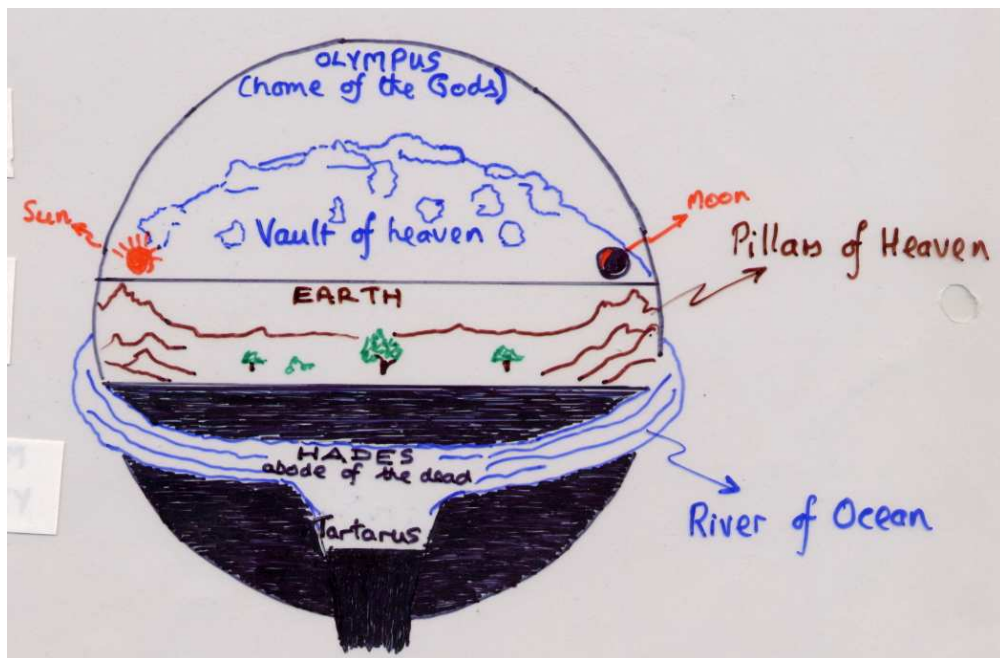


Greek Science

I The Myths

- Hesiod's *Theogony* is a poem of 1023 lines which is generally accepted as the recognised version of the Greek 'creation myth'; it has had a huge influence on Western art and literature.

Theogony tells the story of the coming into being - out of a state of primordial chaos - of what we might term the 'whole of creation', in terms of the interactions (including sexual and asexual reproduction) of gods, some of whom (such as Gaia, Earth, and Ouranos, the Starry Sky) are features of the physical world we inhabit: at this stage, *theogony* (the genealogy of the gods) and *cosmogony* (the creation of the physical universe) are linked together.



First of all there came **Chaos**,
and after him came
Gaia of the broad breast,
to be the unshakable foundation
of all the immortals who keep the crests
of snowy Olympos,

Chaos

Gaia

...

But Gaia's first born was one
who matched her every dimension,
Ouranos, the starry sky,
to cover her all over,
to be an unshakable standing-place
for the blessed immortals.

Ouranos

II The Pre-Socratics

- The Milesian Natural Philosophers - first to suggest that, behind all the variety and changes of nature, there exists one basic immutable element, filling the whole universe.

Thales: water

Anaximander: apeiron

Anaximenes: air

– Comments

- * They coped with things undergoing changes without losing their identities: e.g. water can occur in solid, liquid and gaseous forms.
- * They were aware of problems: e.g. the illogicality of finite things like pebbles or people existing in a boundless universe made of one substance.
- * In their system, fundamental substances, having an eternal nature, were often identified with gods.

- Heraclitus fire

Introduced the influential idea that the universe and its changes are governed by a ‘cosmic reason’ (or logos).

- Pythagoras deserves a page to himself!

Pythagoras (c 570 BC - c 480 BC) and the Harmony of the Spheres

- **Pre-Socratics:** on the whole, materialists - the focus of their attention was the basic stuff of the universe.
- **Vision of Pythagoras** more completely holistic.

Penrose: ... it unites religion and science, mathematics and music, medicine and cosmology, body, mind and spirit ...

- **Pythagoras discovered** that the frequency (pitch) of a musical note on a string bore a simple relationship to its length:

e.g. **halve length** \implies **double frequency**

- **Deep mystery:** the amenability of nature to a mathematical description.

Nobel laureate Eugene Wigner's paper: "*The Unreasonable Effectiveness of Mathematics in the Natural Sciences.*"

- **For Pythagoras** numbers and mathematics were sacred.

He regarded the mathematical length ratios (2:1 for an octave, 3:2 for a fifth, etc.) as music - pure and eternal.

We actually hear imperfect this-worldly versions of the mathematical music.

- Turning to the cosmos, Pythagoras believed that the celestial bodies should move in perfectly circular orbits which he pictured as the strings of ‘cosmic lyre’. The radii of these orbits cannot take on any values, but should bear simple mathematical relationships to each other, producing a cosmic music - pure and eternal - known throughout history as the ‘harmony of the spheres’. This is a music of the mind/soul, not something humans can actually hear with their ears.

- Leads us to the mystical/religious view of mathematics held by the Pythagoreans: the everyday world of our senses falls short of the mathematical ideal.

This mindset was picked up later by Plato in his *Theory of Ideas*.

- Bertrand Russell: the combination of mathematics and theology, which began with Pythagoras, characterized religious philosophy in Greece, in the Middle Ages, and in modern times down to Kant ...

I do not know of any other man who has been as influential as he was in the sphere of thought.

- Parmenides

Argued that only reason can establish ultimate reality; our senses can only address transitory phenomena, not ultimate reality which is eternal.

This pre-empts **PLATO'S THEORY of IDEAS**.

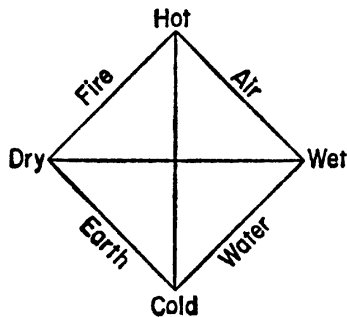
- Anaxagoras - a great before-his-time astronomer.

- Suggested that no matter how finely matter was sub-divided, each little bit of anything contains some of everything; the difference between things was controlled by the relative proportions of the ingredients.

- Proposed idea that there existed a sort of cosmic mind-substance (**nous**) which enters some things when they become living. (Picked up by Aristotle.)

Even with the 'nous' idea, Anaxagoras belonged to the mechanistic tradition of the Milesian philosophers - not the more spiritual Pythagoreans.

- Empedocles - earth, water, air and fire picture



Difficulties with the single basic element idea were 'overcome' by asserting that all matter is composed of four elements - earth, water, air and fire; each of these shares two of the four 'qualities' of hotness, coldness, wetness and dryness.

The behaviour and variety of matter was seen as resulting from combinations and re-arrangements of these elements.

- Xenophanes - a poet/philosopher who rejected the mythological gods with their human weaknesses and postulated a single all-pervading God with no human characteristics.
- Leucippus and his pupil Democritus:
 - All matter is made of completely solid, homogeneous, invisibly small, indivisible atoms, moving in a void.
 - Postulating a void (vacuum) - very controversial.
 - Atoms can differ in size, shape and weight.

All this was very dramatic because it was challenging the idea, as Schrödinger has put it, that the world is *a stage on which spirits and gods act according to the impulses of the moment and in a more or less arbitrary fashion . . . but is something which could be understood if someone dedicates himself to observing it attentively . . .*'

Here we are witnessing the birth of the idea that the universe may be understandable, rational (accessible to human reason). We also see the seeds of *empiricism* - the idea that knowledge of the world is to be gained from our senses.

Despite this euphoria, what existed here was an intellectual climate of uneasy tension:

- No agreement about what the basic stuff of the universe is, or about how the rich variety of processes in nature take place
- Status of myths - ambiguous
- Not much was being said about the idea of 'life'
- What is ultimately behind it all? A variety of ideas ...

[**III The Sophists** (Protagoras: *Man is the measure of all things*)

- Fee-charging itinerant teachers who flourished in these uncertain intellectual times who taught a ‘relativist humanist doctrine’: there are no absolutes such as absolute truth; every person, via his/her own experiences comes to his/her own individual truth.
- Rejected
 - myths
 - application of reason to cosmos
 - even the existence of knowledge (‘nihilism’ of Giorgias)
- Taught
 - ‘life skills’ e.g. public-speaking and argumentation
 - no absolutes - the purpose is to win arguments

Sophistry - showy and fallacious reasoning in order to deceive, mislead, persuade, or defend a point regardless of its value or truth.

End of sophists

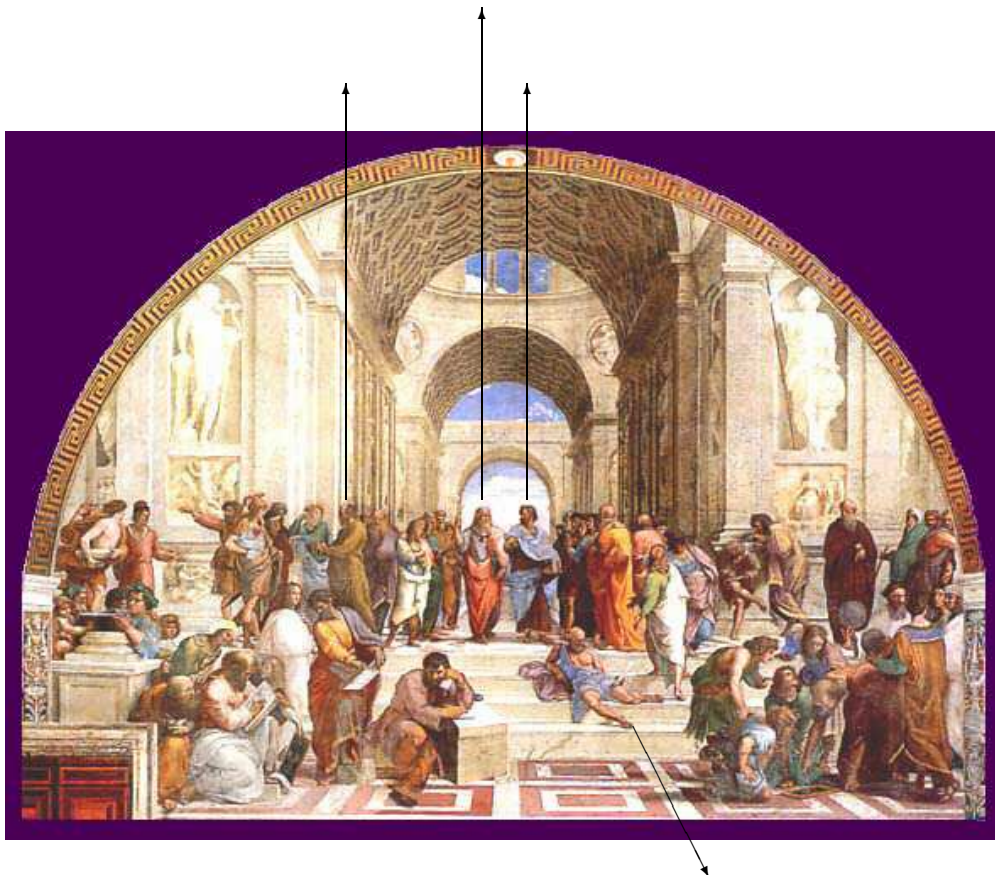
- popular to begin with
- fell into disrepute as their rejection of ideas like justice and truth led to moral decline in Athens.

]

And so to the ‘golden age’ of Greek philosophy

-

Socrates, Plato and Aristotle.



School of Athens (Raphael)

- Plato: pointing upwards - ‘world of ideas’ - rationalism
- Aristotle: pointing down - observe with senses - empiricism

IV Socrates

His objections to the ‘mechanistic philosophers’

- Building-block approach ignores the essential unity/inter-relatedness of nature
- Life and humanity are relegated to an insignificant position
- The possibilities (**earth-water-air-fire, mathematics, atoms ...**) were arbitrary and mutually inconsistent.

Years of dialogue, meditation and self-searching led him to his DOCTRINE of FORMS or THEORY of IDEAS - which we find in the writings of his pupil Plato.

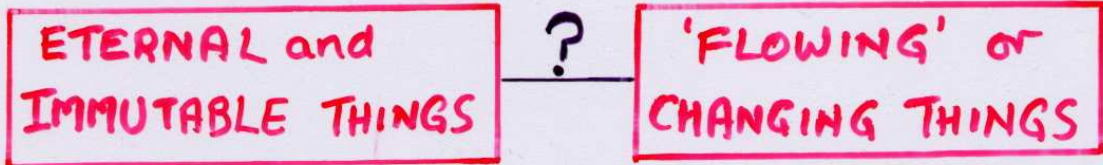
V Plato's THEORY of IDEAS

Key features:

- universe is evolving rationally and with purpose, under the influence of a divine cosmic intelligence (or God)
- sense knowledge is illusory because
 - our senses are unreliable
 - objects that can be sensed have a transitory existence
- beyond our senses there exists a 'world of ideas' which are eternal and immutable; these ultimate realities are accessible to our minds/souls
e.g. truth, beauty, cat ...

The creator of the world of ideas, referred to as the 'demiurge', marks the introduction of a 'divine creator' into Western thought.

THEORY OF IDEAS (Plato 428-347 BC)



REALITY — the WORLD of IDEAS

MATERIAL WORLD — WORLD of the SENSES

TRUE KNOWLEDGE

Mind/soul access world of ideas with reason



OPINIONS

Bodies - which change and have (unreliable) senses

The Allegory of the Cave - (from Plato's *Republic*)

Plato compares men to prisoners in a cave, who are bound and can only look in one direction.

They have a fire behind them and see on a wall the shadows of themselves and of objects behind them. Since they see nothing but shadows, they regard these shadows as real, and are not aware of the actual objects.

Then, one of the prisoners escapes from the cave into the light of the sun. For the first time he sees the real things and realises that he had been up to this time deceived by the shadows.

For the first time he knows the truth and thinks only with sadness of his long life in the darkness.

The real philosopher - possessing real knowledge is the prisoner who has escaped from the cave into the light of truth.

The point of this story is that there is knowledge - a higher level of truth - beyond the realities that we perceive with our senses.

Our connection with this truth happens within the soul, and not through our senses.

This was the problem that dominated human thought more than anything else in the 2000 years that followed Plato.

In particular

- The soul and its relation to the creator of the world of ideas - who later became 'identified' with the God of the Judaeo-Christian tradition.
- Ethics
- ...

Meanwhile ... what was happening to SCIENCE?

VI Nature as a Living Organism

or Aristotle's Teleological Philosophy

Substance and Form

- Recall the objection of Socrates to the mechanistic world view of the pre-Socratic philosophers, expressed in Plato's *Timaeus*:
 - ‘ . . . this world came to be in very truth . . . a living being with soul and intelligence’.
- Plato had the greater influence on Western philosophy, but for 200 years it was the writings of Aristotle that dominated ‘natural philosophy’.
- Aristotle rejected Plato's world of ideas, arguing that it is the things that we perceive with our senses that are real, and it is to these that we should apply our reasoning (‘empiricism’).
- To explain what he means by real, two concepts are introduced, ‘substance’ and ‘form’.

Oversimplifying, ‘substance’ is a word that seems to be used to refer to the underlying material out of which the thing is made; but the thing cannot be perceived until the substance is united with the ‘form’ which gives it its characteristics, including the ability to change from a current potential state to a later actual final state.

For example: the form of an egg allows it to (move in such a way as to enable it to) change into a bird, but not into an apple!

The purpose of the egg’s existence is to ‘strive’ towards becoming a bird.

- What we are working towards is the idea that it is in the nature of everything to move spontaneously towards its end and that to achieve this end is the purpose of its existence. This goal-oriented (‘teleological’) natural philosophy of Aristotle’s even applies to inanimate objects like stones: these drop spontaneously to earth because the purpose of their existence is to do so, the natural place for a stone (made of earth) being on the earth.
- It is this purposeful behaviour that characterises the Greek view of the **universe as a living organism**.

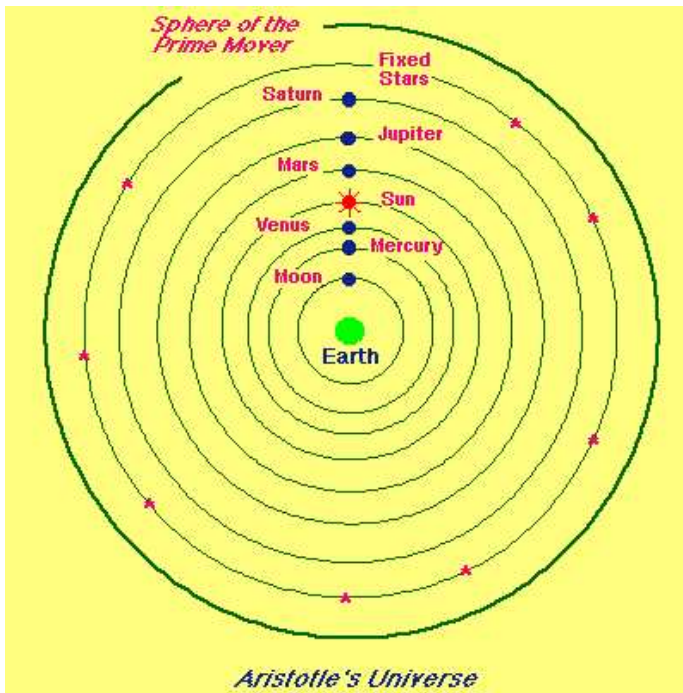
Aristotle's Universe

Divided into two parts:

- (i) the **earthly region**, a sphere with the earth motionless at its centre, extending almost to the moon;
- (ii) the **celestial region**, again spherical, surrounding the earthly region.

These regions are very different.

In the inner, **earthly region**, all things were made from four elements - earth, water, air and fire - and these were arranged in their proper places: earth, being the heaviest, at the core; next water, air and finally, uppermost, fire, being the lightest). [See note on Empedocles in the Pre-Socratics hand-out.] Things are in a state of change and decay.



The **Prime Mover** somehow imparts motion (circular) to the sphere of fixed stars, from where it is transmitted downwards, eventually reaching our earthly sphere.

In the outer **celestial region**, there was but one, fifth element (sometimes called ‘æther’, sometimes ‘quintessence’). All things being made of this, Aristotle argued that there can be no change or non-uniformity in the stars and planets. This region, also referred to as the ‘heavenly’ sphere, is eternal and has divine qualities. It is composed of concentric divine spheres, beginning with the lunar sphere, the lowest and least divine, and working upwards through the solar sphere and the planetary spheres to the sphere of the fixed stars; outside this is the sphere of the Prime Mover or ‘God’.

Some scholars think that this Aristotelean view - the Prime Mover (or God) being directly responsible for the motion of the stars and planets - has caused difficulties

- for the development of science because it makes God part of physics (which is not the way we see it nowadays);
- for theology because it makes the motion of the stars and planets a part of theology.

For Plato, this ‘God’ is more abstract, being the divine creator of the world of ideas, not of the physical universe we live in and appreciate with our senses.



Motion in Aristotle's Universe

Important to know what the Greeks taught about motion because it was this that, to a great extent, held back progress in science for 2000 years:

- In the **inner, terrestrial sphere**, two kinds of motion were recognised:

* **Natural motion:** an object not in its proper place will move in a straight line to that place, where it will remain at rest in its 'natural state'. For example: a stone (made of earth) released over a cliff, finding itself in air (not its proper place), will move in a straight line until it reaches the ground (earth!).

To move in this way, the stone was said to have experienced a force, a sort of 'internal' force characterising the tendency of objects to move to their proper place.

* **Violent or Forced motion:** an object that is moving - but not in a straight line. For example, a cart being pulled by a donkey.

To move in this way, the cart is experiencing an 'external' force.

This way of thinking about movement is crucially tied up with the idea (as taught by Aristotle) there is no void (or vacuum, to use a modern word). Objects are moving through a medium which offers resistance. If the force stops, the motion will cease as a result of the resistance.

So: a key feature of Greek natural philosophy is that any movement results from a force; or, forces produce motion.

i.e. forces produce velocities.

Accepting this held back progress in science for 2000 years!

- In the **celestial sphere**, the natural motion is circular, reflecting ultimately, the idea that the Prime Mover sets the sphere of the fixed stars in circular motion, and that this is then transmitted down to the other spheres.
(Note that circles, having the perfect shape, are appropriate for the celestial sphere!)

VII Greek Influence on Development of Science

- Greeks: first to think that the universe is rational, accesible to the human mind.
- Established two intellectual traditions that have, and are still, influencing thought after 2500 years;
Tarnas¹ calls them

Secular skepticism and

Metaphysical idealism

¹This section is based on a chapter entitled 'The Dual Legacy' in *The Passion of the Western Mind* by Richard Tarnas

– Secular skepticism

This tradition evolved from pre-Socratic times:

- * the naturalistic empiricism of Thales;
- * the rationalism of Parmenides;
- * the mechanistic materialism of Democritus;
- * the skepticism, individualism and secular humanism of the sophists.

Their guiding principles included:

- * Genuine human knowledge comes from empirical observation and human reason
- * One must search for truth in the (immanent) world of experience, not some (transcendent) other-worldly reality. **(Including mathematics?)**
- * Natural phenomena are caused by impersonal, this-worldly physical effects; not mythological or supernatural effects.
- * Theoretical understanding must be measured against empirical reality.
- * Knowledge is never final - must always be revised in the light of new empirical evidence

– Metaphysical idealism

Evolved from the coming together of rationalism and Greek ‘religion’ in the spirit of Pythagoras and Plato (and even the self-professed empiricist, Aristotle).

The guiding principles:

- * The universe is ordered, with an order similar to an order that exists in the human mind; so a rational analysis of the universe is possible.
- * The universe ‘possesses’ an intelligence which is accessible to human awareness, if that has been developed to a high enough degree.
- * Intellectual analysis, at its most penetrating level, shows that the universe has a timeless order that goes beyond the world of our senses; there is a deeper, eternal reality which is both the source and goal of our existence.
- * To get at this deeper level of knowledge we need to use a plurality of human mental faculties - rational, empirical, intuitive, aesthetic, imaginative, mnemonic, and moral.
- * This deeper level of apprehension is not only intellectually decisive, but also spiritually liberating.

Tarnas reflects:

The constant interplay of these two partly complementary and partly antithetical sets of principles established a profound inner tension within the Greek inheritance, which provided the Western mind with the intellectual basis, at once unstable and creative, for what was to become an extremely dynamic evolution lasting 2500 years.

To see that this is so, let us fast-forward these 2500 years and consider the words of Freeman Dyson of the Princeton Institute for Advanced Studies:

The Rôle of Science in Human Understanding

There are two extreme points of view concerning the rôle of science in human understanding.

At one extreme is the reductionist view, holding that all kinds of knowledge, from physics and chemistry to psychology and philosophy and history and ethics and religion, can be reduced to science. Whatever cannot be reduced to science is not knowledge ...

At the other extreme is the traditional view, that knowledge comes from many independent sources, and science is only one of them. Knowledge of good and evil, knowledge of grace and beauty, knowledge of ethical and artistic values, knowledge of human nature derived from history and literature or from acquaintance with family and friends, knowledge of the nature of things derived from meditation and religion, all are sources of knowledge that stand side by side with science, parts of a human heritage that is older than science and perhaps more enduring.

Most people hold views intermediate between
the two extremes ... I am ...

Freeman Dyson

