived in the 3rd Century BC. Up to that time, the commonly held view was that the Moon, the Sun, the stars, and the planets all revolve around the Earth. He was the first person, so far as we know, to propose that Earth is also a planet, and that **Earth and all the other planets revolve around the Sun.** This may have been because he had figured out that the Sun is many times larger than the Earth. He received a lot of opposition from other Greeks who were convinced that the Earth could not move, however, and his idea did not stick.

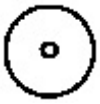
In the Sixteenth Century, a Pole named **Nicolaus Copernicus** rediscovered the concept of the Sun-centered, or heliocentric, model of the solar system. Copernicus was aware of Aristarchus's view; apparently he referenced Aristarchus in a pre-publication version of his own manuscript, although the reference did not appear in the final published version.

Both the Earth-centered and Sun-centered models required "epicycles". (At the time, everyone thought orbits had to be perfect circles, but that didn't give correct values for orbital positions or distances from the Earth. Their solution: add subsidiary circles, *i.e.* epicycles.)

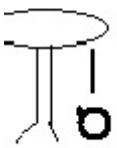


However, the Copernican system required fewer epicycles than the Earth-centered system. Copernicus noticed something else. In the Sun-centered system, the planets' distances from the Sun were correlated with their speeds of motion. In his system, Mercury, the fastest moving planet, was closest to the Sun, while Saturn, the slowest planet, was farthest from the Sun. (This was before telescopes; Saturn was the most distant planet then known.)

Galileo made observations with his telescope which provided evidence for the Sun-centered view. He discovered four moons orbiting Jupiter. This demonstrated that objects could orbit around something other than the Earth. He also noticed that Venus has phases like the Moon. This made much better sense if Venus were going around the Sun, not the Earth.

Johannes Kepler found that planetary orbits are not circles  with the Sun at the center, but **ellipses** with the Sun at one focus.  He developed his **3 Laws of Planetary Motion**, with planetary orbits being ellipses as one law. What wasn't clear was why the orbits should be elliptical, or why the Sun should hold the planets in orbit at all.

Isaac Newton found what holds objects in orbit. According to his account, he saw an apple fall from a tree (the apple didn't hit him on the head; he just watched it), and wondered if **the same force that drew the apple to the Earth also holds the Moon in orbit around the Earth.**



He proposed the **Universal Law of Gravitation:** **every mass** attracts **every other mass**. The strength of attraction is proportional to the product of the masses. But the attraction

gets weaker as objects get farther apart: the force is proportional to the inverse square of the distance between objects. Newton also discovered the rules for how masses would respond to any force: his **3 Laws of Motion.** (Not to be confused with Kepler's 3 **Laws of Planetary Motion.**)

Newton found that when the **Universal Law of Gravitation** is combined with the **Laws of Motion**, elliptical orbits (and Kepler's other laws) come out **automatically**. These laws govern the motion of all celestial bodies, and all spacecraft. When a spacecraft fires its rockets, other forces also come into play, but all forces are governed by Newton's laws. Even unbound (escape) trajectories follow what are called **conic sections**. Bound conic sections (orbits) are ellipses and circles. A circle is a limiting case of an ellipse. Unbound conic section trajectories are parabolas and hyperbolas.

The Law of Gravity and the Laws of Motion control the orbit of the Moon around Earth. They also controlled the motions of the Apollo spacecraft when they traveled to the Moon. When one Apollo astronaut's son asked "Who is driving?" at one point on the capsule's journey to the Moon, the astronaut father answered, "Isaac Newton."

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