**Lecture 6**

**HSS102**

**Jan 21, 2016**

Mathematization of Nature: Pythagoras and Plato

In a previous lecture on naturalism, we saw that the general trend among pre-Socratic philosophers in Ionia was:

a, Moving away from supernatural and mysticism to naturalism: Explaining natural phenomena in terms of physical matter.

b. concern with the question: what is the stuff the world of nature is made of?

Pythagoras stands as an exception to this trend for two reasons:

1. He develops his views on mathematics as a part of his religious beliefs which were distinctly mystical. Greeks of his own time saw him more as a priest of a mystery cult than as a philosopher. Mathematics for him was a way for the soul to see the divine.
2. He moves away from the question regarding the stuff of nature to questions regarding form, shapes, patterns and proportions– thing that are more abstract.

Who was Pythagoras?

Pythagoras (570-500 bce) : .

Born on the island of Samos, N-West of Miletus. Samos was a wealthy trading community, and where a massive temple to Hera, the wife of Zeus existed.

Even in his own life, he was a legend. Many myths surround his life: His followers treated him as half-God and half-Man (quite like Jesus). He was said to be the son of Apollo by a virgin birth to his mother, Pythia who was the oracle of Delphi. He is said to have worked miracles, conversed with gods and heard the music of the stars.

The story is that P gets fed up with life in Ionia and goes off to the East, to Egypt and studies with the priests of at the temple of Diospolis for many years. Following the Egyptians, he developed a life-long habit of keeping his knowledge secret.

From Egypt, he ends up in Babylon as a prisoner of war. He picks up mathematical and astrological beliefs from his captors.

Returns to Samos and sets himself up as a teacher of mathematics and philosophy. But he was too other-worldly and mystical for the tastes of down-to-earth people of his home-town. So he leaves again to settle in Croton, now in southern Italy , where he sets up a secret society, a cult-like community which combined Greek religious rituals with Egyptian inspired rituals.

The community also operated as a mathematical and philosophical school. It had two kinds of members:

--ordinary people who lived outside the commune but visited for spiritual guidance; they were not taught mathematics but only elements of a simple, non-violent life based upon a belief in reincarnation.

--The *mathematikoi*, the inner circle of Pythgoreans who lived inside the community and followed all the rules of the community life, including a strictly vegetarian diet that avoided beans (!) for some reason. They had to sell off all their property and renounce all worldly pleasures and purify themselves: only then they were allowed to receive training in mathematics.

One remarkable feature of this community was that it allowed women as equals. There is evidence that P’s wife, Theano, was a mathematician-philosopher.

This commune was destroyed by a local nobleman. Pythagoras spent the rest of his life as a wandering sage.

Role of mathematics in the religious beliefs of Pythagoras and his followers:

* He founded a religious brotherhood of ascetic, strictly vegetarian communities
* Believed in the immortality and reincarnation of the soul. Pythagoras probably picked up this idea from Egyptians. It is possible that he was influenced by Indians while he was in Egypt.
* The highest goal of life was to prepare the soul for reunion with the divine after death. This required “purification” of the soul. Pythagoras taught that soul can be purified by living a life of contemplation and inquiry.
* Mathematics was the highest form of inquiry that was most suitable for the purification of the soul. The good Pythagorean was to study numbers, geometry, astronomy and music because they revealed the order of the cosmos. This knowledge of the cosmos enabled the soul to escape the confines of the body and meet the divine.
* But for those who did math for salvation, they had to treat it as something pure and abstract and NOT a tool for measurement of land or such things. If you use geometry purely for pratical affairs, as the Egyptians did, it would not benefit your soul.

MUSIC and Ratios

While we don’t have any evidence for Pythagoras discovering the Pythagorean Theorem, his role in discovering the laws of musical sounds is well-attested. It appears that one day as he was walking past a blacksmith’s workshop, he was intrigued by the sounds coming from within. So he went in to investigate and found that the longer the sheets of metal being hit by the blacksmith’s hammer, the lower was the pitch of the sound. When he came back home, he experimented with bells and water-filled jars and observed the same relationship: the more massive an object that is being stuck or plucked, the lower the pitch of the sound it produces. He experimented with strings and observed that the pitch of the sound is inversely proportional to the length of the string that is vibrating. He figured out that if a string is plucked at a ratio of 2:1 it produces an octave, 3:2 produces a fifth, 4:3, a fourth.

This was a pivotal discovery – of far greater importance to Pythagoras than the famous theorem that he is known for. It made him realize that human experience of something as subjective as music could be understood in terms of numerical ratios: the quality of what pleases the ear was determined by the ratios of the lengths that were vibrating. This was the first successful reduction of quality to quantity, and the first step toward mathematization of human experience.

This discovery is important for two reasons

1. Abstraction: the strings of the lyre could be made of different materials, in various thickness and length, but so long as their proportions are preserved, the pitch will vary with the ratio of the lengths. What produces the music are the ratios, the numbers, the pattern of the scale. This pattern you cannot see – it does exist in the material realm, but you can discover it through thought. NOT OF MATTER, BUT OF MIND. So the REAL reality lies beyond matter.

Abstraction is the foundation of mathematics:

Number for e.g.: take any number, say 5. It does not exist in nature. We think of number 5 as applying to appropriate group of ANY entity whatsoever: 5 fingers, 5 apples, 5 days, 5 stones.

We are abstracting form any consideration any particular entities, or even particular sorts of entities, which go to make up the number 5.

1. Ratio: the Pythagoreans took the abstraction one step further: numbers could vary, but what matters is the relationship between them.

In fact, Greek geometry expressed all geometric relations not in numbers but in ratios.

For example: let say there is rectangle with long side 3, short side 1.5 units. The Greeks would express this measurement as 2:1, not as 3: 1.5.

They were more interested in relationship between measures than the numerical values of the measures. In fact, they represented all numbers as ratios: thus 71 was 71 to one.

**All of the universe can be explained as ratios – which alone are eternal and can be understood by the mind. Thus ratio- meant reason, logos.**

That is why the discovery of irrational numbers – that cannot be expressed as ratio of whole numbers – was devastating. They called these numbers alogon – against reason, irrational.

Numbers and numerology:

Pythagoreans also associated numbers with human values – this is what we do even today in numerology: some numbers are good and other

--A point corresponds to number 1/ number 1 corresponds to mind

-A line, to number 2/stands for argument and maleness

--A surface, to number 3/for harmony and femaleness

--A solid, to number 4, and also for justice, according to the minimum number of points needed to complete the dimensions/justice, sum of equal parts.

* Pythagoreans saw odd numbers as masculine and good
* Even numbers as feminine and evil.

On one side were the qualities of oddness, goodness and masculinity; on the other side, qualities of evenness, evil, femininity. Qualities regarded better or higher were associated with the masculine side of things.

**Pythagoras ad the Music of the Heavenly spheres**

From their discovery of musical notes, Pythagoreans made a bold hypothesis: that the heavenly bodies (stars, planets) make sounds as they hurtle through the space at various speeds. The ratio between the speeds is such that the sound the heavenly bodies produce is a harmony. Ordinary mortals cannot hear the harmony because we are immersed in it from our very birth. But those with pure minds – like Pythagoras – could actually hear the harmony and then work out the mathematical relations between the heavenly bodies.

This theory of harmony of heavens was such a beautiful idea that it remained alive in the imagination of astronomers through the centuries. Johannes Kepler (1571-1630) is considered the “last Pythagorean” as he believed very strongly that heavens must be arranged in a harmonious pattern that reveals itself in mathematical relationships. In his final book, The Harmony of the World (in 1619), Kepler actually speficied the different tunes played inaudibly by the orbits of the plantes.

INFLUENCE of Pythagoras

Bertrand Russell has called Pythagoras the most influential thinker of all times, as his ideas influenced many areas of thought outside of mathematics.

* Nearly a third of Euclid’s geometry was first worked out by Pythagoras and his followers.
* Influence on Plato and through him influenced the entire western tradition (“ Platonism is in essence Pythagoreanism. The whole conception of the eternal world, revealed to the intellect but not to the senses is derived from Pythagoras. (Russell, p 45)
* The dogma of planets and stars as moving in perfect circles
* Kepler – the last Pythagorean – HARMONY OF THE SPHERES>
* The idea that the universal order has been written in the language of mathematics – goes back to P.

# Socrates and Plato

Socrates and Plato

# SOCRATES:

Socrates was mistaken to be a Sophist and therefore a danger to the society. That is part of the reason he was sentenced to death.

Who was Socrates ? b 469, sentenced to die in 399 when he was 70 years old.

He came from a poor family: his father was a stone-cutter and his mother a midwife. He spent his entire life in Athens where he was a familiar figure conversing with anyone and everyone who would care to talk to him. He attracted many young men – including Plato – who became his life-long friends and disciples. Unlike the sophists, he did not accept any fee for his teachings. **He never wrote anything. All that we know about him and his philosophy comes from what his well-known student – Plato – has left behind in his writings.**

When he was 70yrs old, he was tried and condemned to death. **The exact charge against him was that he corrupted the young by teaching them to question everything. The method of questioning—the Socratic Method (below) -- that he is so famous for, cost him his life.**

**The SOCRATIC METHOD:**

Socrates is best known for what is called the Socratic Method, a style of asking questions that can expose false beliefs and bring out truth. It is designed to make you think harder and clarify your beliefs. **The Socratic Method aims less at knowing the right answers than at asking the right questions: the right answer is expected to emerge at the end of the process**.

Philosophy for Socrates was a life-long quest. To practice philosophy in the Socratic manner was to continually subject one’s thoughts to criticism of reason in a sincere dialogue with others. Genuine knowledge was not something that could be purchased in a school or a college, but a personal achievement, won at the cost of constant intellectual struggle and self-critical reflection. As Socrates famously said: **“An un-examined life is not worth living.”**

Socrates was famous for starting conversations with anyone and everyone – rich or poor -- he could get to talk. He would wander into the market-place, visit the temples, the courts and other public places and simply talk to people. Unlike the Sophists, he did not charge any fees from his disciples. ( Plato was one of the very rich young men who became his admirer and recorded some of the conversations of Socrates. )

In any discussion, Socrates would claim that he was totally ignorant of the matter under discussion and politely ask the other person to teach him, Please! He would ask people to define what they mean (e.g., when they say they are “just”, or “good” or “religious.”) He would then subject these definitions to tough questions, meant to show their weak points. The idea was not to insult the people he talked to , but to make them think harder, to question the foundations of their beliefs.

By asking questions and analyzing the implications of the answers, Socrates would make his students see that the foundations of their beliefs were shaky: they did not have good reasons or they had not thought through all the implications and contradictions. The idea behind this style of questioning was to make the participants aware of their own knowledge and ignorance, their own strengths and weaknesses. Socrates saw himself as an “intellectual midwife” who helps people give birth to their own ideas, by making these ideas clearer.

Like the sophists, Socrates was NOT interested in cosmological speculations about the stuff of nature> His chief concern was how to live a virtuous life; a just life, a happy life. He saw it has his mission to bring his fellow Athenians to a better understanding of themselves.

BUT UNLIKE THE SOPHISTS, Socrates was NOT a relativist. He believed that there were objective standards for what is truth, beauty, justice, piety and other such virtues. He believed that in order to be live a happy life, for example, you first had to have a crystal clear idea of what THE ESSENCE (or a precise definition) of happiness is (and likewise with virtue, courage, justice etc.). Only those who understand the essence –those who have the knowledge of the truth of things – can then live in accord with truth and lead satisfying lives.

Socrates’ aim was the opposite of that of the sophists: he was trying to get to the exact definitions which would capture the essence of ideas /concepts. (eg., what makes something beautiful? What makes a person pious? Etc.) He believed that once we can get to the essence of an idea, it becomes true for all. Therefore he went around asking “what is virtue?” what is wisdom?”, “what is beauty?”

Moreover, he believed that a man cannot be act rightly unless he first knows what is right; he cannot be just without first knowing what justice is, etc. He also believed that once a person KNOWS what it means to be true and just etc., he/she cannot do wrong: rather he/she MJUST and WILL do what is right. So he thought KNOWLEDGE WAS VIRTUE. (Here Socrates is ignoring the irrational streak in human nature where you do not always do the right thing, even though you know what is right and wrong. )

For more on Socrates, read the chapter from Magee posted on Moodle.

Plato

Plato is no doubt one of the founding fathers of **western philosophy**. But opinion is divided over his influence on the course of **history of science**. Some like Alfred A. Whitehead consider “all of science is a footnote to Plato,” while others like Bertrand Russell see him as setting science back by downgrading empirical observations and spiritualizing nature.

# Plato and his Academy

Plato (427-348 bce ) came from an aristocratic family. Despite his background, he became an ardent admirer and a follower of Socrates. He was an eyewitness to Socrates’ trial and death, and wrote a dialogue called *The Apology* which describes the trial.

Plato was 28 years old when Socrates was put to death.

After Socrates’ death, he left Athens for what is now Italy where he came in contact with followers of Pythagoras. He remained a Pythagorean in his commitment to the idea that the secret of the universe is to be found in numbers and forms.

In 388 returned to Athens and formed a school called the ACADEMY. The Academy was located in a sacred grove of olive trees dedicated to the goddess Athena, the goddess of the city of Athens. It started as a meeting place for discussions and gradually grew into an institution with senior and junior scholars and students, the most famous being **Aristotle** who studied there for 20 years.

At the Academy students learned all subjects – politics, ethics, philosophy. Given his Pythagorean beliefs, study of geometry was central to Plato’s understanding of the universe. In fact, so central was geometry to his teachings that he had this inscribed on the **gate of the Academy: “Let no one ignorant of geometry enter my door.”**

The Academy continued through the Roman period, but suffered physical destruction due to wars. It was finally closed down by the Roman emperor Justinian in 529 CE. So, Plato’s school lasted for a total of around 900 years.

Plato wrote his philosophy in the form of dialogues with Socrates as the central figure. He puts his own ideas in the mouth of Socrates. It is actually quite difficult to distinguish what Socrates himself believed and what Plato makes us think Socrates believed. (Socrates himself did not write anything. )

PLATO’s PROJECT:

Plato COMBINED the SOCRATIC METHOD WITH PYTHAGOREAN COSMOLOGY AND MATHEMATICS. In this process, he turned Pythagoras’ number mysticism into an essence of the universe.

If you recall from our previous discussions, the Sophists denied that there was any absolute truth…

Socrates disagreed with the relativism of the Sophists and believed that there were objective, eternally true essential qualities of what is right and what is wrong. True knowledge is knowledge of these essential qualities of ideas.

But while Socrates used the objective essence of ideas as an ideal to regulate how to live, Plato transforms the objective essences into **real things that exist in a spiritual dimension**: the concepts or definitions of objective truths are not merely ideas in the mind, but something with reality of their own, outside and independent of the mind. He treats the concept in our heads as a copy of a concept that exists outside of all minds, in another dimension which is beyond our ability to sense. This is his famous “Theory of Forms,” or the “Theory of Ideas” which we will look at below.

**Plato’s relevance for History of Science.**

Two main ideas of Plato played a very influential role in history of science:

1. THEORY OF FORMS:The “allegory of the cave” in Plato’s best-known book, *The Republic*
2. Pythagorean cosmology based upon geometry described in his last major work*, Timeaus.*

**The Theory of Forms**

Plato divides the world in two:

1. The world of FORMS or IDEAS that contain the perfect form (or mental model) of everything that exists. This world is not visible, but exists in a spiritual plane, in the mind of God.
2. The material world which is made of imperfect or rough copies of the perfect forms. This is the world we can see, touch, smell etc.

The basic idea is contained in a dialogue in his well-known book, The Republic. This is what is trying to get to:

He asks us to imagine a table made by a carpenter. He says that before the carpenter actually made this this table, he must have had an IDEA, a FORM -- or what we would call a model – of what a table looks like. The carpenter tries to replicate the model as closely as possible when he makes an actual table. So, Plato argues, any given physical table must be rough copy of the ideal table that exists in the carpenter’s head.

Now, Plato argues, just like this humble carpenter, there is a **divine craftsman** who constructed the universe according to an idea or a form. Thus, everything in the universe that we can see, touch etc. is a rough or imperfect copy to that ideal form that exists in the mind of the divine craftsman.

Plato calls this divine craftsman the “Demiurge” which literally means (in Greek) a “public worker.” For Plato, the Demiurge is this good, kind, divine worker/craftsman who wants to the world to be good and beautiful and has given shape to shapeless matter according to idea forms that exist in his mind.

**Why is this theory of forms important for history of science?**

The short answer can be given in two parts:

1. The ideal forms, for Plato, are the TRUE or PRIMARY reality, while the material things are only rough copies. So REAL KNOWLEDGE consists of knowing these FORMS. (see the “allegory of the cave” below (and watch the video clip on Moodle).
2. The ideal forms can be understood through Pythagorean geometry. Thus, with Plato, mathematics becomes the Queen of all sciences, as it is through mathematics that the knowledge of FORMS can be obtained.

**2. The “allegory of the cave”**

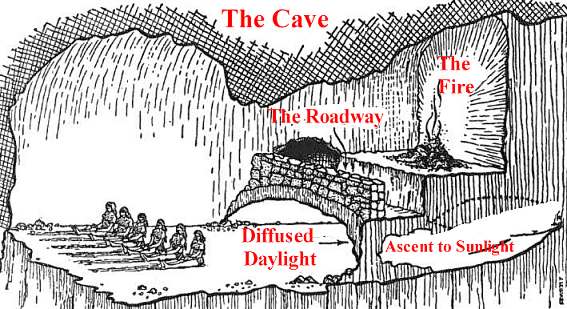
**(**the word “allegory” means **“**a story, poem, or picture which can be interpreted to reveal a hidden meaning,”

The FORMs have a very special status in Plato’s philosophy. For Plato they are NOT like what we think of as models that we create. But these forms are supposed to objectively exist, on their own. Forms, in other words, have an independent existence, over-and-above and separate from the physical object: thus for Plato, there exists a form of a dog, separate from the dog that is your pet; there exists a form of a table, separate from the table in your room etc.

These forms cannot be seen by the eyes, or touched by the hand or accessed by any other senses. Yet, Plato insists, they exist in the world that is beyond matter.

Not only do they exist, Plato says, that REAL KNOWLEDGE consists of KNOWING THE FORMS, because they are PRIMARY (the physical object being a rough copy), TIMELESS, UNCHANGING and TRUE.

Plato illustrates this conception of reality in his famous “allegory of the cave” found the book VII of *The Republic.* Plato describes men imprisoned in a cave, chained so as to be incapable of moving their heads. Behind them is a wall and a beyond that a fire. People walk back and forth behind the wall carrying objects and statues etc. These objects cast a shadow on the wall that the prisoners are facing. Remember: the prisoners cannot move their necks and therefore can only see these shadows on the wall in front of them. Because they have lived in this cave all their lives, they accept the SHADOWS as REALITY. They don’t have any idea that the shadows are simply imperfect images of objects they cannot see. ONLY those who can escape the cave into the sunlight are able to see the real objects.

Plato

What is Plato trying to tell us through this story?

He says that like the prisoners in the cave, our souls are imprisoned in our bodies. Like the prisoners think that the shadows are real, we think that the world we can see through our senses is real. Like the prisoners in the cave who take the shadows to be all there is, we don’t realize that there exist real forms behind the physical world.

How do we know the real forms? BY ESCAPING THE BONDAGE OF THE BODY and the BODILY SENSES. Just like only those prisoners who could escape from the cave could see the reality, only those who can go beyond sensory knowledge can acquire knowledge of the forms.

How does Plato’s philosophy relate to the naturalism of the pre-Socratic philosophers we have met in an earlier lecture?

Plato was deeply opposed to naturalism. He felt that the naturalists had removed all meaning and purpose from the universe. He wanted to bring back some kind of a design in nature.

Also, naturalists generally trusted sensory knowledge. Plato places true knowledge and sensory or observational knowledge in OPPOSITION. Senses only give us knowledge of the shadows in the cave etc.

Pythagorean Cosmology of *Timaeus:*

Timaeus is Pythagorean philosopher from Samos. Timaeus means “Honor”

He starts with the origin of the cosmos: He imagines god as a craftsman (“Demiurge” in Greek) who uses geometry to give order to pre-existing elements that are in chaos. (see ppt)