# ATOMISM IN ANCIENT MEDICAL HISTORY

*by*

R. A. HORNE

*Science has shown the great circles in which nature works.*

RALPH WALDO EMERSON

THE history of the development of the atomic theory is usually imagined to be the exclusive province of chemistry and physics, and there is a tendency to suppose that molecular biology is one of the most recent products of twentieth-century science. For these reasons it is surprising to discover that the paths of the corpuscular world-view and theoretical physiology crossed more than two thousand years ago and that this encounter resulted, not in a casual and passing acquaintance, but in an important and productive liaison which continued, albeit with interruptions, over a period of twenty centuries.

Far from being cloistered academicians the pre-Socratic philosophers of ancient Greece were expected to be the brains of their community, intellectuals in the most responsible sense of that term. They were consulted by their fellow townspeople concerning every type of problem, practical as well as speculative, and ranging from epistemology to sanitary engineering. Indeed, their formal philosophizing may have been a pleasant diversion of their spare moments. Clearly they were not specialists. All human knowledge was their 'field', biology as well as astronomy, physics, chemistry and metaphysics, not to mention psychology, sociology and ethics. In addition to theorizing about the life processes, some of them undoubtedly prepared and dispensed medical treatments. Empedocles, we know, claimed miraculous 'cures'. In view of his personality the treatment, in this instance, probably consisted of a mixture of hocus-pocus and genuine therapy. The physiological opinions of the philosophers, together with the ancient practices of the priests of Asclepius and the usages of the gymnasia superintendents, formed the basis of Greek medicine.[1]

Biological observations sometimes exerted a profound influence on the cosmological speculations of the pre-Socratics. For example, Thales' choice of water as the primal element may very well have been the product of a number of biological observations—that water is vital to the life processes, that blood and the other body fluids are composed mostly of water, that the generative seed of all creatures is moist, that the sea teems with life, that water condenses from the breath.

We find in ancient Greek philosophy two well-defined examples of what we might properly call proto-atomism prior to the true atomism of Leucippus and Democritus. The first of these is the geometrical atomism of the Pythagoreans which found its most influential presentation in the *Timaeus* of Plato.[2] Later in our discussion we will return to Plato's application of this type of corpuscular theory to physiological phenomena. The second is the famous 'seed' hypothesis

of Anaxagoras of Clazomenae (*c.* 460 B.C.). Empedocles had proposed four primal elements;[3] Anaxagoras moved even further away from the monism of the Ionians by adopting a most extreme form of pluralism. There are, he maintained, an infinite number of elements.[4] The operation of the dissection of matter leads to a point beyond which further subdivision yields no new species although the motions of subdividing may be continued indefinitely. The materials known to us are mixtures consisting of a limitless variety of parts or elements. But these elements are themselves homogeneous. The properties of bulk matter depend on which element or 'seed' (spermata) predominates. Gold consists mostly of seeds of gold, bread of bread seeds.[5] This brings us immediately to the principal difficulty which vexed the seed hypothesis, and, interestingly enough, this crucial difficulty hinges upon a physiological phenomenon—digestion. When we eat a crust of bread how does the bread subsequently become blood, flesh and bones? How can this chemical transformation of bread into what is not bread be explained? All things, Anaxagoras hypothesized, must contain all seeds. Bread must contain seeds of blood, flesh and bone. Before ingestion bread seeds predominate but upon digestion, since the seeds themselves are not subject to alteration, the seeds of blood, flesh and bone must somehow come to predominate.[6] Just how they manage to do this is left unclear. Whereas Empedocles could account for chemical change by simply attributing it to a separation or combination of the four elements, Anaxagoras awkwardly had to resort to some manner of sorting or reshuffling of a limitless number of seeds. His attempt to account for change is a particularly vulnerable point of his philosophy. The fact that digestion and related phenomena brought Anaxagoras' theories to grief is especially distressing for these were not problems which his cosmological views stumbled on while in full career. Quite the contrary, these were the very problems which he had in mind when he formulated his theories. The theory was tailored to solve them, and we are left wondering how Anaxagoras could ever have thought that he had succeeded. Perhaps the key has been lost, and the crucial idea is not contained in the fragments we have inherited.[7]

The classical problems of pre-Socratic speculation, the problem of The One and The Many and of Being and Becoming, were finally satisfactorily resolved by the Atomists. The Ionian philosophers and the Eleatics insisted that all is One but the Pluralists found everywhere evidence for four and, in the case of Anaxagoras, many elements. How can we account for the endless richness and diversity of Nature in terms of a minimum of explanatory parameters?

Heraclitus saw man immersed in flux, in constant change. The Eleatics, on the other extreme, insisted that all is Being, that there is no Non-Being and hence no Becoming, that change is an illusion. The resulting philosophical crisis was particularly grave because the Eleatics had invented a proto-logic, the dialectic, so cogent that one appeared to be obliged thereby to choose between reason and the evidence of the senses.

The Atomist Democritus (*fl. c.* 420 B.C.)* represents the culmination of early

* I will not attempt to distinguish between the philosophical tenets of Leucippus and those of his pupil Democritus.

Greek philosophy for it was he, rather than Plato or Aristotle, who first succeeded in resolving these issues. The world of the Many, the world of Change that we apprehend through the agency of the sensory equipment is a consequence of the incessant motion and the formation and dissolution of aggregates of indivisible and unchanging corpuscles or atoms. These atoms are perceived logically; they are imperceptible to the senses. The atoms, and the Void in which they move, are the One and changeless principle of nature. The necessity which directs their movements constitutes natural law. The Many arise through their permutations; Change through the motion, formation and disintegration of their aggregates.

We are told that as a young man Democritus consumed his inheritance with extended travels in Egypt, Persia and perhaps even India, thereby accumulating the vast store of knowledge in every discipline, including medical lore, that gained him a formidable reputation.[8] When the famous physician Hippocrates passed through Abdera, the townspeople are said to have prevailed upon him to examine their savant, whom they feared to be mad. The doctor discovered the eccentric philosopher performing a dissection:[9]

> Old Democritus under a tree
> Sits on a stone with book on knee;
> About him hang many features,
> Of Cats, Dogs and such like creatures,
> Of which he makes Anatomy
> The seat of Black Choler to see.
>
> ROBERT BURTON
> *The Anatomy of Melancholy*

A short interview sufficed for Democritus to better the noted doctor and send him retreating badly shaken.

Democritus was a voluminous writer and few topics failed to catch his attention. Among the titles in the partial lists of his works are many of physiological interest: *On Cheerfulness or Well-Being*, *On Perception*, *On Tastes*, *Causes of Animals*, *Prognosis*, *On Diet*, and *On Medical Method*. It is disappointing to find, however, that atomism plays very little role in his physiological writings. Bailey has summarized the situation:

> It is hard to find in them anything specially atomic and his speculations were no doubt inspired by the same contemporary interest in these matters which gave Anaxagoras the starting point in physiology for his main theory of the constitution of matter. But there is nothing in the views recorded which is inconsistent with Atomism and it may be taken as certain that Democritus took . . . pains to accommodate his theories to his main principles.[10]

When we say that the philosophy of the ancient Greek Atomists, like that of modern scientists, is logical-empiricism we need neither apologize for, nor qualify, our assertion, but we must add a word of explanation for the relation between the logical and the empirical content of Greek Atomism is not identical with that of modern Atomism or even, for that matter, with that of ancient Indian Atomism. The atomistic system of the Indian philosopher Kanada (dates very uncertain) was designedly empirical; its expressed purpose was to

give an account of the image of the external world which we receive through our senses.[11] It is not surprising to find, therefore, that this world-view attributes the sensual qualities of perceptible objects such as colour and odour to the imperceptible atoms. The logical implications of Indian Atomism were apparently developed imperfectly and tardily. Children, too, develop atomistic concepts which seem to be based for the greater part on empirical observation coupled with a certain juvenile impatience when confronted with the prospect of endless tedious subdivision.[5]

Modern chemical atomism is similarly based on empirical observation, in particular on the laws of chemical change and constant chemical composition. For this reason Dalton rather than Democritus, Epicurus, Lucretius or anyone of the host of Dalton's corpuscularian predecessors such as Gassendi, Bacon, Boyle, or even Newton, is commonly credited, and not improperly so, as being the 'father of the atomic theory'. Here again the logical implications of an empirically based hypothesis tardily disclosed themselves. Not until the development of quantum mechanics did the metaphysical significance of the atomic hypothesis begin to emerge. Again, as in the case in ancient India, the empirically oriented Atomists were caught very much off their guard, and the ensuing debate has been persistently amateur in quality and uniformly unsatisfactory in results.

Heidel[12] and others have advanced the suggestion that Greek Atomism was the consequence of an attempt to account for specific empirical observations, especially certain physiological phenomena such as ingestion and respiration. Such was indeed the case, as we have seen, in the instance of the 'seed' hypothesis of Anaxagoras, and we find a much later Atomist, the Roman poet Lucretius (96?–55 B.C.), at great pains to explain a wide range of phenomena in atomistic terms. But the philosophy of Leucippus and Democritus was based on metaphysics rather than on physics; it sought to resolve the Monist-Pluralist and Heraclitean-Parmendidean antinomies rather than to account for specific empirical observations. In fact, as intimated above, Democritus appears to have been rather reticent about applying his atomic hypothesis to particular physical problems. Just as Socrates complains that Anaxagoras, having introduced the concept of *nous*, then proceeds to ignore it,[13] so we might object that Democritus fails to exploit the physical potentialities of his doctrine of the atom. Herein as well perhaps lies the explanation of the fact that Leucippus and Democritus apparently owe so little to the Anaxagorean 'seed' hypothesis.

Lactantius (*c.* A.D. 290) scornfully asked who had ever seen an atom. Democritus would have been the first to reply, 'Not I.' The atom is imperceptibly small. It is not an object of empirical knowledge. The atom of Democritus, like the Non-Limited of Anaximander (*c.* 546 B.C.), is a logical concept, an idea perceived by the reason rather than by the senses. The logical character of the Atomism of Leucippus and Democritus is further emphasized by their insistence that a strict Necessity governs all natural events.*

Democritus next takes the logical idea of the atom and proceeds to endow it

* Some writers who certainly should know better still claim that the atomists attributed all to chance thus leading one to suspect that such statements are slanders rather than mistakes.

with physical significance by attributing primary qualities such as extension and possibly weight to the atoms. Familiar objects are constructed of atomic aggregates. Finally the secondary qualities of objects—taste, colour, odour—are attributed to the interaction of atoms and their aggregates with the sensory organs. Whereas ancient Indian and nineteenth-century atomists 'deduce' atoms from empirical observations, Democritus 'induces' the sense-impressions from the atoms. Democritus' atomism is truly logical-empiricism but in quite a different sense from modern science.

In the foregoing paragraphs I have tried to reconstruct the historical development of the ideas of the Greek Atomists. I hope that I have not given the impression that they regarded logic or reason to be in any way more important than sensation. In contrast to the Eleatics, the Atomists were sensible enough to acknowledge the fact that, deficient though our senses may be, nevertheless our knowledge of the external world is received almost entirely through their mediacy. For this reason they deeply concerned themselves with the mechanism of sensation. The starting point of their efforts was in all probability the Empedoclean theory of effluences, but Leucippus and especially Democritus greatly refined and enlarged the idea, and they assigned an atomic nature to the 'idols' or images and a mechanistic interpretation of their interaction with the sense organs. The theory of sensation that resulted from these efforts was the most detailed and highly developed of classical antiquity, and it carried with it an unmistakable implication that the basis of epistemology is physiology, an implication entirely unacceptable to idealists such as Plato.

Plato detested Democritus. Not once in any of the dialogues does he even mention the hateful name of the Atomist. Diogenes Laertius intimates that Plato was afraid to match his wits against those of 'the prince of philosophers'.[14] According to Aristoxenus, Plato collected the writings of Democritus with the intention of burning them and was deterred only when a disciple pointed out that the wide circulation enjoyed by Democritus' works made such a scheme futile.[15] In view of the vehement animosity that Plato felt towards those 'terrible men . . . [who] drag down everything from heaven and the invisible to earth . . . [and who] lay their hands on all such things . . .'[16] it is surprising and ironical to discover that when called upon to write a cosmological text of his own, the *Timaeus*, a book incidentally of enormous influence during the Middle Ages and Renaissance, Plato had recourse to atomism,[17] but the geometrical atomism of the Pythagoreans rather than the material atomism of Leucippus and Democritus. Almost a half of the text of the *Timaeus* is devoted to physiology; it is in fact one of the largest and most important physiological tracts that has survived from classical times. Pain and pleasure are explained in terms of particle depletion and replenishment (64A); then taste (65C), odour (66D), and finally sight (67C) are explained in terms of the primary qualities of particles and particle interaction with the organs of sense. In a remarkable passage (78A) Plato describes the movement of substances through the tissues and organs, especially in connexion with the digestive processes, in terms of the diffusion of particles of different size through membranes of selective permeability. The respiratory as well as the digestive functions depend on the circulation of corpuscles

(78E). Plato speaks of 'nutritive particles' (80E) and 'blood particles' (81B). Old age and death are attributed to changes in the structure of the primary particles (81D) and the subsequent dissolution of inter-particle bonding. Were we to base our opinion solely on the surviving Democritean fragments and the *Timaeus* of Plato we might hold that Plato, the arch-foe of Atomism, was more diligent than Democritus in applying the principles of corpuscular chemistry and physics to physiological theory.[18]

Aristotle characteristically responded to atomistic philosophy in a much more mature and objective manner than had his master. After paying his due respects to Democritus, whom he applauds for having 'thought carefully about all the problems',[19] Aristotle proceeds to reject the atoms and the void on observational grounds.[20] He is also discomforted by the failure of deterministic Atomism to leave room for the teleology so dear to his own heart.[21] Generally speaking, Aristotle tried to avoid the problem of the ultimate nature of matter by concentrating on the macroscopic rather than on the microscopic properties of substances. In a sense his point of view was thermodynamic rather than atomistic. As for the final divisibility of matter Aristotle is reticent and ambivalent. He attempted to distinguish between the actually and the potentially divisible. He rejects atomicity yet refuses to admit infinite divisibility.[22] With the theories of Anaxagoras probably in mind, Aristotle writes: 'It is clear that from the minimum quantity of flesh no body can be separated out; for the flesh left would be less than the minimum of flesh.'[23] The commentators subsequently took up this germ of an idea—the Aristotelean minima—and made much of it. Aristotle himself did not extend the idea beyond the confines of biology, but his successors extended the concept of the minima to include the inanimate world. Atomism in the guise of the Aristotelean minima reappears time and time again in medieval metaphysical and physiological theory, and the theory of minima, as we shall see, in due course of time served as a point of departure for more Democritean atomistic tendencies.[24]

The School of Democritus, we must confess, came to a sorry pass. This philosophical persuasion, which today we would call logical-empiricism, led to the most extreme form of scepticism. The master himself 'had shown very clear traces of a sceptical tendency',[25] and certain ambiguities in his theory of knowledge gave impetus to scepticism.[26] Nessas of Chios (fifth-fourth century B.C.) is said to have been a pupil of Democritus, Metrodorus of Chios (fourth century B.C.) was a pupil of Nessas (and perhaps of Democritus himself), and Anaxarchus of Abdera (*c.* 340 B.C.) was in turn a pupil of Metrodorus. The most radical form of scepticism, Pyrrhonism, takes its name from Pyrrho of Elis (*c.* 360–270 B.C.), a pupil of Anaxarchus.[27] But among all of the ideas of modern science, not excepting the notions of heliocentricity or of evolution, none has been more resilient than that of the atom. Time and time again this key scientific concept has sprung phoenix-like to life anew, even when its fortunes appeared to be most desperately ruined. Among the pupils of Metrodorus was another, Nausiphanes of Teos, who was to become the teacher of Epicurus.

Epicureanism became one of the principal philosophies of the Roman world. It was primarily an ethical system, nevertheless to lay claim to being a complete

philosophy it needed an explanatory basis for the physical world, and for this purpose Epicurus selected the Atomism of Democritus, albeit with an important reservation.* In his home and garden Epicurus formed an idealistic community of his family and disciples. The regulations which governed this group appear to have included a strict regimen which strongly emphasized a simple diet and the avoidance of over-indulgence. Although this moderation might be attributed to the legendary poor health of Epicurus and his three brothers,[28] it is difficult to imagine that the philosopher failed to provide a physiological theory, probably based on Atomism, as a rationale for his dietary rules.

Epicurus' ill-health did not prevent him from reaching the age of seventy-two. He apparently died of a kidney stone. As death approached he entered a lukewarm bath and asked for unmixed wine. Inasmuch as this request represented a departure from the rules and his habit we must suppose that the intent was sedation rather than indulgence.

A splendid presentation of Epicurean philosophy has survived—the great Latin poem *De rerum natura* by Lucretius (*c.* 96–55 B.C.). This poem is of particular interest to historians of science for it is one of the few extended scientific texts which has come down to us intact, and, although its fortunes have varied as the fortunes of physical science have fluctuated, it represents a more or less uninterrupted scientific tradition over a period of twenty centuries.[29] I wish to call attention to one biological idea in particular which is advanced in vivid terms by the poem, the notion of the continuous exchange of matter between an organism and its environment. This doctrine did not originate with Lucretius. Heraclitus of Ephesus (*c.* 500 B.C.) had taught that all things are in an eternal state of change, that even 'the sun is new each day'[30] and that 'it is not possible to step twice into the same river'.[31] Anaxagoras sought to explain this ceaseless flux in terms of the dominance of different kinds of 'seeds'; Democritus in terms of the shuffling and regrouping of atoms. But the poetic powers of Lucretius give this idea of change and the conservation of biological substance an emphasis far more striking than had the writings of any of his predecessors:

> [Naught]
> Perishes utterly, since Nature ever
> Upbuilds one thing from another, suffering naught
> To come to birth but through some other's death . . .
> Mixed with the funeral is the wildered wail
> Of infants coming to the shores of light.

Our corporeal being is not the same as that of our youth, and by the time we turn towards our graves the atoms of our substance will have been many times renewed. More than two thousand years after the ancient Greek Atomists advanced this daring hypothesis, their atomic theory was developed to the point where it provided the very technique necessary for the idea's experimental confirmation—the discovery of radioisotopes which can be used as 'tags' to follow in detail the travels of atoms during metabolic processes.

The topic of the relationship between ancient medical theory and practice

* The strict determinism of Democritean metaphysics left no room for volitional action and thus moral quality so Epicurus introduced a measure of indeterminacy by his celebrated 'swerve hypothesis' which allowed the possibility of certain eccentricities in the atomic motions.

and the prevailing religious beliefs is one ample enough to form the basis of many monographs. Suffice it here to generalize by saying that most ancient doctors either worked within the established religious framework or at least were careful to avoid a serious affront to popular religious convictions. Even the famed Hippocratic text on the 'sacred disease' (epilepsy), which Singer has described as 'perhaps the first book in which there is clear opposition between the claims of science and of religious tradition',[32] is a very guarded statement at pains to give the pious no cause to take offence.[33] On this point again Lucretius' poetic emphasis clarifies a philosophical difficulty which his predecessors preferred to let lie in shadow. He flatly denies the immortality of the soul. The implication is obvious—organisms including man, like all other objects, are composed of material atoms. Physiology, even psychology, therefore, may be scientific in the same sense as chemistry and physics. The body is a phenomenon which admits of physical explanation without recourse to theological notions. Hippocrates may have been the founder of scientific medicine as a practice, but it was Lucretius who provided the philosophical foundation of materialistic physiology.

The School of Democritus dissolved into scepticism. The revival of Atomism by the Epicureans did not fare much better. Even as Lucretius was composing his memorable verses the Atomism that he was expounding was declining in prestige and influence. This decline was a facet of the general deterioration of science in the Hellenistic world. The causes of the decay of Greek natural philosophy were many and complex and lie somewhat afield of our present interest. As for the causes of the decline of Atomism in particular, they are not hard to discover and are deserving of mention. In the first place Epicureanism was primarily an ethical system. It was in no sense based on an atomistic world-view. In order to round out his philosophy Epicurus needed a model of physical reality, and Atomism was adopted because it was not incompatible with his moral suppositions. When necessary for moralistic purposes Epicurus did not hesitate a moment before destroying one of Democritus' most essential fundamental precepts—determinism. Atomism was accidental to Epicureanism in the same sense that, because Marx happened to be an atheist, atheism has become an accident of modern communism. Inasmuch as Atomism was not an integral part of Epicureanism as Epicurean philosophy developed its Atomism was de-emphasized and allowed to wither away.

In addition to this internal decline of Atomism, Epicureanism was besieged from without. Another philosophy appeared to challenge Epicureanism's claims to the intellectual allegiance of the Roman world. That other philosophy was Stoicism. The equipage of Stoicism also included a theory of matter, but the Stoics returned, not to Democritus, but rather to the Eleatics for the bases of their natural philosophy. Prompted by the renowned paradoxes of Zeno of Elea they made continuity, not atomicity, the primal property of substance and the ultimate character of all natural processes.[34]

Stoicism proved to be the more accurate reflection of Roman temper and times and so gradually triumphed over the rival Epicureanism. But far more important than the immediate issue of that contest was the fact that the struggle sapped the vigour of both philosophies and rendered them incapable of

combating successfully a far more sinister adversary—Neoplatonism. Stoicism differed from Epicureanism with respect to its world-view; Neoplatonism was anti-scientific. It rejected the physical world, whether continuous or atomic, and substituted for science a fabric of cosmological myths. Not content with simply ignoring science, Neoplatonism characterized the physical world as evil and its study damnable. A fanatic Christianity embraced these perverse notions. Western civilization died and its scientific accomplishment perished with it. The word 'atomist' remained only as an insulting epithet.

This brings us to one of the most fascinating footnotes in the history of science and medicine. Long after it had fallen into disuse and even disrepute in other disciplines atomism continued to maintain a viability in theoretical medicine! In the first century B.C. Asclepiades of Bithynia abandoned the prevailing Hippocratic theory of humours and founded a 'methodic' school of medicine based on the atomism of Heraclides of Pontus (*c.* 388–310 B.C.). Disease, in his view, was a consequence of a disturbance of the normal motions of the body's constituent atoms.[35] The application of atomism to physiology enabled this school to formulate a highly consistent mechanistic view of medicine, and these doctrines appear to have enjoyed some popularity among physicians until the time of Galen (A.D. 130–200?).

But before I attempt to account for this isolated survival of atomistic theory, I should like to point out that prior to Asclepiades others had applied the basic ideas of atomism to medicine. The major Greek Atomists, as we have seen, invoked corpuscular theories to account for physiological phenomena, particularly in connexion with the mechanism of sensory perception. The Alexandrian physician, Erasistratus of Chios (b. *c.* 304 B.C.), a disciple of Strato, and Aegimius of Elis both incorporated atomistic notions into their medical theories.[36] An earlier medical authority, Diogenes of Apollonia (440–425 B.C.), was strongly influenced by the Milesian School but his atomism was more implicit than explicit. In the words of Tasch[37] he was a proponent of 'atomism without atoms'. But the atomistic ideas of Asclepiades exerted a greater influence than those of any of these men.

The public feels that it has a particular dependence on the ministrations of the medical profession and for this reason adopts permissive attitudes towards it. If I may be pardoned for citing two contemporary and controversial examples of public diffidence paid to physicians—no civilized society would tolerate the practice of vivisection save in the name of medical research, and both public and legal opinion is relatively tolerant of the reluctance of doctors to testify against their co-practitioners in malpractice suits. This same permissive attitude, I submit, enabled Atomism to persist in medical theory long after it had been extirpated elsewhere. As evidence to substantiate this view I point to the survival of atomistic theory in the esoteric philosophy of another profession immune from public censure—the clergy. Atomism enjoyed a reprieve in the sister sciences of hydraulics and pneumatics. Strato of Lampsacus, head of the Lyceum from 286 to 268 B.C., had formulated a detailed atomistic foundation for these disciplines,[38] and these ideas were subsequently incorporated into the *Pneumatica* of Hero of Alexandria (first century A.D.).[39] The works of Hero, which

were for the greater part textbooks on natural magic, were conscripted into the service of the religious cults which came to flourish as Hellenic civilization sickened and thus became the working manuals, as it were, of professional miracle-workers.[40] The priesthood, while publically damning Atomism, covertly accepted it as a theoretical basis for designing devices to awe the gullible.

The death of Atomism in the ancient world was a protracted affair. The doctor, to continue the simile, guilty of the act of euthanasia in this particular case was none less than the celebrated physician Galen (A.D. 130–200?). Sambursky writes that 'the conception of the world as a living body was present in all periods of Greek science. Any deviating tendency, such as the atomic theory, did not take firm root in the Science of the Ancient World'.[41] Galen affords an excellent illustration of this predilection. He rejected the 'absurd molecules' of Asclepiades and reverted back to Hippocratic vitalism. His organismic physiology routed Atomism from its last foothold in Western thought.

As an epilogue to this paper it is worth while to point out that, not only did medicine provide ancient Atomism's final stronghold, but also that many centuries later physicians were among the first heralds of the revival of Atomism.

From the third century A.D. to the fifteenth Atomism's role in Christendom was insignificant.[42] The paradoxes of Zeno and the minima of Aristotle sometimes brought a few of the more venturesome intellects to the verge of Atomism at which point they either retreated timidly or else, if venturing further, discreetly kept their ruminations to themselves. By the thirteenth century the more alert Churchmen had begun to realize that they had to acquaint themselves with the great philosophical works of pagan antiquity if they were to become intellectually competitive with contemporary Muslim and Jewish scholars. The Church foolishly hoped that it could open the door a crack to admit Aristotle and then quickly slam it in the face of Empedocles, Anaxagoras, Democritus and Epicurus. But the awakening of interest in antiquity proved too strong. The Renaissance tempted and emboldened the minds of men; the Reformation weakened ecclesiastic power thus enabling them to pursue their scholarly inclinations without fear of inescapable reprisal. Buried in the books of Aristotle they discovered allusions to the theories of Democritus; in the *Timaeus* of Plato, an especially popular and influential work, they found an account of the strange spacial atomism of the Pythagoreans; and a few with a taste for verse rediscovered the splendours of Lucretius' poem.[43]

In 1530 Girolamo Fracastoro of Verona (1478–1553) published a Latin poem entitled *Syphilis, sive Morbus gallicus* in which he suggested that infectious diseases are carried by minute bodies (*seminaria contagionum*) from person to person, an idea reminiscent of the 'seeds of disease' of Lucretius.[44] Inasmuch as Fracastoro in turn influenced Giordano Bruno (1548–1600)[45] we may say that he was one of the links connecting the Epicurean poet with the great Renaissance atomist and martyr of science.

In the seventeenth century atomists began to step forward to be counted. Men like Robert Burton (1566/7–1640) and Francis Bacon (1561–1626) bluntly declared their preference for Democritus over Aristotle.[46] Among the more

important of these early atomists was Daniel Sennert (1572–1637), professor of medicine at Wittenburg.[47] Sennert recognized the importance of chemistry in medical practice and the convenience of the atomic theory in accounting for chemical processes.[48] Sennert's atoms appear to be intermediate between those of Democritus and the Aristotelean minima. Significantly, he was surprised when others accused his ideas of being novelties. Zeller[49] writes that Sennert allied himself chiefly with Asclepiades.

The end of the seventeenth century, thanks to the efforts of Pierre Gassendi, found Atomism completely restored to its former rank as one of the key ideas of natural philosophy. And then, as if to repay the debt owed to medicine for sustaining it in its endangered years, corpuscular philosophy began to plant new ideas in the life sciences, ideas which, although sometimes at first ill-defined, were to prove enormously productive. Corpuscular philosophy was extended from inert matter to the animate; might not organisms be composed of minimal parts analogous to the atoms of matter? With the invention of the microscope a window was opened up on this remarkable world of the very minute. The cell theory of organisms was a direct parallel of the atomic theory of matter. Then too, if disease is transmitted by tiny seeds, perhaps heredity can be explained in terms of genetic atoms! Gassendi had published a theory of panspermatic preformation based on the atomic hypothesis.[50] Buffon, Béchamp and Maupertuis advanced theories of vital particles, comparable to atoms, responsible for the transmission of inherited traits. Much later we find Erasmus Darwin subscribing to a similar view, and his famous grandson, Charles, in his theory of pangenesis postulated atom-like 'gemmules'.

> The remarkable success of the atomic theory in leading to a scientific understanding of the phenomena of physics and chemistry has led to many analogous modes of explanation in the biological sciences.[51]

## *REFERENCES*


1. FARRINGTON, B., *Greek Science*, Harmondsworth, Penguin Books, 1944, vol. 1, ch. V.
2. PLATO, *Timaeus*, 53Cff.
3. ARISTOTLE, *Topica*, 105b17; *De Caelo*, 302a29; *De Generatione et corruptione*, 314a16, 329a4, 330a16; *Metaphysica*, 984a8, 985b1, 988a27.
4. —— *De generatione et corruptione*, 314a16; *Metaphysica*, 984a11; *Physica*, 187a27, 189a17, 203a20.
5. It is interesting to notice that the atomic ideas formulated by young children tend to resemble more closely the seed hypothesis of Anaxagoras rather than the atomism of Democritus. *Vide* HORNE, R. A., Atomistic notions in young children and young cultures, *J. Chem. Educ.*, 1958, **35**, 560.
6. Similar views were held by the Upanisad philosopher Uddalaka. Curds do not become butter; butter particles were previously present in the curds. *Vide* RADHAKRISHNAN, S., *Indian Philosophy*, London, Allen & Unwin, 1929, vol. 1, p. 201. For further comparisons of Greek and Indian atomism, *vide* HORNE, R. A., Atomism in Ancient Greece and India, *Ambix.*, 1960, **8**, 98.

7. In his defence let me hasten to say that Anaxagoras was certainly no ignoramus in biology. He located the gall bladder as a trouble spot for disease (ARISTOTLE, *De partibus animalium*, 677a6), he suspected the respiration of plants (ARISTOTLE, *Opuscula*, 816b26), and he had some bold insights concerning sex differentiation (ARISTOTLE, *De generatione animalium*, 763b31).
8. But not in Athens. Democritus visited Athens but soon left discouraged: 'I came to Athens and no one knew me' (Frag. 68.116 in FREEMAN, K., *Ancilla to the the Pre-Socratic Philosophers*, Oxford, Blackwell, 1948). Later, however, even Aristotle admired his knowledge (*De generatione et corruptione*, 315a35).
9. There is a tradition that the physiologist Erasistratus of Chios (*c.* 280 B.C.), a follower of Democritus, dissected living men. *Vide* SARTON, G., *A History of Science*, Cambridge, Massachusetts, Harvard University Press, 1959, vol. II, pp. 132–4.
10. BAILEY, C., *The Greek Atomists and Epicurus*, Oxford, Clarendon Press, 1928, p. 151.
11. HORNE, R. A., Atomism in Ancient Greece and India, *Ambix*, 1960, **8**, 98.
12. HEIDEL, W. A., Antecedents of Greek corpuscular theories, *Harvard Stud. Class. Philology*, 1911, **22**, 111.
13. PLATO, *Phaedo*, 98B-C.
14. DIOGENES LAERTIUS, *Lives*, IX, 40.
15. —— *Ibid.*
16. PLATO, *Sophist*, 246A.
17. —— *Timaeus*, 53C *et seq.*
18. Plato may have unintentionally exerted a profound influence on the history of anatomy. Singer (SINGER, C., *A Short History of Scientific Ideas*, London and New York, Oxford University Press, 1959, p. 67) suggests that the depreciation of the corporeal body in the *Phaedo* may have been instrumental in removing the long-standing abhorrence of dissection.
19. ARISTOTLE, *De Generatione et corruptione metaphysica*, 315a35.
20. —— *Physica*, 214a28; *De caelo*, 305b17; *De Generatione et corruptione*, 328a27.
21. —— *De caelo*, 300a20; *Metaphysica*, 1071b32.
22. —— *De caelo*, 303a3; *De Generatione et corruptione*, 328a6; *Physica*, 187b6.
23. —— *Physica*, 187b6.
24. The role of the Aristotelean minima in the history of atomism is emphasized in VAN MELSEN, A. G., *From Atomos to Atom*, Pittsburgh, Pa., Duquesne University Press, 1952.
25. BAILEY, C., *op. cit.*, p. 218.
26. SEXTUS EMPIRICUS, *Adversus Dogmaticos*, vol. I, p. 135 *et seq.* (vol. II, pp. 74–5 in Loeb ed.); HORNE, R. A., *Criteria of Truth in Pre-Socratic Philosophy*, Thesis, Boston University, 1953, ch. VIII.
27. DIOGENES LAERTIUS, *Lives*, vol. IX, p. 61; see also PATRICK, M. M., *The Greek Sceptics*, New York, Columbia University Press, 1929, ch. IV–VI.
28. —— *Lives*, vol. X, p. 7.
29. HADZSITS, G. D., *Lucretius and His Influence*, New York, Longmans, Green & Co., 1935.
30. FREEMAN, K., *op. cit.*, Frag. 22.6.
31. —— *op. cit.*, Frag. 22.91.
32. SINGER, C., *A Short History of Scientific Ideas*, London and New York, Oxford University Press, 1959, p.34.
33. BOWRA, C. M., *The Greek Experience*, New York, Mentor Books, 1959, p. 193.

34. For an excellent exposition of the conflict between the Atoms of the Epicureans and the Continuum of the Stoics, see SAMBURSKY, S., *The Physical World of the Greeks*, New York, Macmillan Co., 1956, especially chaps. V and VI.
35. GREEN, R. M., *Aesclepiades*, New Haven, E. Licht, 1955, especially pp. 73–6; LASSWITZ, K., *Geschichte der Atomistik vom Mittelalter bis Newton*, Hamburg, L. Voss, 1890, pp. 212–14, 425 *et seq.*
36. FARRINGTON, B., *Greek Science*, Harmondsworth, Penguin Books Ltd., 1949, vol. II, pp. 36–7, 66–8; SARTON, G., *Introduction to the History of Science*, Baltimore, Williams & Wilkins, 1927–48, vol. I, p. 215.
37. TASCH, P., Diogenes of Apollonia and Democritus, *Isis*, 1949, **40**, 10.
38. FARRINGTON, B., *op cit.*, vol. II, pp. 27–43; RODIER, C., *La physique de Straton de Lampsaque*, Paris, F. Alcan, 1890; ZELLER, E., *Aristotle and the Earlier Peripatics*, London, Longmans, Green & Co., 1897, vol. II, pp. 450–72.
39. BOAS, M., Hero's Pneumatica, *Isis*, 1949, **40**, 38; BRUNET, P. and MIELI, A., *Histoire des Sciences: Antiquité*, Paris, Payot, 1935, pp. 321 ff; FARRINGTON, B., *op. cit.*, vol. II, pp. 31–5.
40. FARRINGTON, B., *op. cit.*, vol. II, pp. 58–60.
41. SAMBURSKY, S., *op. cit.*, p. 40.
42. Atomic philosophy fared better in Islam where it was adopted and curiously modified by the theologians of the Mutakallimun, *vide* MACDONALD, D. B., Continuous creation and atomic times in Muslim scholastic philosophy, *Isis*, 1927, **9**, 326.
43. HADZITS, G. D., *op. cit.*, pp. 250 ff.
44. —— *op. cit.*, p. 336 n.
45. SINGER, D. W., *Giordano Bruno*, New York, Henry Schuman, 1950, p. 71.
46. *Vide* STONES, G. B., The atomistic view of matter in the XV, XVI and XVIIth centuries, *Isis*, 1928, **10**, 444.
47. VAN MELSON, A. G., *op. cit.*, pp. 81 ff.
48. CROMBIE, A. C., *Augustine to Galileo*, Cambridge, Massachusetts, Harvard University Press, 1953, pp. 359–60.
49. ZELLER, E., *A History of Eclecticism in Greek Philosophy*, London, Longmans, Green & Co., 1883, p. 31, n. 3.
50. CROMBIE, A. C., *op. cit.*, p. 385.
51. HOLMES, S. J., Micromerism in biological theory, *Isis*, 1948, **39**, 145; see also GILLISPIE, C. C., Lamarck and Darwin in the history of science, *American Scientist*, 1958, **46**, 388, 408; and ROSTAND, J., Esquisse d'une histoire de l'atomisme en biologie, *Rev. hist. Sci.*, 1949, **2**, 241; 1950, **3**, 156; 1951, **4**, 41; 1952, **5**, 155.