

## From the *atomon* of Democritus to the therapeutic nuclear medicine of today

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By the beginning of the twentieth century, two of the fundamental laws in nature, those of gravity and electromagnetism, had been elucidated. The development of classical mechanics, from Galileo Galilei and Isaac Newton through to Joseph Louis Lagrange and William R. Hamilton, had proved the dominion of the law of gravity on earth and in the universe, while studies by Michael Faraday, James Clerk Maxwell and Heinrich R. Hertz on electromagnetic forces had made parallel potent contributions to scientific knowledge. The evolution of the kinetic theory of gases and thermodynamics had led scientists to consider matter in terms of molecular or atomic constituents. However, many properties of the basic building blocks of matter remained undiscovered or poorly understood.

The quest for detailed knowledge of the fundamental constituents of matter dates back to the ancient world. In the 6th century B.C.E. (Before the Common Era), Kanada and Pakhuda Katyayana in ancient India had propounded ideas about the atomic constitution of the material world. However, it is the great pre-Socratic Greek philosopher Democritus (born in Abdera, in Thrace, in the 3rd year of the 77th Olympiad, around 469 B.C.E., one year before Socrates) and his mentor, Leucippus of Miletus (born about 500 B.C.E.), who are considered the main representatives and proponents of the atomic theory, called atomism (in Greek the prefix 'α' means 'not' and the words 'τέμνω' and 'τομή' mean 'to cut' and 'cut' respectively; thus 'ά-τομον' means that which cannot be further divided into smaller pieces) (Fig. 1). This theory [1] was mainly pos-

tulated in their works 'Μέγας Διάκοσμος' (*Megas Diakosmos*), i.e. the 'Great World System' and 'Μικρός Διάκοσμος' (*Mikros Diakosmos*), i.e. the 'Small World System'. According to them, the hidden substance in all physical objects consisted of (a) the atoms and (b) the void. Atoms were considered to be full, incredibly compact and completely solid, with no internal structure, and could not be further divided into smaller particles, whereas the void was empty. Even though the void was empty, it existed; in other words, it occupied an area. Atoms differed in shape, arrangement and position. Atoms were indestructible, eternal and in continuous vibration. Coming into contact with other atoms, they formed bodies. Neither the atoms nor the void had ever been created and neither would ever end. The void is infinite and provides space [2].

Although the atomic theory was supported by later philosophers and scholars, it was fiercely attacked by others, including surprisingly, Plato (born in 427 B.C.E.) and Aristotle (born in 384 B.C.E.), who argued against the existence of such atoms or 'atoma' [3]. Additionally, since atomists' work was considered to contradict Christianity's concept of an immortal soul (in that if this soul is composed of atoms, it must perforce perish upon death, with the consequence that there is no afterlife), it was actively suppressed by Christian writers, leading unfortunately to the dismissal of the atomic philosophy for nearly two millennia (!). However, the Greek atomic concept ironically survived in Aristotle's works among his arguments against it [4], as well as in the superb classical manuscript by the Roman author Titus Lucretius Carus (born in 1 B.C.E.), '*De Rerum Natura*' ('On the Nature of Things'); furthermore, it is to some extent also preserved in the philosophy of the Islamic medieval scholars.

During the Middle Ages (the Islamic Golden Age) and up to the end of the sixteenth century, Islamic scholars developed atomic theories from a synthesis of Greek and Indian atomism. Characteristically expressed in '*kalam* philosophy', completely dependent on God, it was argued that atoms are perpetual material things in existence whereas all else in nature is accidental. 'Accidents' were the direct results of God's constant intervention. Great personalities of this enlightened period of the tenth and eleventh centuries, the philosopher and thinker Avicenna

This editorial is dedicated to the *asklpiads* of nuclear medicine, and in particular to the first-generation European nuclear physician pioneers, on the occasion of the annual European Congress on Nuclear Medicine in Athens, October 2006.

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Fig. 1. Democritus from Abdera

(Abu Ali al-Husain ibn Abdallah ibn Sina of Transoxiana, born in 980) and the physician and scholar Abu'l Walid Ibn Rushd, of Cordoba, better known as Averroes (born in 1126), secured and spread in the Islamic world the ideas of Greek atomism as well as the Aristotelian position in scholastic thought.

At the end of the sixteenth century in the West, scientific discussion brought the criticism of Aristotle to its zenith owing to the progress in experimental philosophy. The dawn of the atomic renaissance was heralded by the atomistic theory of Rene Descartes, Pierre Gassendi and Robert Boyle. This renaissance was continued in the eighteenth century by Rudjer Boscovich, who based his theory on classical mechanics, published it in 1758 in *Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium* (*Theory of Natural philosophy derived to the single Law of forces, which exist in Nature*). Thereafter atomic theory was applied in chemistry by John Dalton and studied further by Amedeo Avogadro and the developers of the kinetic theory of gases, James Clerk Maxwell and Ludwig Boltzmann. Although Dalton was without doubt the founder of modern atomic theory, it was Ernest Rutherford who gave the first coherent explanation of the structure of an atom, reporting that its mass is concentrated in its positively charge core, the nucleus, and the negatively charged particles, the electrons, that orbit it. However, he concluded that as the electrons orbit around

the nucleus they should be continuously accelerated, radiating electromagnetic energy, finally losing their energy and spiralling into the nucleus. This dilemma was solved in 1913 by Niels Bohr (Fig. 2) of Copenhagen (born in 1885), who developed the Bohr model. According to his theory, “electrons could orbit about the nucleus without losing energy only in orbits for which their orbital angular momentum was an integral multiple of Planck’s constant  $h$  divided by  $2\pi$ ”. The latter led finally to the development of quantum theory, by Max Planck and Albert Einstein.

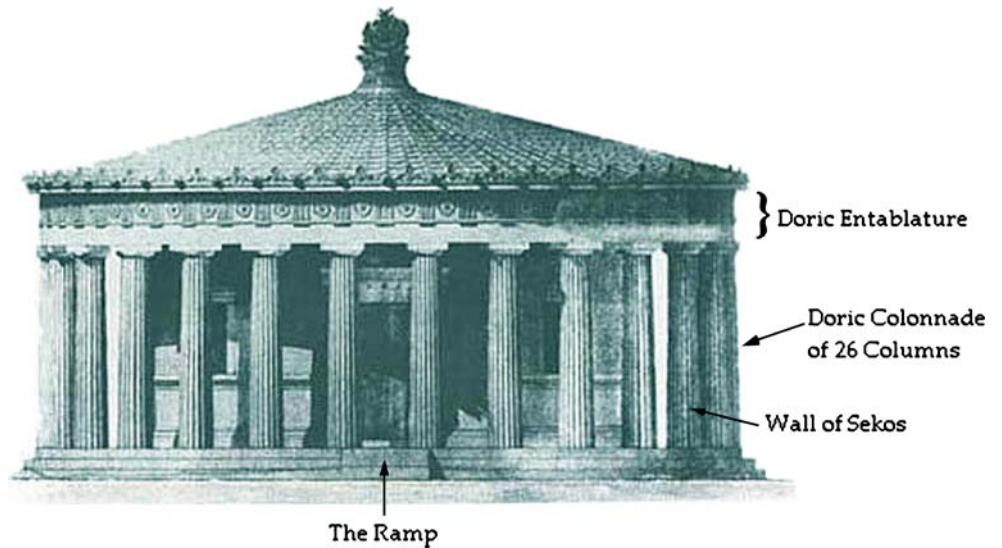
Today, everything we know about the atomic theory derives from original manuscripts by propounders of the theory or from the plethora of works by subsequent authors, philosophers and researchers who cited, explained, analysed or disagreed with their work. While in Greece, you may have the opportunity of visiting the still existing Asclepieion at Epidaurus. There you will be able to read a description of its Tholos (Fig. 3), which unfortunately has been partly destroyed [5], and see its surviving floor (Fig. 4) as well as its labyrinth (Fig. 5). You will discover incontrovertible evidence that the atomic theory stimulated



Fig. 2. Niels Bohr from Copenhagen



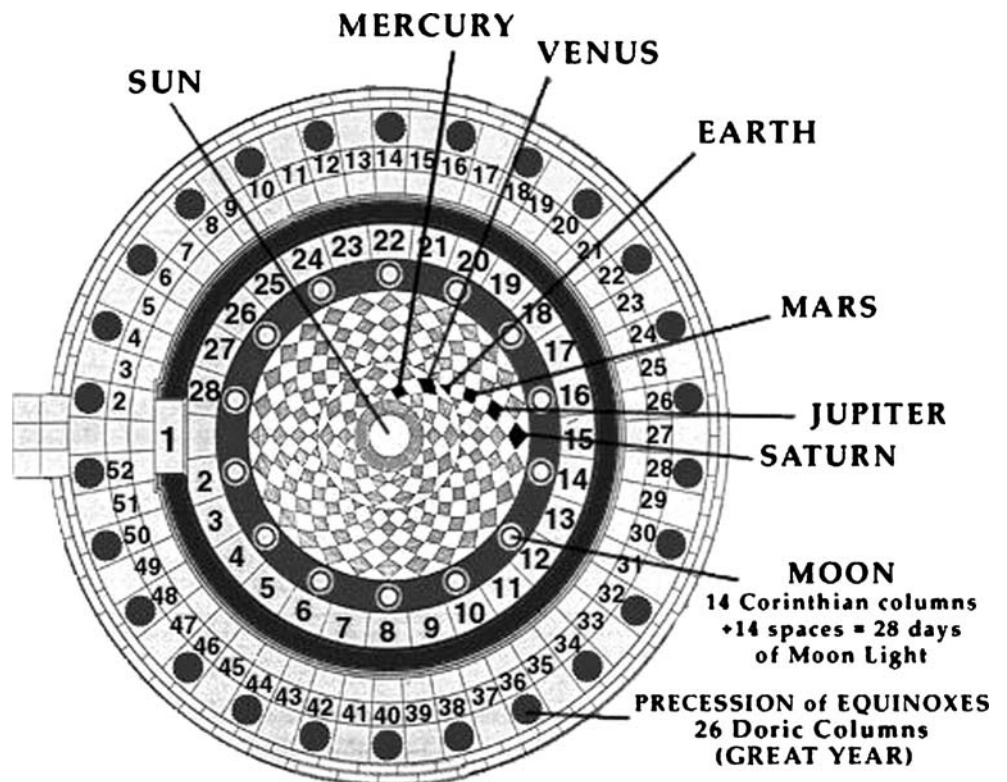
**Fig. 3.** Representation of the Tholos (round house) at Epidaurus



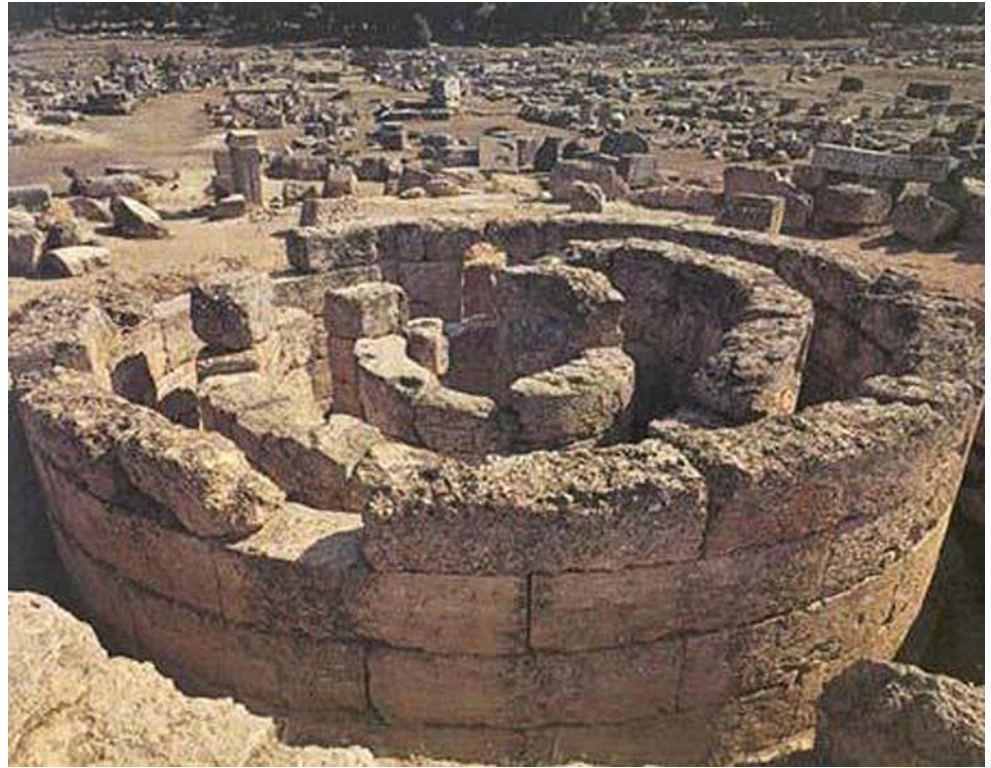
therapeutic applications by famous physicians of the day. Personally, I do not know of any ancient Greek papyri that refer to particle therapies with, for example, strontium, rhenium, samarium or lutetium. However, in Epidaurus one can find the ruins of a well-known healing centre of excellence of the ancient Greek world where therapeutic schemes were implemented. Particularly impressive is the amazing heliocentric, astronomical model on the floor; while its precise function remains unexplained, it must

have played a major role in the planning of treatments performed to “harmonise the human soul with the Planetary Order” [6] (!). What kinds of procedure were carried out (as discovered and reported in escalations) to complete this harmonisation? What kinds of intervention were performed upon the human target who was brought to the centre of this heliocentric astronomical model for the treatment prescribed? Was it radiation originating from the universe (the endless source of our heliocentric system)

**Fig. 4.** The heliocentric planetary system depicted on the floor of the Tholos at Epidaurus



**Fig. 5.** The labyrinth of the Tholos at Epidaurus



depicted in the Asclepieion, to which the patient was admitted in order to undergo a universe matter–body interaction? What else? If, in those treatment theatres, believers in atomism progressed from theory to application, two kinds of procedure might have been used or intended: either electromagnetic waves to affect the spin of the hydrogen body or exposure of the patient to radioactive particles from the heliocentric system originating from the universe. A supposition or a utopian idea? At that time in ancient Greece no prophecy foresaw the coming of radionuclide therapies or of Ernest Rutherford with his heliocentric atom theory or of Niels Bohr with his atomic model and the Copenhagen School of excellence [7]! This Congress leads us on to Copenhagen next year. A chance phenomenon or a symbolically inspired sequence of events?

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