1.3: Early Scientific Thought

Western scientific thought began in the ancient city of Athens, Greece [8]. Athens was governed as a democracy, which encouraged individuals to think independently, at a time when most civilizations were ruled by monarchies or military conquerors. Foremost among the early philosopher/scientists to use empirical thinking was Aristotle, born in 384 BCE. Empiricism emphasizes the value of evidence gained from experimentation and observation. Aristotle studied under Plato and tutored Alexander the Great. Alexander would later conquer the Persian Empire, and in the process spread Greek culture as far east as India.

Aristotle applied an empirical method of analysis called deductive reasoning, which applies known principles of thought to establish new ideas or predict new outcomes. Deductive reasoning starts with generalized principles and logically extends them to new ideas or specific conclusions. If the initial principle is valid, then it is highly likely the conclusion is also valid. An example of deductive reasoning is if A=B, and B=C, then A=C. Another example is if all birds have feathers, and a sparrow is a bird, then a sparrow must also have feathers. The problem with deductive reasoning is if the initial principle is flawed, the conclusion will inherit that flaw. Here is an example of a flawed initial principle leading to the wrong conclusion; if all animals that fly are birds, and bats also fly, then bats must also be birds.
This type of empirical thinking contrasts with inductive reasoning, which begins from new observations and attempts to discern underlying generalized principles. A conclusion made through inductive reasoning comes from analyzing measurable evidence, rather than making a logical connection. For example, to determine whether bats are birds a scientist might list various characteristics observed in birds—the presence of feathers, a toothless beak, hollow bones, lack of forelegs, and externally laid eggs. Next, the scientist would check whether bats share the same characteristics, and if they do not, draw the conclusion that bats are not birds.

Both types of reasoning are important in science because they emphasize the two most important aspects of science: observation and inference. Scientists test existing principles to see if they accurately infer or predict their observations. They also analyze new observations to determine if the inferred underlying principles still support them [9; 10].

![1271 drawing of Avicenna (Ibn Sina). He is among the first to link mountains to earthquakes and erosion.](image)

Greek culture was spread by Alexander and then absorbed by the Romans, who help further extend Greek knowledge into Europe through their vast infrastructure of roads, bridges, and aqueducts [11]. After the fall of the Roman Empire in 476 CE, scientific progress in Europe stalled [8]. Scientific thinkers of medieval time had such high regard for Aristotle’s wisdom and knowledge they faithfully followed his logical approach to understanding nature for centuries. By contrast, science in the Middle East flourished and grew between 800 and 1450 CE, along with culture and the arts.

Near the end of the medieval period, empirical experimentation became more common in Europe. During the Renaissance, which lasted from the 14th through 17th centuries, artistic and scientific thought experienced a great awakening [12; 13; 14]. European scholars began to criticize the traditional Aristotelian approach and by the end of the Renaissance period, empiricism was poised to become a key component of the scientific revolution that would arise in the 17th century [15].
An early example of how Renaissance scientists began to apply a modern empirical approach is their study of the solar system. In the second century, the Greek astronomer Claudius Ptolemy observed the Sun, Moon, and stars moving across the sky. Applying Aristotelian logic to his astronomical calculations, he deductively reasoned all celestial bodies orbited around the Earth, which was located at the center of the universe. Ptolemy was a highly regarded mathematician, and his mathematical calculations were widely accepted by the scientific community. The view of the cosmos with Earth at its center is called the geocentric model. This geocentric model persisted until the Renaissance period when some revolutionary thinkers challenged the centuries-old hypothesis.

By contrast, early Renaissance scholars such as astronomer Nicolaus Copernicus (1473-1543) proposed an alternative explanation for the perceived movement of the Sun, Moon, and stars. Sometime between 1507 and 1515, he provided credible mathematical proof for a radically new model of the cosmos, one in which the Earth and other planets orbited around a centrally located Sun. After the invention of the telescope in 1608, scientists used their enhanced astronomical observations to support this heliocentric, Sun-centered, model [16; 17].
Two scientists, Johannes Kepler and Galileo Galilei, are credited with jump-starting the scientific revolution [15]. They accomplished this by building on Copernicus' work and challenging long-established ideas about nature and science.

Johannes Kepler (1571-1630) was a German mathematician and astronomer who expanded on the heliocentric model—improving Copernicus’ original calculations and describing planetary motion as elliptical paths. Galileo Galilei (1564 – 1642) was an Italian astronomer who used the newly developed telescope to observe the four largest moons of Jupiter [18]. This was the first piece of direct evidence to contradict the geocentric model since moons orbiting Jupiter could not also be
orbiting Earth.

Galileo strongly supported the heliocentric model and attacked the geocentric model, arguing for a more scientific approach to determine the credibility of an idea [19]. Because of this, he found himself at odds with prevailing scientific views and the Catholic Church. In 1633 he was found guilty of heresy and placed under house arrest, where he would remain until his death in 1642 [18; 19].

Galileo is regarded as the first modern scientist because he conducted experiments that would prove or disprove falsifiable ideas and based his conclusions on mathematical analysis of quantifiable evidence—a radical departure from the deductive thinking of Greek philosophers such as Aristotle [15; 18]. His methods marked the beginning of a major shift in how scientists studied the natural world, with an increasing number of them relying on evidence and experimentation to form their hypotheses. It was during this revolutionary time that geologists such as James Hutton and Nicolas Steno also made great advances in their scientific fields of study [15].

References


15. Cohen, H. F. How modern science came into the world: Four civilizations, one 17th-century breakthrough. (Amsterdam University Press, 2010).


