

SIMPLICITY AND COMPLEXITY IN NATURE

- SOME SUCCESS STORIES:
 - Human-scale physics: MOTION
ELECTRICITY AND MAGNETISM
HEAT
- PHYSICS OF THE VERY SMALL:
 - Quantum physics: ATOMS
MOLECULES
ELEMENTARY PARTICLES
- PHYSICS OF THE VERY LARGE:
 - Astrophysics/Cosmology: STARS (life and death)
CHEMISTRY OF UNIVERSE
EVOLUTION OF UNIVERSE

- SOME (PRESENT) FAILURES:
 - Complex Phenomena: WEATHER
BRAIN
LIFE
HUMANS

The reductionist approach has been VERY successful...Why?

There is simplicity in the apparent complexity of Nature

- It is possible to understand and predict the behavior of many phenomena with **simple, general laws** (e.g. gravity)

PHYSICS IS THE METHOD BY WHICH WE UNCOVER THIS SIMPLICITY

UNDERSTANDING
NATURE



SEARCH FOR LAWS
OF PHYSICS

HOW DID IT ALL START? AND WHERE?

THE PRE-SOCRATICS (ca. 620-470 BCE)

Questions about Nature answered within Nature

1. IONIAN SCHOOL: Miletus

What is the stuff of cosmos? “Physis”

• Thales • Anaximander • Anaximenes • Heraclitus

2. ELEACTIC SCHOOL: Elea

Radical Monism: One Being

• Parmenides • Zeno

3. PYTHAGOREAN SCHOOL: Croton

Mathematical mysticism: Number is All

• Pythagoras • Philolaus

4. ATOMISTIC SCHOOL: Abdera

All things made of atoms

• Democritus • Leucippus

I. Ionian School:

- Questions are asked
- what is the stuff cosmos is made of?

Thales of Miletus (ca. 624-545 BCE)

First to suggest single substance: WATER

Universe is a living organism (unifying Nature with body)

Search for simplicity in Nature

Earth is a circular disk surrounded by water

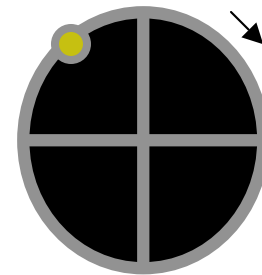
Anaximander of Miletus (ca. 611 - 546 BCE)

Universe is infinite in extension and duration

Raw material is unknown substance: all things born from it and

“Boundless: The cosmic breath” return to it

First mechanical model of cosmos



Anaximenes of Miletus

Air is basic stuff: Different densities --> different substances
fire --> water --> earth --> stones

Stars attached to crystalline spheres (key idea in astronomy
for 2,000 years...)

Heraclitus of Ephesus (fl. Ca. 500 BCE); “The Obscure”

“All things are in flux and nothing is stable” (river)

Balance in cosmos achieved from tension between opposites

“logos” (bow and arrow)

Basic substance is fire: Transformation

Emphasis in **PROCESS: BECOMING**

IONIANS → BECOMING

II. Eleatic School: (fl. 5th BCE in Elea, Italy)

Parmenides of Elea (ca. 515 - 450 BCE)

- * Radical Monism: There is one Being, Immutable
→ change is second-rate reality
- * Eon: Cosmic Deity - ungenerated, all-pervading
- * What IS cannot change for... **BEING**
- * Physics as search for immutable laws
- * Zeno and his paradoxes of motion

III. Pythagorean School: (fl. 6th - 5th BCE in Croton, Italy)

Mathematical mysticism: “All is number”

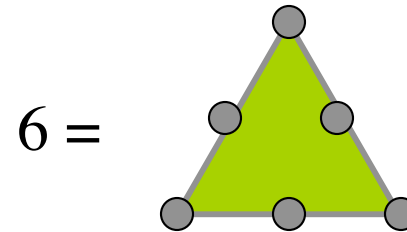
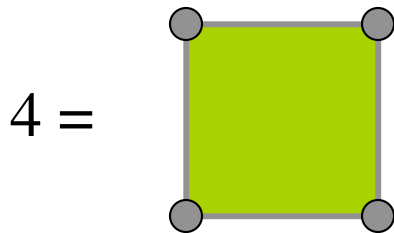
all things have forms, and forms are described by numbers

Pythagoras of Samos (ca. 585 - 510 BCE)

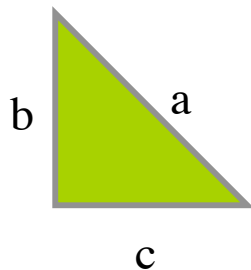
- * Legendary; possible pupil of Anaximander
- * Synthesis of philosophy and religion: rational and mystical
- * Knowledge is gateway to the Divine:
numbers are the bridge between human reason and
divine mind
- * Self-transcendence through the beauty of numbers (“ekstasis”)

Pitch of note depends on length of string

- * pleasing sounds correspond to simple ratios: $2/1$ - Octave
 $3/2$ - Fifth
- * expression of quality as quantity: mathematization of sensorial experience
- * beauty (HARMONY) can be expressed mathematically
- * Numbers have form:



- * get square numbers by adding odd numbers:
 $\underline{1} + 3 = \underline{4} + 5 = \underline{9} + 7 = \underline{16} + 9 = \underline{25} \dots$

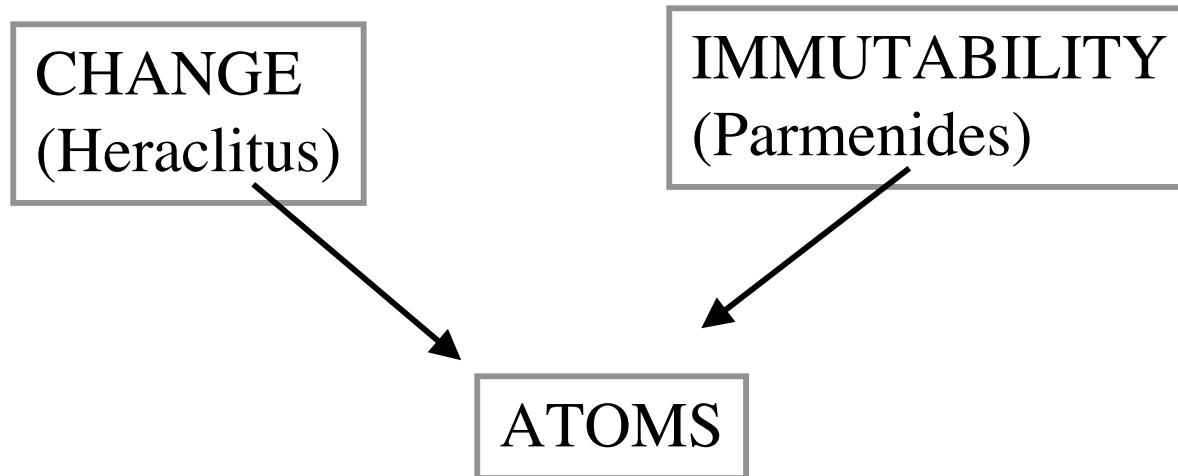


$$a^2 = b^2 + c^2$$

- * The harmony of the spheres
- * Earth is spherical

IV. Atomistic School: (fl. 4th BCE)

- * All things are made of indivisible, fundamental dense bricks: atoms
- * Reconciliation of change and immutability



*Quantitative change - qualitative immutability

→ synthesis of being and becoming

*Leucippus (fl. 450-420 BCE): basic ideas

*Democritus (ca. 460-370 BCE): The Laughing philosopher
-detailed elaboration; infinitely many, infinitely many shapes
moving in the Void



-compare with modern atoms: not infinite in number, not indivisible, not hard

* extension to humans, emotions; liberation from fear; Lucretius

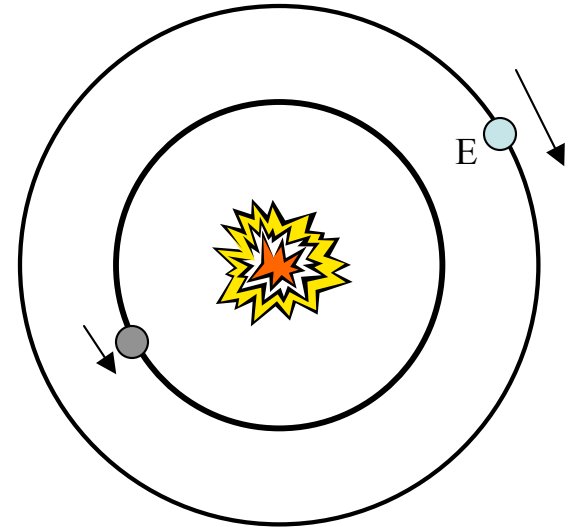
Precursors of Change

- Philolaus (ca. 550 BCE)

A Pythagorean

Breaks away with geocentrism:

- ➔ earth moves around a “central fire”
- ➔ postulates the “antichthon”



- Heraclides of Pontus (ca. 350 BCE)

Studied under Plato and Aristotle

Earth rotates around its axis!

Mercury and Venus rotate around Sun!

- Aristarchus of Samos (ca. 310 - 230 BCE)

Meticulous observer: puts Sun in the center!!

Resistance from Aristotelians and absence of stellar parallax (cosmos would be too big)

