

ATOMISM



Early Hypotheses

- the early Greek philosophers were the first to introduce the concept of indestructible atoms as the basic units of material substances
- the earliest ideas involved **one primary element**, existing in an infinite variety of forms, eg,

Thales of Miletus (fl 600BCE)	water
Anaximenes	air
Anaximander	fire

- Heraclitus (fl 500BCE) believed it was more important to explain

change than permanence and favoured **fire** as the agent of change

- Parmenides (fl 475BCE) disagreed (these guys were philosophers remember), and insisted that reality had to be unchangeable, and observed change was illusory
- Xeno illustrated this view with his paradox of Achilles and the turtle, eg, if the speedy Achilles started out 100 yds behind a turtle and closed the distance between them by one-half in each time interval, would he catch the turtle? (This paradox brings attention to the infinite division of space)
- Empedocles (fl 450BCE) sought to unite these differing viewpoints by proposing **4 primary elements** - air, earth, fire and water; the four elements were immutable
- Anaxagoras (fl 450BCE) argued that the fundamental elements were **divisible without limit** - consequently the world is continuous and full of matter

The Atomic Hypothesis

- **Leucippus of Miletus** (440BCE) proposed the novel idea that all matter was made of **atoms** (from Gr. 'a tomos' = not breakable)
 - there existed an infinite number of atoms which differed in size, shape and weight, but all were composed of **one, neutral matter**
 - different substances formed by intermixture and entanglement of atoms, which moved around freely in a **void**
- **Democritus** (420BCE) extended the theory by proposing that **atoms were eternal**, impossible to create or destroy; and their intermingling to form substances resulted from **random collisions**, not divine purpose

- thus by ca 400BCE there existed two competing theories of matter:

- 1) multiple elements, infinitely divisible in a full world; substances differed by composition
- 2) indivisible atoms of one prime matter, moving in a void; substances differed by architecture

(Does modern matter theory correspond to any one of these?)

Aristotelian Theory

- **Aristotle's** ideas (ca 330BCE), based largely on those of Empedocles, became the favoured explanation for the structure of matter

- as covered in Composition, Aristotle combined the 4 qualities, hot, cold, wet, dry with a neutral substance to produce the four fundamental chemical elements ***air, earth, fire and water***

- Aristotle argued that the elements were homogeneous and divisible without limit; no void could possibly exist

- the conversion of one substance to another, whether by nature or by an artisan, was a full transmutation

- Aristotle rejected atomistic ideas for several reasons, chiefly a refusal to accept that a void could exist, which was a basic requirement of indivisible atoms; consequently atomistic thinking largely disappeared

- Aristotelian thought, preserved in his many books, first in Greek, then Arabic, then Latin became incorporated into the ascendent monotheistic religions of the Middle East and Europe as a satisfactory description of the physical world

- but rational explanations rapidly became inferior to divinely-inspired "truths" in the foundational books of Judaism, Christianity and Islam after the end of the Greek "golden age"

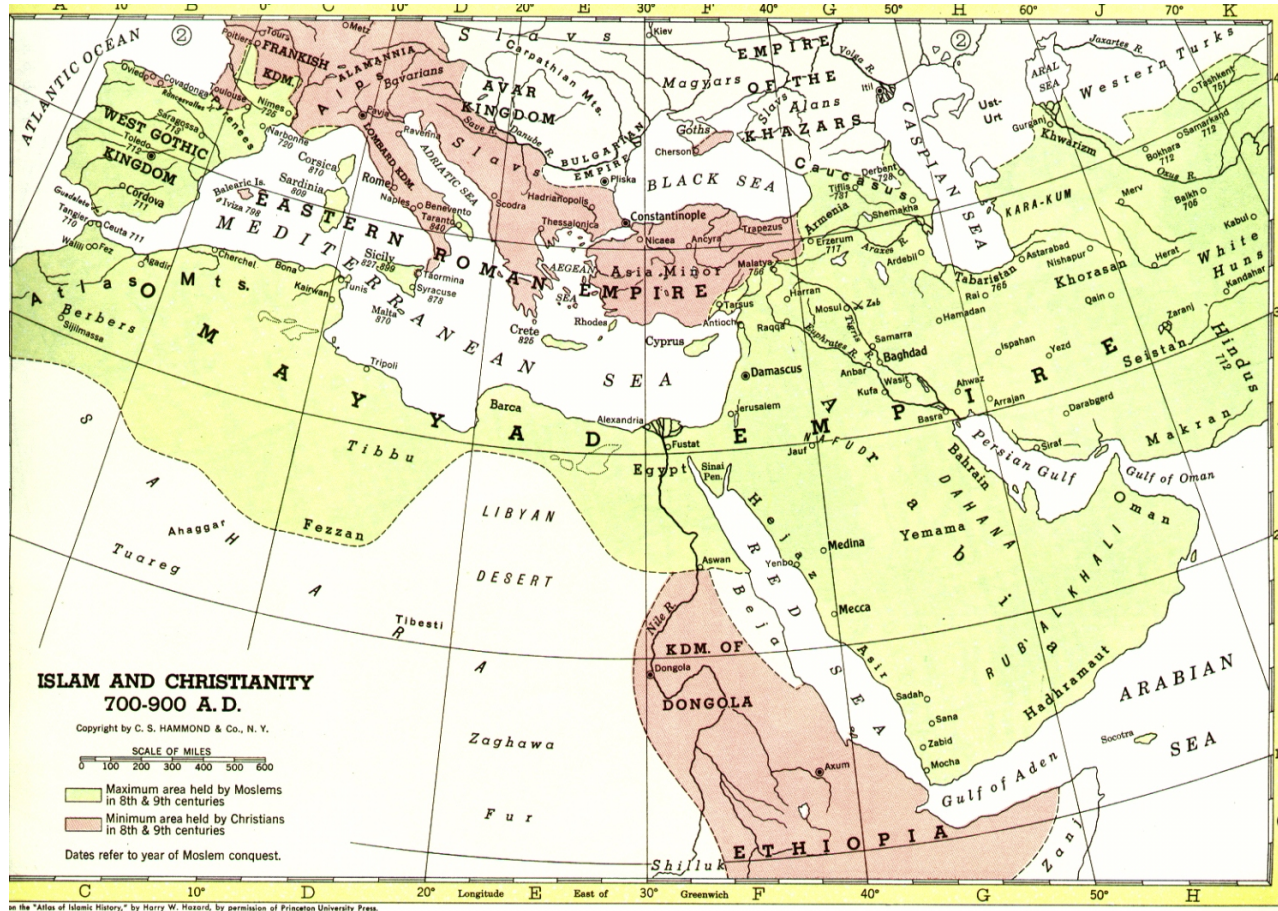
❖ The Next 1500 Years

- a brief, and superficial, history lesson
- the Greek civilization was inclined to a naturalistic, “real as perceived” world. This world view is represented by various artworks, eg, classical Greek sculpture, ca 400BCE



- such sculptures and stone carvings were very lifelike and true to scale; mankind was dominant in nature; heroes and gods were human in form and proclivities
- the major religions became dominant from about 1-1500 AD, and naturalistic explanations came to be viewed as inferior to truths contained in holy books and ultimately even became atheistic and heretical as religious leaders became powerful political figures as well
- one historian (*A History of the Modern World*, Palmer and Colton, (4th edition), Knopf, 1971) has said
“If any historical generalization may be made safely, it may be safely said that any society that believes reason to threaten its foundations will suppress reason”

- Aristotle's ideas were valued even more highly by Muslims than by Christians, and his works were translated into Arabic, even as they disappeared in their original Greek



- in Christian Europe, Catholic theologians continuously worked to harmonize human perceptions and naturalistic thinking with revealed truths. By the 4th century the whole Roman world had become Christian and the bishop of Roman Africa, St. Augustine (ca 400AD), wrote in the 10th book of his Confessions

“At this point I mention another form of temptation more various and dangerous. For over and above that lust of the flesh which lies in the delight of all our senses and pleasures...there can also be in the mind itself, through those same bodily senses, a certain vain desire and curiosity, not of taking delights in the body, but of making experiments with the body's aid, and cloaked under the name of learning and

knowledge... Thus men proceed to investigate the phenomena of nature - the part of nature external to us - though the knowledge is of no value to them: for they wish to know simply for the sake of knowing...

...when dare I say that no such thing can draw me to look at it or through vain curiosity to desire it? Certainly the theatres no longer attract me, nor do I care to know the course of the stars..."

- let's look at art again to see how the depiction of the word had changed, eg, the Cluny tapestry of 1200AD



- obviously, symbolism has become more important than realism

- and look at Villard de Honnecourt's "Apostles" and "Lion" (drawn from life) of about 1200



-as a result of the crusades and other wars, Christian states recaptured lands from Muslim ones



- and in the process rediscovered Greek ideas in their Arabic translation; the recovery of Greek ideas spurred the remarkable changes of the Italian Renaissance

- look at the changes in religious art



Francesca, Resurrection, 1460



Mantegna, Dead Christ, 1506

- and in the depiction of natural things

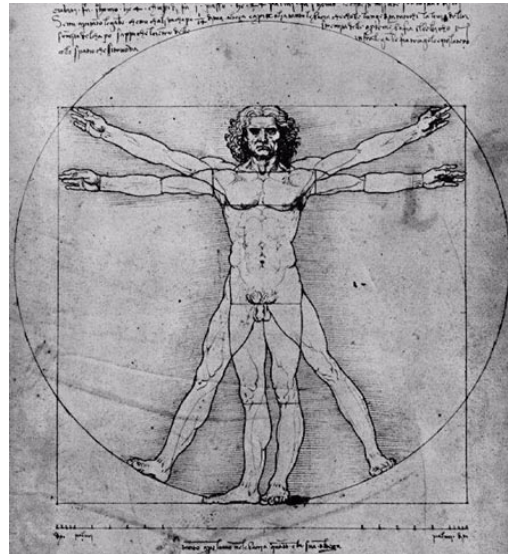


Albrecht Durer's "Hare and "Sedge", both early 1500s

- Renaissance thinkers, inspired by Greek ideas, began to view Nature as a testament to the Creator's attention to detail, and wisdom through the laws of nature
- it became intellectually valid to observe nature carefully and critically, for doing so was to appreciate God's creation
- again shown in art



Wm Blake, Ancient of Days, 1794



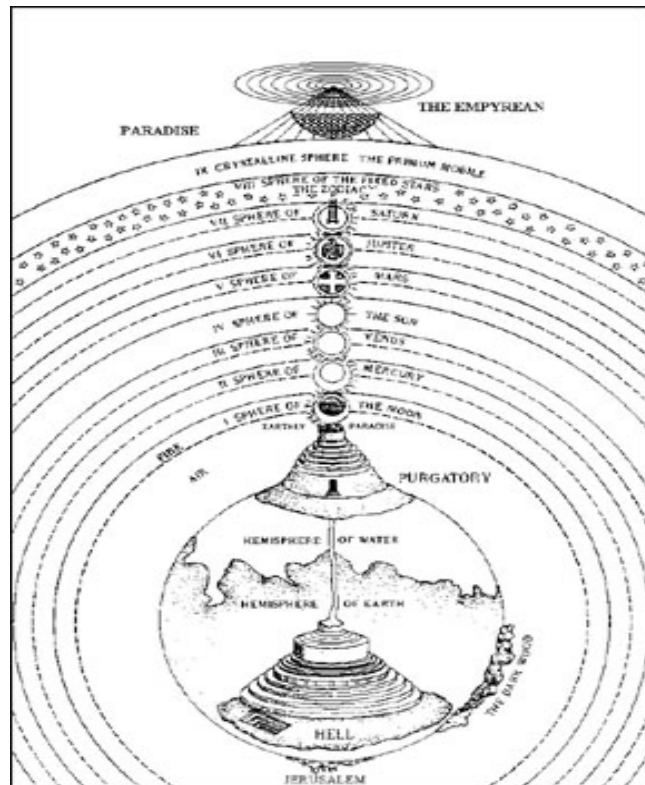
Leonardo, Vitruvian Man, 1490

- what did Renaissance thinking do for science?
- Aristotle's picture of the universe had the earth at the centre of a series of crystalline, concentric spheres which held the planets and the outermost stars, eg,

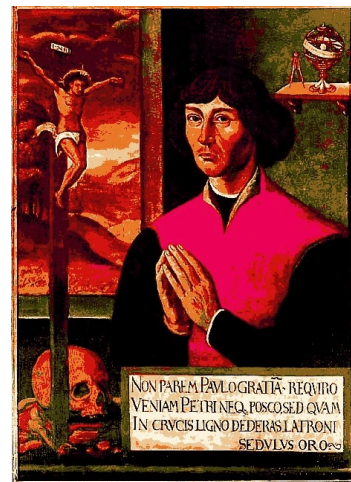
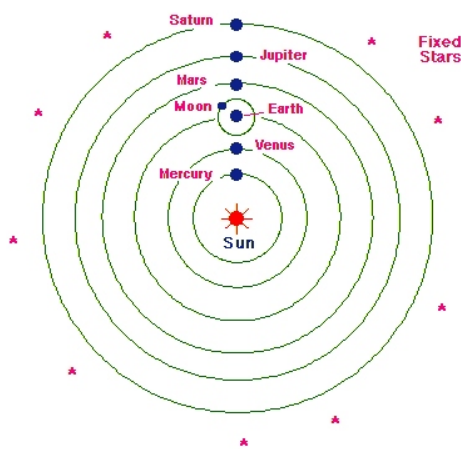


- the Aristotelian became embedded in the Christian universe, as described, and pictured by Dante (ca 1310), at the start of the Renaissance

- in this view, man is placed on the earth midway between the heavens just outside the outer sphere and hell which lay deep below the earth's surface



- in the spirit of the Renaissance, Copernicus, a Catholic canon in Poland, studied astronomy and discovered that he could predict the positions of the planets and the timing of the seasons much better based on a model of the universe that had the sun as its centre, and the earth on a sphere outside the sun



- Copernicus published his ideas in 'De Revolutionibus' in 1543, a year that is usually taken by historians to mark the start of the Scientific Revolution - the study of nature and nature's laws in a rational, quantitative way
- in 1610 Galileo published his 'Starry Messenger' in which he revealed that with a newly invented telescope he had observed the orbiting moons of Jupiter and claimed that the sun-centred universe was real; observation of the stars had indeed led believers away from Christian teaching, as Augustine had feared it would
- once astronomy had broken Aristotelian "truth", other sciences quickly followed, and now we return to chemistry ❖

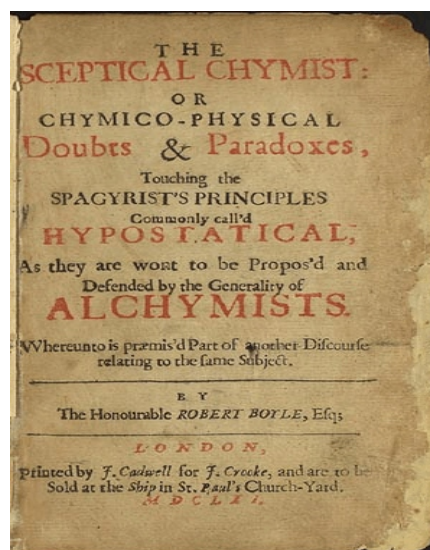
The Re-emergence of Chemical Atomism

- in 1600 Daniel Sennert attempted to reconcile atomism with Aristotelian elements by suggesting that atoms were the physical limits to division of substances, ie, Aristotelian homogeneity was maintained only until the smallest possible particle
- these ultimate particles could cluster together to form the simple substances chemists found in compound substances
- in 1661, **Robert Boyle**, a wealthy English natural philosopher published the first famous chemistry text written in english, The Skeptical Chymist
- Boyle stated that chemistry needed to be based on experimental results only but then, ignoring his own recommendation, hypothesized that all chemical behaviour could be understood by mechanical principles, ie, everything was reducible to ***particles of matter and their motion***

- his ideas appeared about the same time as Newton was explaining planetary motion on the basis of material bodies and motion (under the influence of gravity)
- Boyle postulated an infinite number of characterless particles, which aggregated together in specific geometries



Robert Boyle (1627-1691)



- Boyle is also famous for giving the first “modern” definition of a **chemical element** as (see notes p.A8)
 - i) primitive...bodies
 - ii) which make up compound bodies, and
 - iii) are found in all chemical substances
 but he followed his definition by doubting that such elements actually existed as all could be reduced further to more fundamental particles

Forces in Chemistry

- **Isaac Newton** (1642-1727) also adopted a mechanical philosophy, and used it with outstanding success in physics and astronomy

- in the last 30 yrs of his life Newton tried to understand chemistry in the same mechanistic way. He proposed:

1) an infinite number of particles, all of one neutral matter, moving in a vacuum (he avoided the word "atom" because of its controversial theological overtones)

2) the particles acted on each other through **short-range forces**, both attractive and repulsive (similar to, but different from, gravity)

3) the forces were transmitted through an invisible, weightless fluid termed **the aether**



- Newton's chemical ideas were included as "Queries" at the end of his remarkable 1706 book Optics (which reported that light could be refracted through a prism into different colours). One query contained his speculation that "...it seems probable to me that God in the beginning formed matter in solid, massy, moveable particles, as such sizes and figures...as most conduced to the end for which He formed them"

- very many 18th century philosophers tried to measure short-range chemical forces by a number of ingenious but ultimately unsuccessful techniques; chemical forces were much more difficult to quantify than gravitational ones and consequently Newton made little lasting impact on chemistry, but he did make the idea of ultimate chemical particles philosophically respectable