

# Beliefs & Physics

Some Lessons from  
Ancient Greek Science

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# Introduction

- How do our beliefs and our science interact?
- Let's look at a case study of ancient Greek physics from Thales to Aristotle.
- Their science seems to us today to be crude, rash, absurd.
- But then, how will our science look 200 years from now?



# The Physical Substratum

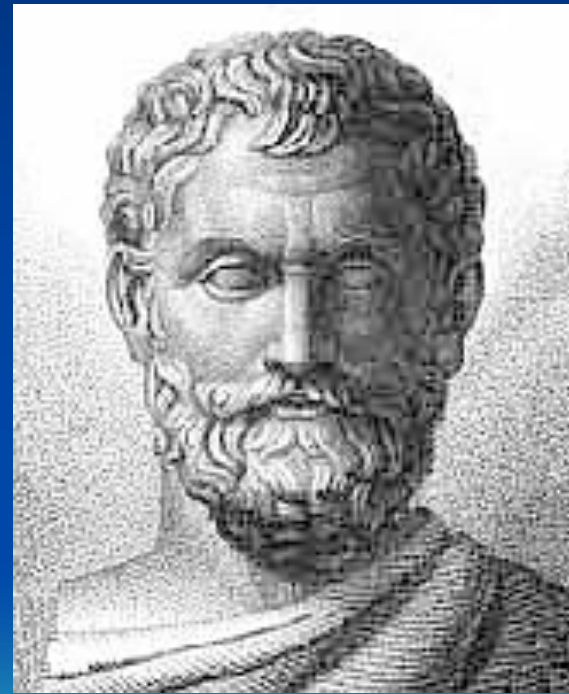
What is the most basic substance out of which everything is made?

- Thales (~585 BC) – water
- Anaximander (~555 BC) – *apeiron*
- Anaximenes (~535 BC) - air



# Thales (~585 BC)

- A practical thinker
- Reputed to have made contributions to law, politics, civil engineering, math & astronomy
- Even credited with predicting an eclipse of the sun!



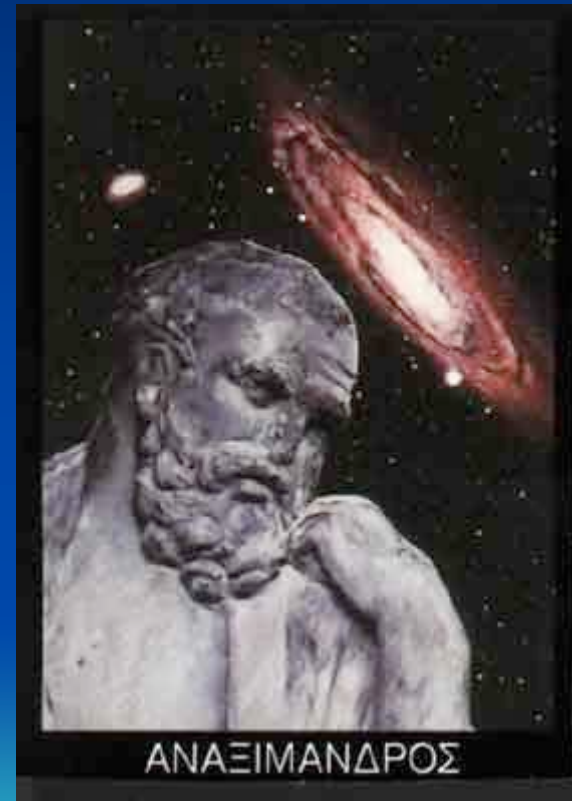
# Thales (~585 BC)

- Thought that water was the basic substance behind all other phenomena
- Not sure why:
  - Necessity of moisture for life?
  - Knew water could be solid, liquid, vapor?
- He preferred natural explanations:
  - Not a atheist
  - Observation of agriculture and industry?



# Anaximander (~555 BC)

- Student of Thales
- Believed in single universal substance
- Rejected water for this
  - Couldn't see it as source of fire
- Proposed an abstract substance:
  - *apeiron*
  - Unlimited, infinite, boundless
  - Contained all opposites



# Anaximenes (~535 BC)

- Also from Miletus, as were Thales and Anaximenes
- Favored a single ultimate substance, but returned to an observable material, air
- Rarefied air → fire
- Condensed air → wind, cloud, water, earth, stone



# Milesian Cosmologies

Based on their physics

- Thales:
  - earth floats on water
- Anaximander:
  - cold earth & fiery heaven
  - formed by separation from *apeiron*
- Anaximenes:
  - Earth floats on air
  - Wind pushes stars around



# Milesian Physics

The history of Milesian views about the primary substance is chiefly remarkable for the way in which the awareness of the problems grew from one philosopher to the next... Their actual theories strike a later age as childish... But the measure of their achievement is the advance they made in grasping the problems. They rejected supernatural causation and appreciated that naturalistic explanations can and should be given for a wide range of phenomena... they took the first tentative steps toward an understanding of the problem of change. (Lloyd)



# A Mathematical Substratum

Is there some sort of organizing principle behind things?

- The Pythagoreans (525 ff) – reality is number.
- Plato (~350 BC) – reality is unchanging ideas.



# Pythagoras (~525 BC)

- Hard to separate his views from followers
- Observed that harmony comes from vibrating strings of simple ratios
- Proposed that reality consists of numbers



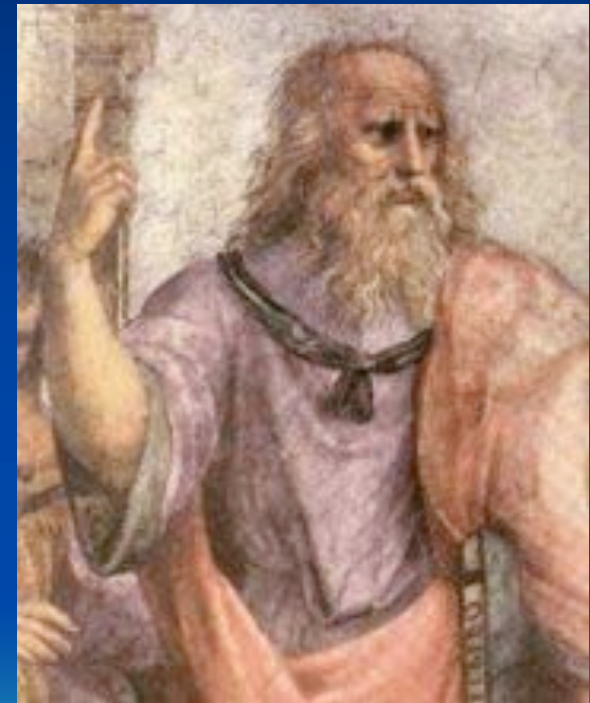
# Pythagoreans

- Followers became a sort of religion
- Suggestion led to increased interest in the **form** rather than the substance of matter
- Ideas have proved fruitful for research
  - Numerical measurement
  - Mathematical modelling
- Led to substantial advances in astronomy
- Also to a great deal of ‘mumbo-jumbo’



# Plato (~350 BC)

- Influenced by Pythagoreans
- Knowledge of geometry necessary for his Academy
- Geometric drawings are only approximations of ideas behind them
- Expanded this to reality as a whole



# Plato & Platonism

- Ultimate reality consists of eternal, unchanging ideas.
- These ideas are only imperfectly represented in the changing world of sense experience.
- Thus true knowledge is knowledge of eternal ideas rather than of unreliable sensory data.



# Motion and Vacuum

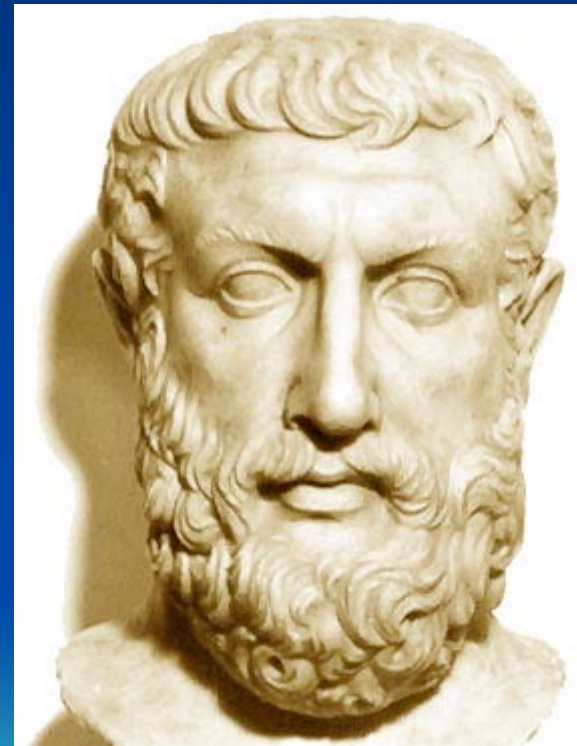
How can motion be reconciled with a single, universal substance?

- Parmenides (~480 BC) – motion is an illusion; there is no vacuum
- Zeno (~445 BC) – motion is absurd
- Empedocles (~445 BC) – four elements
  - Earth, water, air, fire
- Anaxagoras (~445 BC) – infinite number of elements
- Atomists – atoms and vacuum



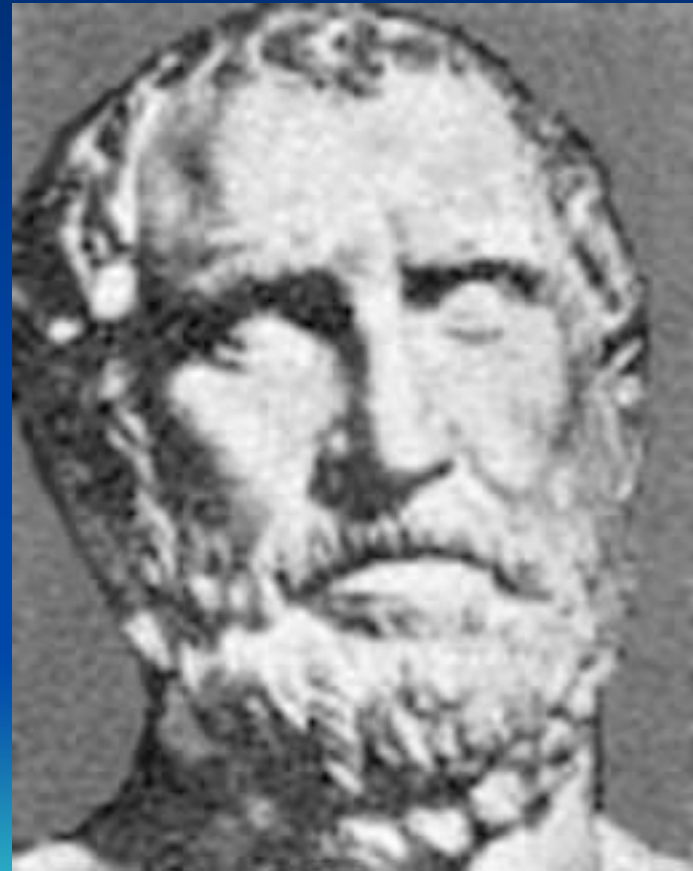
# Parmenides (~480 BC)

- How can motion be reconciled with a single, universal substance?
- Parmenides: it cant!
- So Parmenides denied the reality of motion (& the testimony of human senses).



# Zeno of Elea (~445 BC)

- Disciple of Parmenides
- Constructed several very clever arguments to show that motion cannot exist!
- These were often ignored but not really refuted till the invention of calculus 2000 years later.



# Empedocles (~445 BC)

- One response to Zeno and Parmenides was to have several basic substances rather than just one.
- Empedocles proposed that matter was a mixture of four things: earth, water, air & fire.



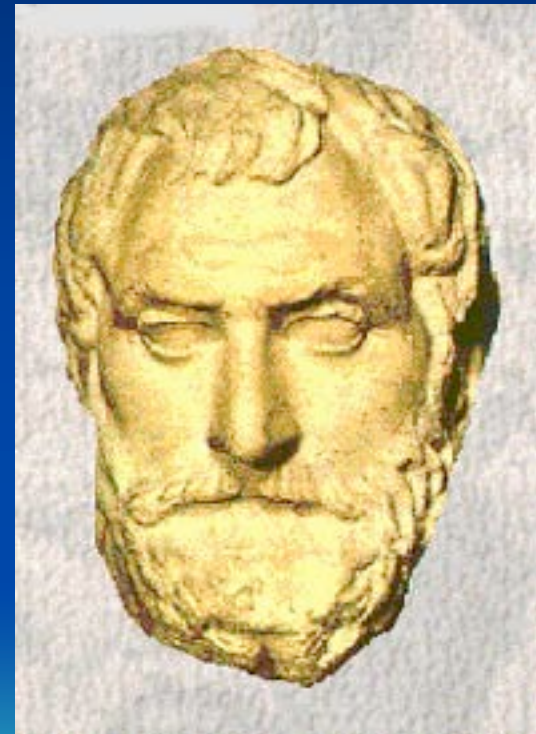
# Empedocles (~445 BC)

- Changes or motion took place when the compositions or positions of these elements changed.
- This was caused by two forces, Love and Strife (attraction & repulsion).
- This model became the dominant view of physics until modern times.



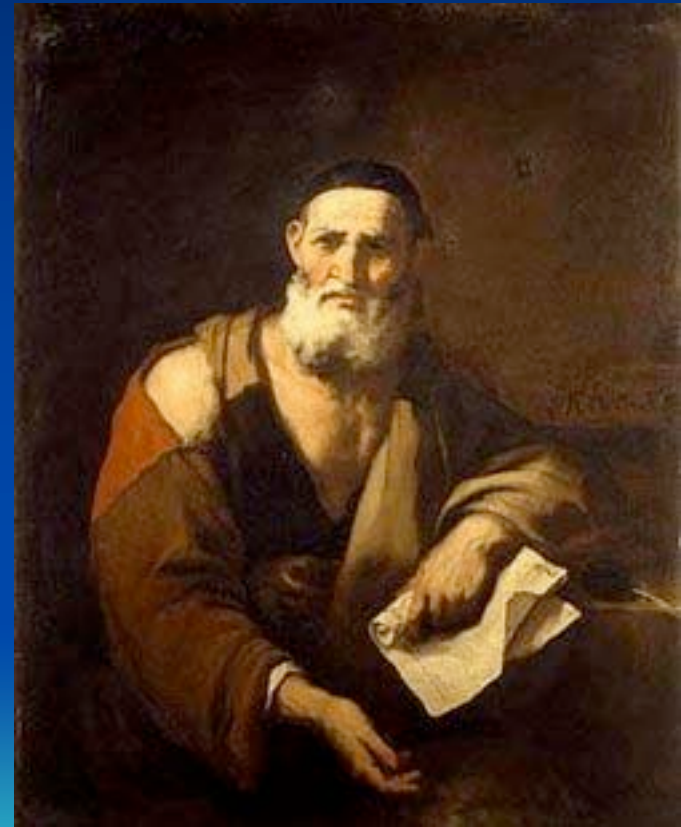
# Anaxagoras (~445 BC)

- Carried the pluralistic idea to an extreme
- There are an infinite number of different sorts of things.
- When a human eats fruit, the body extracts flesh & bone particles.
- Too complex to be very influential



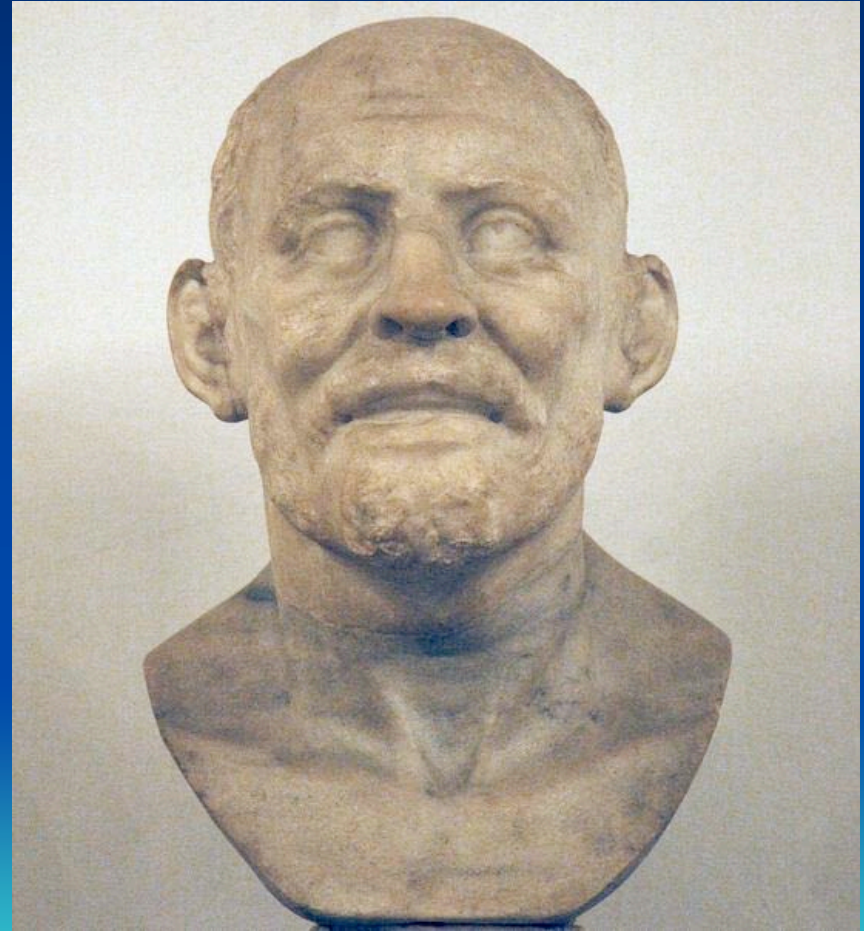
# Leucippus (~435 BC)

- Best ancient solution to Parmenides' problem
- The first of the atomists
- Reality consists of one eternal substance, but this comes in invisibly small particles.
- These are called 'atoms' because they cannot be divided.



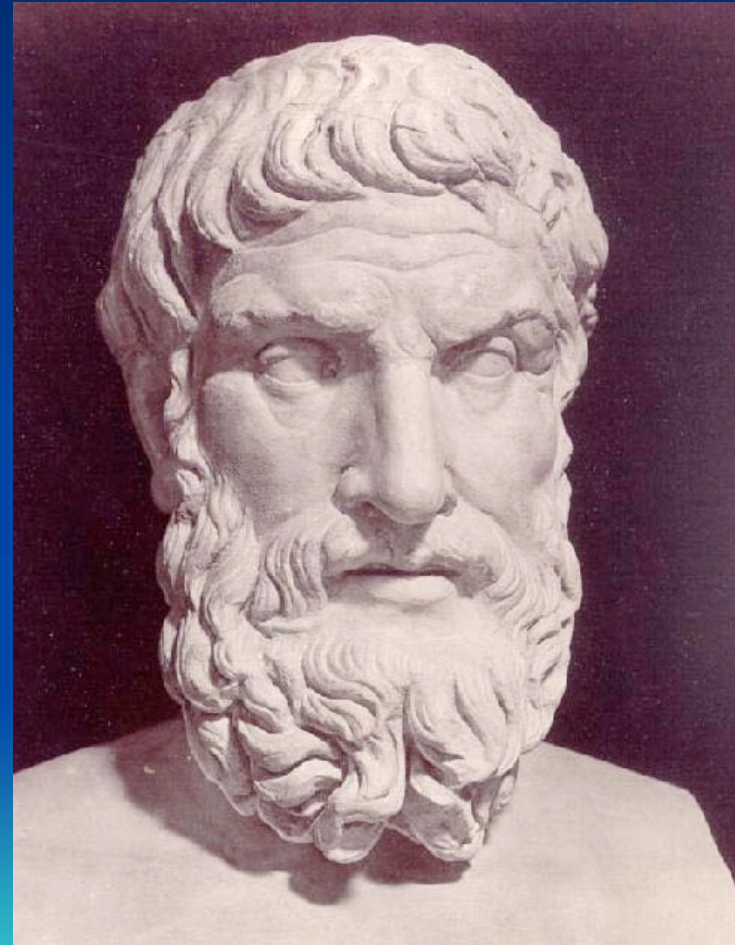
# Democritus (~410 BC)

- The atomic idea was further developed by Democritus and Epicurus.
- The atoms are separated from one another by a void or vacuum, so motion is possible.



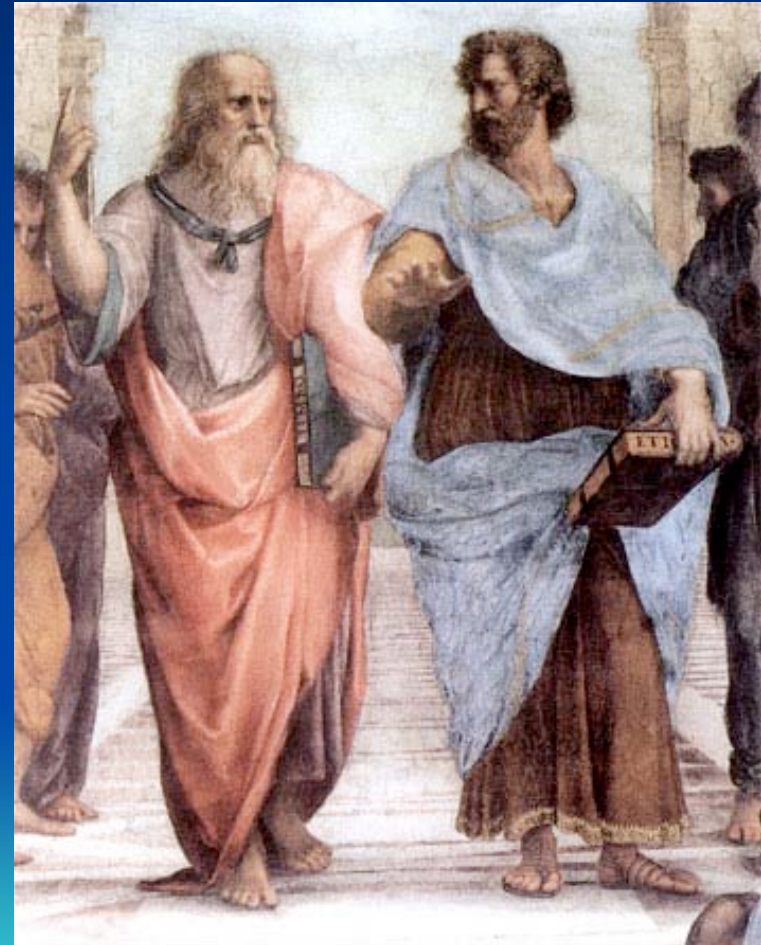
# Epicurus (~300 BC)

- The objects we experience are formed by chance combinations of atoms.
- The ancient theory had no explanation but necessity for large-scale organization



# The Physics of Aristotle

- Advances in Astronomy pointed to a large universe.
- Two-Realm Physics
  - Supralunar realm – no changes, circular motion, aether
  - Sublunar realm – change, vertical motion, four elements



# The Physics of Aristotle

- Four kinds of causation:
  - Material – what something is made of
  - Formal – how structured
  - Efficient – what forces involved
  - Final – what purpose
- The two-realm and four-cause view of reality were strongly influential till modern times, as they provided both consistency and believable explanations.



# Interactions between Beliefs & Physics

- How were physical concepts used to develop and evaluate beliefs?
- How were metaphysical beliefs used to develop & evaluate physical concepts and theories?
- How do shared beliefs of the science community influence its research agenda?



# How were physical concepts used to develop and evaluate beliefs?

- Techniques of craftsmen may have suggested natural causes to Thales.
- Harmonious sounds produced by strings may have suggested to Pythagoras that number is the ultimate reality.
- Geometric drawings as rough approximations apparently convinced Plato that ideas were ultimate reality.



# How were physical concepts used to develop and evaluate beliefs?

- Reluctance to abandon sensory evidence kept many from following Parmenides, proposing instead models of reality in which change and motion are real.
- Astronomical evidence that the heavenly bodies were at great distances (together with a scheme for reducing heavenly motion to circles) led Aristotle to his distinction between the earthly and heavenly realms.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- Melesian metaphysic of natural causation led to their suggesting various natural explanations instead of supernatural ones.
- It also led to speculations re/ a most basic substance.
- This led to attempts to study the basis of matter.
- It also led to (unwarranted) optimism that the nature of the substratum could be easily found.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- Pythagorean metaphysic of number proved very fruitful in some fields, esp. in introducing math as a tool.
- It also led to considerable number-speculation where the subject being investigated was not hospitable to such an approach at that time.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- Plato's view led him to devalue observation and experiment in favor of abstract reasoning, disconnecting theory from observation.
- Parmenides' view that motion was logically impossible led him to reject the contrary testimony of the senses.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- Democritus' view of atoms led him to a number of striking insights, mixed with numerous unwarranted speculations.
- His strongly reductionistic explanations ignored the possibility of higher levels of structure and design in nature.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- The completeness & consistency of Aristotle's two-realm model with two types of physics had long-term (and largely negative) effects on the study of physics, which were not overcome till the late middle ages.



# How were metaphysical beliefs used to develop & evaluate physical concepts and theories?

- By the time of Plato & Aristotle, class divisions had widened to the point of discouraging the leisure class from involvement in physical labor.
- This had a negative effect on any research which looked practical, devaluing the physical studies which would later transform Western society.



# How do shared beliefs of the science community influence its research agenda?

- The Milesian search for purely natural explanations encouraged experiment and observation, but made it difficult to explain the existence of order in nature.
- The Pythagorean concentration on math produced impressive results where this was possible at the time, but rather fantastic number mysticism elsewhere.



# How do shared beliefs of the science community influence its research agenda?

- Plato's Academy tended to produce abstract, logical constructions.
- This both helped and hindered astronomy, but tended to hinder in the other sciences.
- Plato's views of eternal forms gave better explanations for order in nature than the purely natural causation of the Milesians and atomists.



# How do shared beliefs of the science community influence its research agenda?

- Aristotle's proposal of four types of causation (matter, structure, energy, purpose) made better sense of the order in nature.
- Together with his emphasis on observation, this led to some effective biological research in the Lyceum and later.



# Some Lessons for Today

- Given a hierarchical structure to reality, is there any reason to believe that an empirically constructed 'bottom up' metaphysics will be anything more than accidentally correct before the 'final physics' is discovered?



# Some Lessons for Today

- How does 'Occam's Razor' influence physics? Do we tend to jump to unwarranted conclusions about the completeness of very preliminary theories?



# Some Lessons for Today

- In the area of kinematics, is it reasonable to believe that nature can be limited to 3 spatial dimensions and one time dimension of modern relativity theory?



# Some Lessons for Today

- In the area of dynamics, it is reasonable to believe that the four currently-known forces are all that exist? That they may be unified into one single superforce?



# Some Lessons for Today

- In the area of dynamics, is it reasonable to believe that knowing the ultimate particles and physical forces will be sufficient to explain reality without recourse to special initial or boundary conditions?



# Some Lessons for Today

- In the area of dynamics, it is reasonable to believe that the universe is an automaton (like a clock) that runs by itself – whether accidental or designed – or may it be an instrument (like a guitar) that is designed for input?



# The End

We can learn something about  
science from studying its history

