Natural Philosophy: The Ionian Philosophers

Summary

In this Activity, we will discuss the birth of scientific thought by introducing the natural philosophers of antiquity and their search for natural explanations of the world around them. You will learn about:

- the birth of science in ancient Greece;
- the first recorded natural philosopher, Thales, and his materialist followers; and
- the mathematician and philosopher Pythagoras and his followers the Pythagoreans.

Introduction

The Greeks inherited their astronomical knowledge from the Babylonians and Egyptians by about 1000 BC. The Babylonians and Egyptians were excellent at mathematics and geometry and they made extensive observations of the night sky. Such observational and technical activities were part of the religious practices of the Babylonians and Egyptians priests.

Like their neighbours, the Greeks believed that the world around them was created by the gods and that natural phenomena were acts of the gods.

However, the ancient Greek religion was not as "sacred" as that of their neighbours and hence scientific thought was not necessarily related to religion. This gave Greek scientific thought a freedom that the Babylonians and Egyptians didn't have.

By about 700 BC, the Greeks began to move away from their mythical view of the world and started to seek explanations of natural phenomena without the use of gods. This was the beginning of what we now call *science*.

In this Activity, we'll be looking at the *Ionian* (or *pre-Socratic*) period between 600 and 400 BC.

The first natural philosophers

When studying ancient history, we must remember that the information often doesn't come directly from the source, but from later philosophers, scientists and historians.

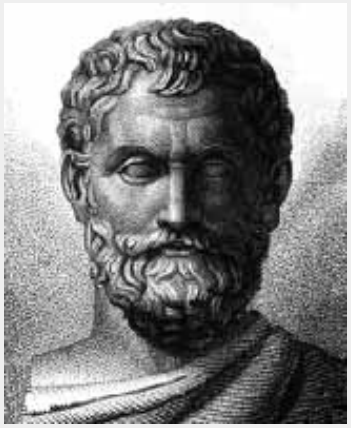
Some scientists and historians may accentuate certain theories of their predecessors, which boost their own theories and/or beliefs, and play down - or even ignore - others which put their theories/beliefs in a bad light. When money and politics are involved in the telling of history, the original stories can be "modified" quite a bit!

Most of the early philosophers' work comes to us from Aristotle, who we shall learn about in the next Activity.

Thales of Miletus

Thales (624 – 547 BC) has been called the father of Greek philosophy, as well as the first Greek scientist and mathematician. By profession, however, he was an engineer.

It is difficult to gauge the real life of Thales as none of his work has survived. It is unsure whether he ever actually wrote down any of his teachings.



Thales.

Credit: © MacTutor History of Mathematics archive

We do know that Thales was born in 624 BC in the port town of Miletus, on the west coast of Asia Minor (now Turkey), and died there in 547 BC.

He was the first recorded person to try to *explain* what he saw in the world around him. Thales thought that natural phenomena - including the heavens - could be discussed as processes governed by natural laws (though not fully understood), rather than relying on supernatural explanations.

The port town of Miletus, Ionia on the Aegean Sea.

Credit: © NASA

The worldview of Thales

Credit: © Henry Davis Consulting

While some of his theories may seem bizarre to us now, the point is that Thales tried to explain the natural world around him.

In particular, Thales believed that the Earth was a large (flat) disk floating on an infinite ocean of water, and that earthquakes resulted from disturbances in this ocean that shook and cracked the Earth. At that time the Greeks believed that when Poseidon, the god of the sea, was angry he produced earthquakes.

He suggested the concept of “unity underlying diversity” – meaning that there were some fundamental principles tying together all the multitude of things we see on Earth. This was certainly an original style of thought for his time.

Thales studied geometry in Egypt and it is thought that he was the first to introduce the subject to Greece on his return.

He is credited with five theories of the basic geometry of triangles and circles, though it is uncertain whether he proved any of these theorems.

He is said to have calculated the heights of various pyramids using his geometric knowledge.

Credit: © Robert Poletti

Predicting an eclipse

One of the main astronomical claims to fame for Thales is the suggestion that he predicted the solar eclipse of 585 BC – though this is unlikely.

At that time, the 19 year cycle for predicting lunar eclipses of the Babylonians was already known, but since solar eclipses are only visible at specific places on Earth, the solar eclipse cycle is much harder to determine.

Thales' prediction of the eclipse was probably a guess, based on the knowledge that an eclipse around that time was possible.

It's also possible that other people suggested – after that fact – that Thales, being so great, would have been able to predict the eclipse.

Thales and the Milesians

Thales was first of the Milesian (people from Miletus) materialists, along with his followers Anaximander and Anaximenes.

They all questioned the origin of the Universe, what was here in the beginning, and what things are made from.

They all believed that *material substance* (rather than some spiritual or supernatural substance; thus the name materialists) made up the Universe.

What this substance was varied for each of them.

Thales believed that in the beginning there was only water, that the world and all things were composed of water. “Water” in this context was some unifying principle.

He asked *’why do things happen the way they do?’* and the answer had to be in terms of the basic matter that the world was built of.

He observed that some rocks contained fossils of ancient seashells and thus concluded that the hills were once part of the sea. He probably also saw mist rising from the Anatolian hills to become clouds, and saw rain fall from those clouds over the Aegean sea - thus land became damp air, which in turn became water. North of Miletus, a meandering river would have been seen to slowly silt up - thus earth rose up out of muddy water. Seeing springs in the nearby hills he would have seen earth become water again.

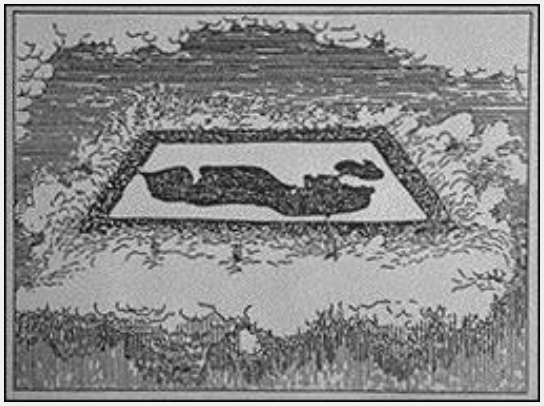
This lead him to surmise that the world originally consisted of water and to conclude that water was the fundamental element from which all things were derived.

Anaximenes (ca. 535 BC) suggested air (or what we think of as gas) was the fundamental material of all things.

He asked "*if everything comes from water, what can account for the diversity of the present world?*", and went on to argue that air was the fundamental element. The world was surrounded by air, which became compressed the closer it came to the centre. When compressed, air turned into water, and compressed water became earth, and compressed earth became stone. So everything was air in a more or less condensed state.

(This was the first attempt to explain the diversity of the world with qualitative differences in terms of quantitative differences.)

Anaximander (ca. 555 BC) thought the Universe formed out of an infinite chaos he called the "boundless" due to a "separating out" of opposites (such as hot and cold, wet and dry).



Anaximenes' world.

Credit: © Henry Davis Consulting

Other materialists followed, including:

Heraclitus (ca. 500 BC) of Ephesus, who believed all things came from fire . What did it mean for air to turn into water, earth, stone etc? For Heraclitus if it didn't remain air, then this couldn't be the one substance that everything was made from. Heraclitus saw the world in a continual state of flux and fire was conceived as the underlying order of the cosmos, transforming itself yet remaining the same.

This idea sounds very much like our modern idea of *energy* . . . (and even accommodates relativity with $E = mc^2$! So energy can transform itself into matter, just like Heraclitus' fire or flux. . .)

Xenophanes (ca. 500 BC) from Ionia thought all things were made of water and earth. He thought that the Earth was infinite, enclosed by neither air nor the heavens.

Empedocles (ca. 450 BC) of Agrigentum, lived in the Greek colony of Sicily and was strongly influenced by Pythagoras (who we will meet later in this Activity). He moved away from the idea of a single fundamental element and instead suggested four – earth, air, fire and water.

Empedocles claimed that nothing could be created or destroyed and maintained that all things consisted of differing amounts of the four fundamental elements. He also added two forces, which he called “love and strife”, with love binding the elements and strife separating them.

(This might be considered as the shadowy beginnings of chemistry: we could extrapolate and say earth is solid, water is liquid, air is gas, and fire is energy.)

The main preoccupation of philosophers in the 5th century BC was to explain why all things seemed to change when they knew that the Universe was constant and eternal.

- Parmenides (ca. 500 BC) thought everything that existed always had and in fact ***nothing*** ever changes. All changes we see are just illusions!
- Heraclitus (ca. 500 BC) said that everything flows, and even objects that appear static have some inner tension or dynamism; and
- Empedocles (ca. 450 BC) suggested that forces between his 4 elements (earth, water, air, fire) caused them to join and separate, resulting in the apparent changes we saw.

Anaxagoras (ca. 450 BC) of Clazomenae was the last of the Ionian natural philosophers of note, who inspired the *atomists* who followed him.

He thought that nothing could be created or destroyed, and that all is made up of, or dissolved into, things that already existed.

He also thought all things were made from minute bits of some universal substance he called *seeds* (though couldn't say exactly what that was).

Leucippus (ca. 440 BC) and his student **Democritus** (ca. 410 BC) continued this idea and claimed that everything was made of tiny unseen atoms in constant motion. Change came from the coming together or breaking apart of these atoms as they formed different materials.

This is a lot like our modern *atomic theory*, but of course they had no experimental backing for this idea and it was later rejected by Aristotle and others.

The first cosmologies

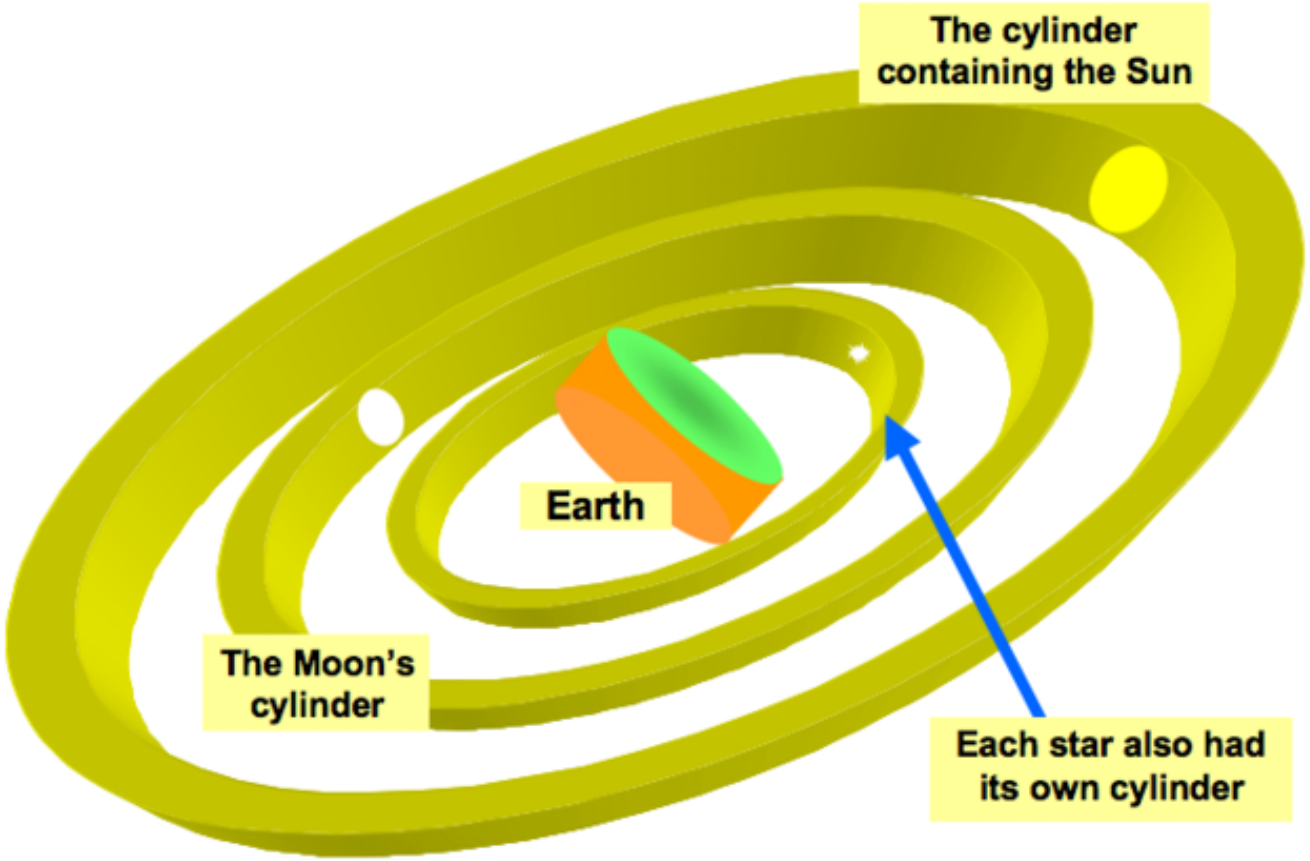
The first recorded attempt to model the Universe came from Anaximander around 555 BC.

He suggested that the Earth was a cylinder and that the Sun, Moon and stars were all located on concentric cylinders, or hoops, rotating about the Earth.

Each hoop is filled with fire which we can only see when the hole in that particular hoop passes over us - these holes allow us to see stars.

Eclipses were caused by blockages in the holes.

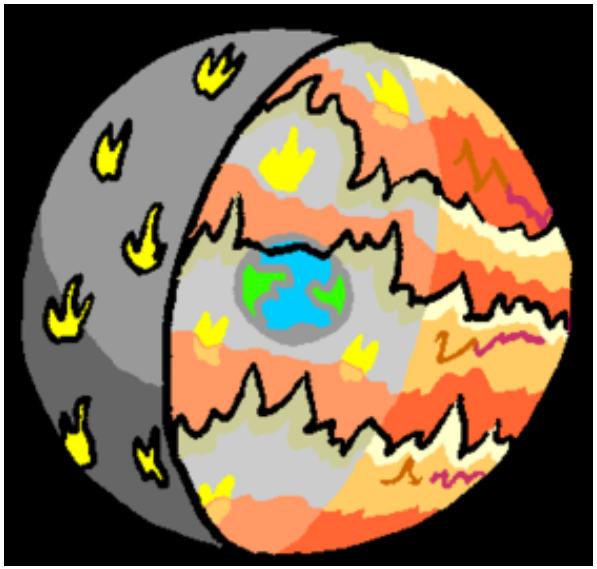
This model was very radical for its time, since all heavenly bodies were thought to be living gods.



In Anaximander's universe:

- Earth is a cylinder 1 unit high and 3 units wide, with the top and bottom faces inhabited;
- The Sun, the Moon and each of the stars is actually a hoop - or cylinder - made of air (so it is transparent);

Empedocles thought that two hemispheres revolved around the Earth, one composed of fire (day) and one composed of air with a little fire (night).



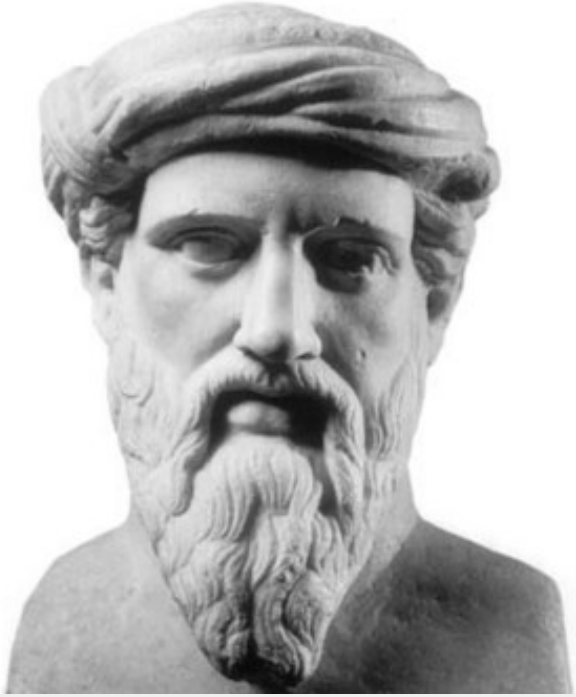
While he didn't think that the Sun was made of fire, the stars were fiery elements, and the Moon was made of air and received its light from the Sun (an idea also suggested by Anaxogoras after seeing a lunar eclipse).

Anaxogoras believed that all heavenly bodies must be made of the same substance as the Earth after he studied meteorites, and that the Sun was a red-hot stone.

Pythagoras

Pythagoras (c.569-c.475 BC) was a Greek philosopher, theologist and mathematician, who also contributed to astronomy.

Again, none of his work has survived and so we must rely on the word of others. Many presented Pythagoras as a god-like figure! His history must be viewed with caution...



Pythagoras.

Credit: © MacTutor History of Mathematics archive

Pythagoras was born on Samos, an island off the coast of Ionia, around 569 BC.

He studied in Miletus under Thales, increasing his interest in mathematics and astronomy, and attended Anaximander's lectures, who at the time was interested in geometry and cosmology.

Pythagoras then spent about 10 years studying geometry and astronomy in Egypt, as well as entering the priesthood there.

From Egypt, he went to Mesopotamia, where he was involved in their sacred rites, as well as learning about arithmetic and music from the Babylonians.

The island of Samos, off the west coast of Ionia.

Credit: © NASA

Pythagoras returned to Samos around 520 BC and from there went to live in Croton (one of the many Greek colonies in southern Italy), where he founded a school based on mathematics, philosophy and religion in 510 BC.

His followers, the *Pythagoreans*, practiced secrecy and communalism, making it difficult to determine what work was actually that of Pythagoras.

During his life's work, he linked geometry with numbers and found basic mathematical relations in music, as well as making many contributions to astronomy. From his observations in music, mathematics and astronomy, Pythagoras believed that all relations could be reduced to numbers.

He died in Metapontum, Lucania, around 475 BC, although there is some uncertainty in this date.

The Pythagorean School

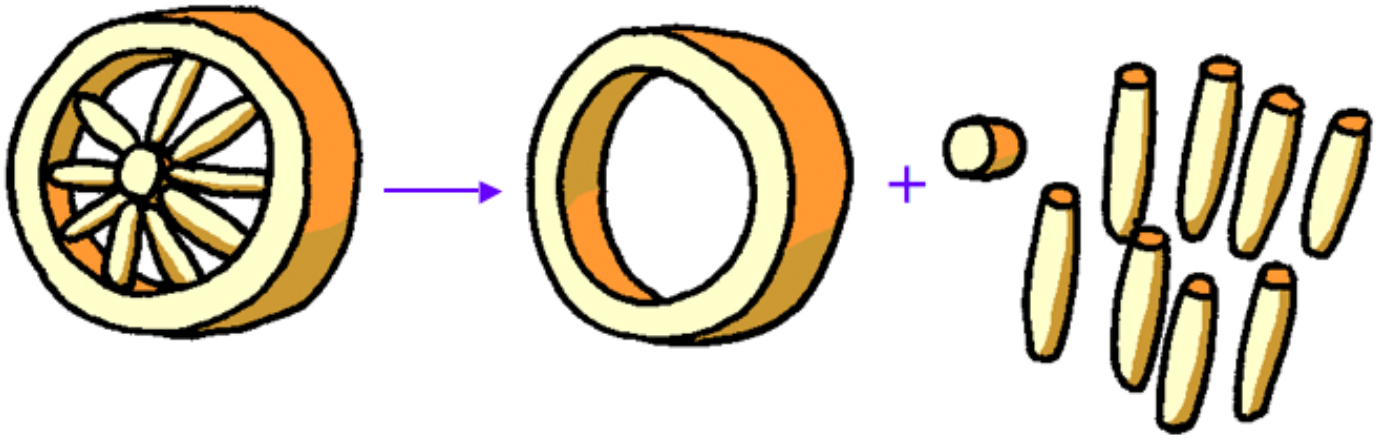
The school in Croton set up by Pythagoras had many followers, both men and women. Pythagoras was the head of the society, whose inner circle of followers were called *mathematikoi.* They lived in the school, whereas those in the outer circle of the society, the *akousmatics,* just visited the society in the daytime.

The Pythagorean beliefs included: that reality is mathematical in nature; that philosophy can achieve spiritual purification; reincarnation of the soul; that certain symbols had mythical significance; and all members of the order should observe strict loyalty and secrecy.

Many of the religious ideas practiced at the school were derived from Egyptian customs.

The Pythagorean philosophy was based on mathematical “perfection”, which in many ways worked *against* a proper scientific approach.

On the other hand, however, they taught that all complex phenomena must be reduced to simple ones.



This idea is known as *reductionism*, which most of science is based on and was used by both Newton and Einstein.

Because of the secrecy of the school, it is difficult to attribute specific work to Pythagoras himself, though the school as a whole made outstanding contributions to mathematics.

Pythagoras was interested in the *principles* of mathematics, rather than solving particular problems. They worked on the *concept* of numbers and mathematical figures like triangles and squares.

It is difficult for us to realise now what a big step it was to go from the notion of 1 apple + 1 apple = 2 apples, to the abstract 1 + 1 = 2, let alone the next step of thinking of 2 as a thing itself!

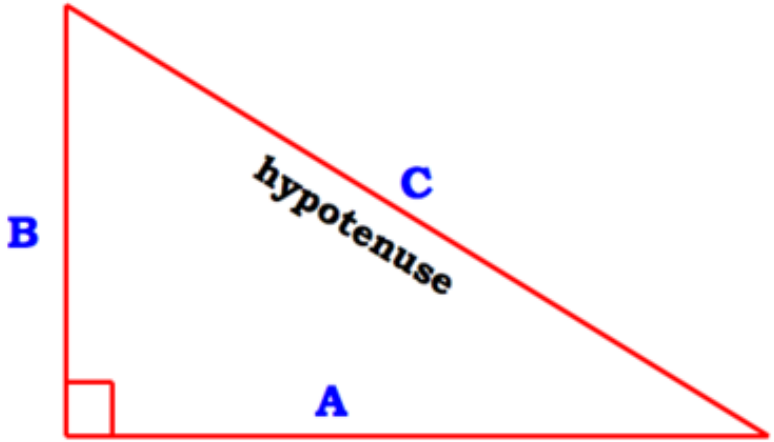
The Pythagoreans also attributed personalities to numbers, such as masculine and feminine, perfect and incomplete, even and odd. Ten was considered the very best number, being made up of the first four integers (1+2+3+4=10). Pythagoras believed that all relations could be reduced to number relations. These ideas were ridiculed by later philosophers!

Pythagoras' theorem

Particular mathematical contributions include the famous "Pythagoras' theorem", which is that for a right angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides:

$$C^2 = A^2 + B^2$$

The Babylonians knew this 1000 years earlier, but Pythagoras was the first to prove the theorem. Pythagoras' theorem is arguably the single most important theorem in mathematics.



From here the Pythagoreans went on to discover *irrational numbers* by trying to find the hypotenuse of a right angled triangle with sides 1 and 1 (whose hypotenuse is root 2).

Rational numbers are numbers that can be written as the ratio of two whole numbers, such as 5 = 10/2 , 0.6 = 3/5 and 0.3333... = 1/3.

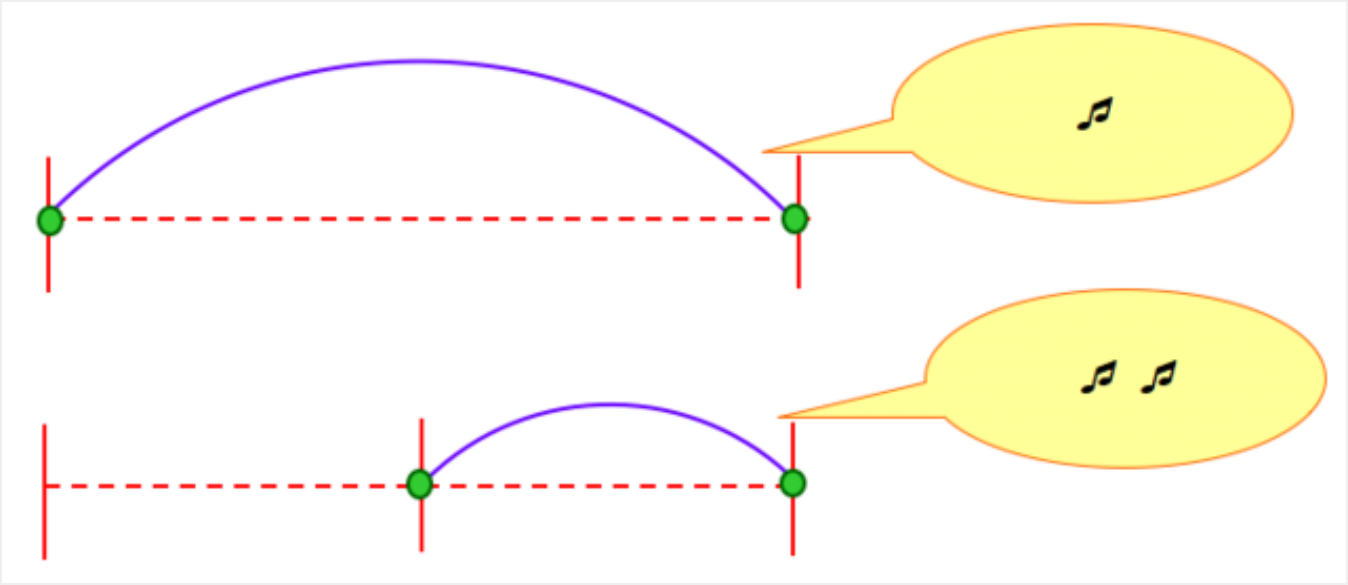
Irrational numbers, on the other hand, are numbers that can't be expressed as a fraction.

This greatly upset the Pythagoreans, who thought all things were numbers, where numbers were thought of as the ratio of two whole numbers.

Pythagoras and music

Pythagoras was also intrigued by the relationship between music and numbers. He was the first person we know of to *mathematically* analyse musical sounds.

By experimenting with vibrating strings, he found that musical tones were related to the string length by exact ratios, and that certain ratios gave more harmonious sounds. In effect, he “discovered” the octave scale!

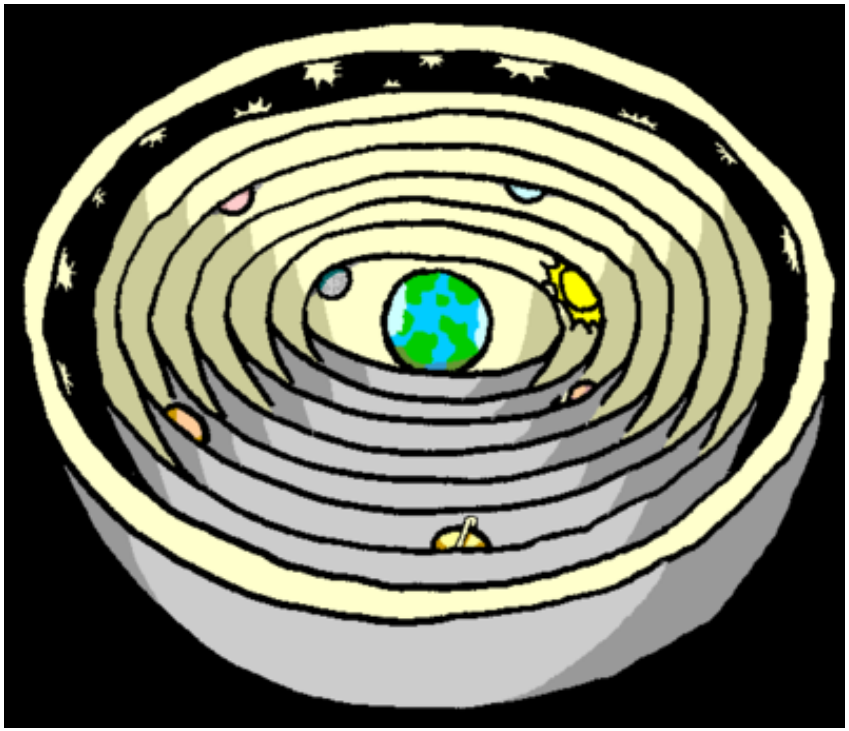


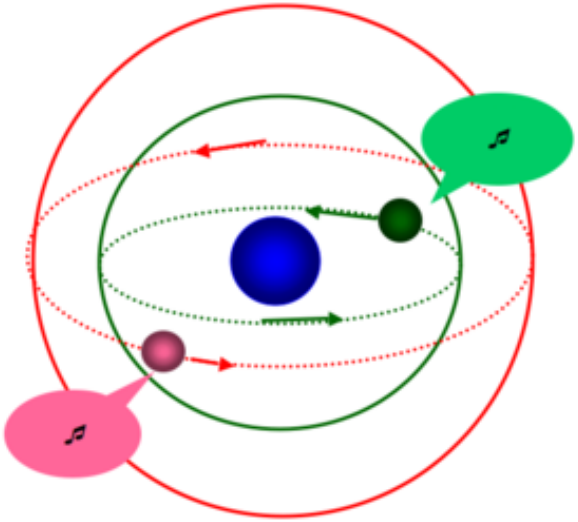
The relationship between string length and tone: halving the string length gives the same note one octave higher.

Pythagoras and astronomy

Pythagoras thought the heavenly motions were perfect, and thus spherical. He recognised that the Earth was a sphere (but probably because spheres were perfect), which he placed at the centre of the Universe.

In the Pythagorean cosmology, the 7 planets (the five naked eye planets plus the Sun and Moon) and the stars all moved in perfect circular orbits, with perfectly uniform speeds.





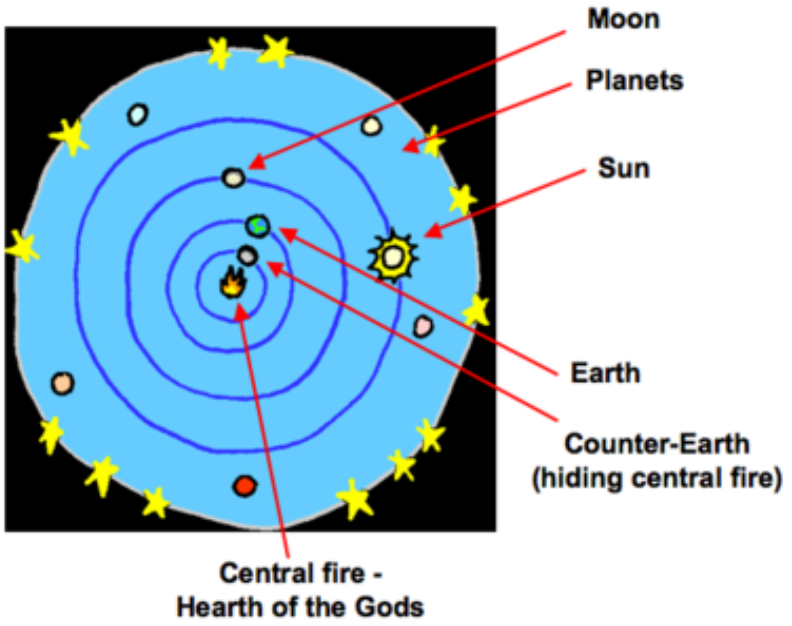
The Pythagoreans also thought that the rapid motion of the stars and planets around the Earth must produce a perfect harmony of music as well (which they argued can't be heard since it's been with us since our birth).

Pythagoras also recognised that the orbit of the Moon was inclined to the Earth's equator, and was the first to realise that Venus as an evening star was the same planet as Venus as a morning star.

The Pythagorean cosmology was advanced around 450 BC by *Philolaus,* the first person to suggest that the Earth actually moves.

He had all the heavenly bodies circle a central fire – which couldn't be seen because there was a counter-earth between the Earth and the fire.

The model was probably proposed to have ten heavenly bodies rather than nine (Sun, Earth, Moon, five naked eye planets, and the stars), since the Pythagoreans thought of ten as a mystical number.



Summary

While the Pythagoreans, compared to the Milesian materialists, still practised some mysticism with their fascination for numbers, both groups were trying to understand the world around them, suggesting models that did not rely on the supernatural forces of the gods. They introduced the notion of *science*.

They presented the first cosmologies of the Universe we live in, which while wrong, formed a basis for later philosophers to work with.

In the next Activity, we will learn about the Socratic philosophers, who developed the foundations of modern science.