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ΙΣΤΟΡΙΑ ΤΗΣ ΕΠΙΣΤΗΜΗΣ. — **The World of the Atom,** by *Pericles S. Theocaris**, Fellow of the Academy of Athens.

Science in Ancient Greece during all its stages of development, shows the constantly recurring attempt to resolve the antithesis between the unity of the cosmos and the plurality of its phenomena. The question raised if this antithesis is a real one, or is it perhaps only an illusion resulting from the imperfection of our senses. Then, is this plurality of phenomena only apparent, and the cosmos in fact is a single unchanging unit, admitting of no movement; or is it this unity that is imaginary, and reality is in fact no more than the sum total of unending mutations and changes?

The answers given to these questions by the early Greek philosophers range from one extreme to the other. **Thales** and his followers held a monistic view, deriving everything from primeval matter, with **Parmenides of Elea** going so far in this monism, as to rule out any change of all possibility of movement. At the other extreme, **Empedocles** introduces a pluralistic conception in his theory of the four elements. On the other hand, **Anaxagoras** carried out pluralism to its logical conclusion in his conjecture that, while matter is continuous, it actually consists of minute quantities of all the various differentiations of which it is capable. Then, he maintains that the plurality of cosmic phenomena results from the plurality of quantities defining every single particle of matter. Of all the answers, that given by the Greek atomists, Anaxago-

* Π. Σ. ΘΕΟΧΑΡΗ, **Ἡ γένεσις τῆς Ἀτομικῆς καὶ Μοριακῆς Θεωρίας τῆς ὕλης κατὰ τὴν ἀρχαιότητα.**

ras' theory, being a synthesis of monistic and pluralistic elements, is the most convincing both in its simplicity and in its comprehensiveness. It showed that the plurality and flux of the macrocosm can be explained by a certain uniformity and by causal laws governing the world, not accessible to our senses.

The whole subject of the ancient atomic hypothesis is particularly instructive for the scientist in the age of the modern atomic theory. The atomic structure of matter has actually been proved by experiment and is accepted as a firmly established and an unquestionable fact. The history of the past one hundred and fifty years shows how this certainty emerged slowly from general conjectures, the reality of which was regarded with scepticism by many scientists, and from a long series of interrelated experiments and deductions, which eventually grew into a uniform and complete theory.

In the light of this modern development, it is of interest to enquire how far the Greeks succeeded at a time when any systematic experimentation was virtually unknown, when the methods employed in that time consisted mainly of observation and speculative conjecture, and when the scientific principles and inferences in use were only a few in number and of the most general nature. There is no question here of comparing the two theories in terms of absolute scientific achievement: such a comparison would obviously be both pointless and unfair. Instead, the main purpose of this comparison is rather to estimate the validity of a method as shown in its internal logic and the extent to which it succeeded in developing to the full its basic premisses at a time when scientific evidence was in the main qualitative. Since it is well known, that the Ancient Greeks hardly knew of experimentation and mathematical deduction as a means of applying scientific intuition to reality: for them analogy and the scientific model were the only connecting-links between the invisible and the visible.

The history of the ancient atomic theory extends over four hundred years and is connected with four famous names. Its author was **Leucippus of Miletus,** who lived in the middle of the fifth century B.C. His pupil was **Democritus of Abdera,** one of the most universal thinkers of the Ancient World. The theory was turned into a philosophical system by **Epicurus of Samos,** who lived at 341-270 B.C., and who made it generally known. Finally, we must mention the Roman poet **T. Lucretius Carus,** whose didactic poem «**De Rerum Natura**» is a paean of praise in honour of the Epicurean philosophy. This poem is also the most detailed source of our knowledge about the atomic theory of Epicurus, apart from Epicurus' letter to his pupil Herodotus. Of the numerous writings of Democritus, only a few fragments are extant, and still less of Leucippus; but quite a number of their sayings are quoted by Aristotle and Theophrastus in the course of their strong polemic against the atomic theory. These quotations, together with some from Plutarch and the doxographic literature, complete our picture of the theory evolved by the founders of the atomic school. Some details, in which Leucippus, Democritus and Epicurus differ from each other, merit a special attention, as indications of the theoretical development within each particular scientific doctrine. But, in general, it may be said that the principles of the atomic theory are the same for all its proponents.

All these thinkers frequently emphasize the view that, there is in nature a general conformity to law, and in particular that there exists a law, which may be called **«the law of the conservation of matter»**. Leucippus is quoted as saying that **«nothing happens at random; everything happens out of reason and by necessity»** [1] and the atomic doctrine of Democritus contains the sentence: **«Nothing can be created out of nothing, nor can it be destroyed and returned to nothing»** [2].

This emphasis on the conservation of what exists is important for the proof of the existence of the atoms, as opposed to the theory that matter is infinitely divisible. It is plausible that Leucippus was acquainted with the Eleatic School, which included Zeno of Elea, whose famous paradoxes taxed the ingenuity of the best Greek philosophers [3]. Some of these paradoxes are based on the principle of *dichotomy or halving*. The argument runs that there is no end to the division of a section into parts, since there is no limit to any form of mathematical division, including halving. Thus, the number of points between two given points is infinite. It is very probable that one of Leucippus' reasons for trying to find a solution to the problem of permanency in plurality was the paradoxe of division. This led him to the conclusion that physical division is not the same as mathematical division: **«The atomists hold that splitting stops when it reaches indivisible particles and does not go on infinitely»** [4]. This assumption of a lower limit to the division of matter is an axiom, which may be proved by arguments of plausibility. Indeed, if matter can be infinitely divided, it is also subject to complete disintegration, from which it can never be put together again, then, if we wish to maintain the law of conservation of matter and to consider the process of its disintegration and reintegration as a reversible one, we must assume that the disintegration or fragmentation stops at a definite and finite limit. Only so does there remain a permanent primary foundation for a new building up from the ultimate particles without any loss in the quantity of matter.

As a corollary to this insintence on the existence of the atoms, Epicurus also insists on an upper limit to their size: **they are always invisible, and a visible atom is inconceivable**. Though no specific reason is given for this assumption, its empirical basis is obvious enough: bodies, that can be seen, are still divisible and therefor cannot be atoms. In contrast to Democritus, who did not postulate a maximum size for the atom, Epicurus apparently evolved the theory that the perceptible and imperceptible are two essentially different categories of existence. The atomic theory was completed by a second axiom, the postulation of a «**vacuum**». The vacuum was introduced with rigorous consistency into the picture of the cosmos as an independent reality. Once again, this assumption is based on plausibility: given that matter is composed of atoms, of ultimate unchanging particles, then all changes must be the result of their movements, and the prerequisite of movement is a vacuum, that is a space entirely devoid of matter in which a particle can pass from place to place. On this view it necessarily follows that there is no possibility of a vacuum inside the atom itself, since in such a case the atom would be subject to changes and to physical influence from outside and would thus be likely to disintegrate. Hence the postulation of a vacuum as a prerequisite for the movements of the atoms inescapably leads to the postulation of the absolute solidity of the atom itself. Matter and the vacuum are entirely separate from each other.

All the atomists, from Leucippus to Epicurus and his disciples, are agreed that both the number of atoms and the extension of the cosmos are infinite. The infinity of the cosmos in time, that is its eternity, was deduced by Democritus from the conservation of matter, which rules out a **creatio ex nihilo**. On the other hand, infinity of space, and of the amount of matter in it, are clearly interrelated. It would appear from this that the essential point in both premisses is the assumption that space is infinite [5]. The infinity of the universe however, is proved by a geometrical argument of the very kind that was rejected by the atomists in relation to the division of matter. In this case the geometrical argument may be regarded as valid, since the problem here concerns spatial qualities. Until the discovery in modern times of non-Euclidean spaces and their properties, it was reasonable to reject the conception of finite space, on grounds such as those advanced by Epicurus. It is likewise worth mentioning that Epicurus' argument to prove the impossibility of a concentration of a finite amount of matter within infinite space has also been used in the modern cosmological controversy.

The universe of the atomic school thus consisted of a vacuum of infinite size filled with «solid particles», atoms, of infinite number. It was accepted that these atoms differ from each other, not in the matter which fills them, for this would contradict the monistic basis of the atomic theory. Indeed, the primeval matter of which the atoms are made is uniform, but there are various kinds of atoms distinguished by their shapes: «*The atoms are differentiated by their shapes: the nature of them all is, they say, the same, just as if, e.g. each one separately were a piece of gold*» [6]. We are also told that «*Democritus and Leucippus say that there are indivisible bodies, infinite both in number and in the varieties of their shapes, of which everything else is composed — the compounds differing one from another according to the shapes, positions, and groupings of their constituents*» [7]. The physical, concrete qualities of macroscopic bodies are therefore determined by the particular kind, or combination of kinds, of their component atoms, and also by various principles controlling the dispositions of the atoms in the space occupied by the body, defined as «**positions**» and «**groupings**».

The shape of the atom corresponds to the chemical element of the modern atomic theory. It is the shape which differentiates the atoms, in the same sense as the atomic number does to-day, determining their chemical properties. Since the ancient atomic theory was built upon purely mechanical conceptions, it is not surprising that the distinguishing marks of the atoms were mechanical or geometrical.

Then, Leucippus and Democritus maintained that the number of shapes was infinite, whereas Epicurus held it to be finite. This difference follows naturally from a variance in the assumptions about the size of the atoms. To every given size, it is possible to assign only a finite number of distinctly different shapes, and once all the possible mutations have been exhausted, a fresh shape can only come into being, through an increase in the volume of the atom. Hence the first atomists, who set no upper limit to the size of the atoms, did not restrict the number of their shapes either. But Epicurus was further obliged, by his proviso that the size of the atom must be invisible, to reduce the shapes to a finite number. Lucretius, who repeats this argument about the finitude of the different shapes of the atom, gives an extremely vivid illustration of how the increasing number of shapes is linked with the increasing size of the atoms.

Leucippus apparently distinguished only the size and shape of the atoms. In Democritus, on the other hand, there is mention of weight, not however as an independent quality, but as a function of the volume of the atom [8]. In this point there is a fundamental change in Epicurus' doctrine: «*Democritus recognized only two basic properties of the atom: size and shape. But Epicurus added weight as a third. For, according to him, the bodies move by necessity through the force of weight*» [9]. The last sentence shows that Epicurus found it necessary to introduce weight, as the cause of the movement of the atoms. Democritus, on the contrary, denied that movement was due to weight, as is clear from the following passage: «*Democritus said that the atoms have no weight, but they move by mutual impact in infinite space*» [10]. The words «**have no weight**» are to be interpreted as meaning that weight is not the cause of movement, as it is explained later-on by Cicero.

The picture drawn by Democritus reminds the modern scientists of the atoms of the ideal gas in the modern kinetic theory of gases, which are kept in perpetual motion, characterized by constant collisions. Throughout the literature of the atomic school, great stress is laid on the perpetual movement of the atoms. Aristotle severely criticizes the absence of a cause of the movements of the atoms in the doctrine of Leucippus and Democritus in his books of: «**On the Heavens**» as well as in «**Metaphysics**».

It was a sound scientific instinct, that saved the founders of the atomic school from this mesh of reasoning in which Aristotle got himself entangled. They did not begin by raising the problem of the cause of movement, but accepted movement as a given fact, just as they did in the case of the atoms. It is not wise to raise all the questions involved in a scientific problem simultaneously. On the contrary, a developed scientific sense is required to limit the range of questions at the start and to consider only some of the phenomena as derivatives of others, while regarding the rest as ultimate data. Even without knowing *the law of the conservation of momentum, or of the quality of movement*, Leucippus and Democritus hit the mark when they assigned to every atom a predetermined movement and described the sum total of atomic movements by the elementary mechanical model of elastic collision. In this way they succeeded in grasping the first principles of the kinetic law of matter entirely without the aid of mathematics and with only the most primitive statistical concepts.

Thus, in the opinion of the atomists, not all the atoms form part of compound bodies, but there are always some left moving freely. Lucretius, in the second book of his poem, describes this phenomenon in great detail, emphasizing that atoms sometimes escape from the compound bodies and resume their free movement in the void. For the atoms, which interlock to form compound bodies, the atomists consistently maintained that they too continue in a perpetual motion. Each of them continues to move in the narrow space bounded by its neighbours, being subject to very frequent collisions, which are like swift vibrations in its narrow enclosure. This means that the interlocking of the atoms does not turn them into a single physical unit: even after combining, each one maintains its individual character, as shown in its movements, which in these circumstances take the form of vibrations.

However, the ancients had no conception of statistics, for determining the laws of phenomena, where very large numbers on individuals, or very large numbers of repetitions of a given occurrence, are involved. We do not find amongst them anything resembling the «*law of large numbers*», or the «*law of averages*», or the like, even though the games of chance, which were so common in the Ancient World, provided plently of opportunities for their study. The one exception to this rule occurs, as might be expected, in the atomic theory, which deals with an enormous number of individuals.On this point we possess two famous descriptions of parts of Epicurus' doctrine, both of them in the second book of: **De Rerum Natura**. In the first, Lucretius discusses the case of many particles moving in all directions within given boundaries. If this is so, the sum total of these particles will be at rest as a single entity in the given space; or, in other words, the total of all the velocities will be zero.

The second description concerns a much more complex phenomenon, one which was discovered by the microscope in the first half of the nineteenth century, but was not fully explained and reduced to mathematical terms until the beginning of the twentieth century. *This is the Brownian movement.* When we look at microscopic particles suspended in a liquid or a gas, we see how they move in a perfectly disorderly fashion, wandering this way and that, without rule and without purpose. This indirectly shows the activity of the atoms in the liquid or the gas, which cannot be seen even in a microscope. It is true that in the average, taken over a longer period of time, the total of all the impacts of the atoms on the microscopic particles is cancelled out. But the statistical deviations from the average, occurring at every moment, result in the particle's being incessantly given impulses this way and that, with constant changes of direction, and it is a random impulse which gives rise to the ceaseless oscillations of the particles.

This is the phenomenon that we find described and concretely illustrated in a passage from Lucretius, which is remarkable for its clarity and the way in which it picks out the main points. To this remarkable description given by Lucretius [11], we need only add the comment, that it perfectly describes and explains the Brownian movement by a wrong example. The movements of dust particles, as seen by the naked eye in sunlight, are caused by air-currents, and it does not correspond to a Brownian motion. The real phenomenon postulated by Lucretius on the basis of abstract reasoning can only be seen in a microscope.

However, this stricture in no way detracts from the importance of the discovery itself. It may be said that the greatest achievement of the atomic school in Ancient Greece was the introduction into scientific reasoning of the **method of inference**, as demostrated by Lucretius [12]. To appreciate the arguments by Lucretius [12], we must remember how important a function in the explanation of a phenomenon, or the interpretation of an experiment, is fulfilled by this kind of scientific reasoning, even in our days of experimental science and mathematical formulation. This essential element of the scientific method reached a peak of development in the Greek period. In this, the atomic school undoubtedly played a decisive part, though examples could be adduced from other schools as well.

We have seen that the basic premisses, from which Leucippus and Democritus started, were the existence of a vacuum and of atoms differentiated by shape, position and arrangement. It is now natural to enquire to what extent these thinkers tried to infer all the consequences of these premisses and to build upon them a physical of chemical theory of matter, as a rational explanation of physical phenomena. It should be mentioned that their approach to all natural problems, including both biological and psychological phenomena, was rigorously mechanistic. The saw everything as due to the movements of matter and to the contacts between its parts, starting from the creation of the universe and ending with man's senses and soul. There was no question of introducing any other motive force, as the cause of physical processes. Such forces, being «irrational», must eventually break up the mechanistic picture of the universe, by becoming firmly entrenched in it, under the guise of «spiritual» causes, like the **Mind** of Anaxagoras; or they may even lead to the confusion of entirely different categories of existence, by turning the Gods into the supreme cause. Thus, by comprehensively ruling out the existence of forces, Democritus and his followers left themselves with only one cause for the explanation of all physical change, that is **impact**, or the collision of atoms or aggregates of atoms.

The application of this principle to epistemology led the founders of the atomic school to take up the same position as Locke and the English Empiricists in the eighteenth century. The objective basis of sensation is simply and solely contact, either direct contact between the person perceiving and the object perceived, as in touching, or tasting, or contact between the person and the atoms emitted from the object and entering his nose, ear or eye. Thus, Democritus, like Locke, distinguishes the «secondary qualities» or bodies —colour, smell, taste, sound— which are the subjective product of our senses and can be explained by the mechanical attributes of the atoms, from their «primary qualities», such as impenetrability, hardness, etc., which are the objective expressions of the «true» attributes of matter.

Since the writings of Democritus are not extant, we have to rely on the references of other writers for our knowledge of his theory of matter. All in all, these writings amount to a feeble enough echo, which is particularly difficult to interpret just on the details of most interest to us. That many passages became obscure in the course of transmission is made probable by various contradictions and by the fragmentary and unintelligible condition of several texts. A considerable part of the whole theory has been preserved in the writings of **Theophrastus**, particularly in his book "*On Perception and Things Perceived*". But here, too, the detail and clarity of the exposition are very uneven. Still, there can be no question that Democritus tried to explain both the primary and secondary qualities, i.e. all the macroscopic properties of things, by the attributes inhering in the primary elements of nature.

Difficulties in explaining various properties in the theory of atomists like the weight, the hardness of the bodies, their brittleness arose between the atomists. It was Epicurus first who restored that position and arrangement of atoms in their place is of equal importance for explaining the properties of the bodies, thus taking the first step from the atomic theory to a molecular theory.

However, according to Epicurus, the molecule has another distinguishing mark, namely the co-ordination of the movements of atoms composing it — the movements which these atoms «mutually pass on and take over» [13]. We have already seen that the perpetuity of motion was one of the basic premisses of the atomic school, being applied even to the «compound bodies» [14], in which the atoms are so close together that the motion inside them takes the form of a vibration, resulting from the rapidly repeated collisions and recoils. The simplest compound body of all is the molecule, called by Lucretius «**concilium**», which means union or association and is close to our modern concept of a chemical compound. The compound is a unit of a higher order that the atom, and its structure is closely associated with the nature of the motion of its components.

Coordination of the movements of the atoms in the molecule, harmony between their various vibrations, governed by a principle regulating their mutual movements — these are the physical factors which characterise the association of atoms, the concilium, and make it a single entity. Once again we are amazed at the imaginative power and scientific intuition displayed in the emphasis laid here on one of the characteristics of the molecule — namely, the sum total of its possible vibrations and their combinations, which Epicurus of course regards simply as a function of position and arrangement and not of forces. It may be that this model of the molecule was to some extent the result of observation. The ancients were aware that the mechanical movement of a body consisting of many parts held loosely together by chains or ropes, depends on the form of these connections and that there is in such cases a kind of «communal motion» of all the parts in which the rhythm of each one is conditioned by the rhythm of the whole. The logical way of passing from this model to the picture of the molecule would have been to put forces in place of ropes, as the cause of molecular vibrations. Only the Greek atomists. being opposed to the assumption of forces, regarded the coordinated motion within the association of atoms, as the result of their mutual arrangement and the nature of their internal recoils, which, in their turn, were determined by the shapes of the individual atoms.

Since Epicurus considered the secondary qualities as originating mainly in the molecules, it is not difficult to uderstand his assumption that any change in the molecule, resulting from a change in the arrangement of its atoms, produces a change of colour, or of taste and smell.

It is clear why, on the basis of his mechanistic theory, he should ascribe mechanical causes to such changes of the molecules, causes such as moving or shaking which put an end to one kind of atomic association and bring others into existence. At the same time, Epicurus assumed that the molecules were structurally strong enough, to continue existing as units, even in isolation, when they escape from bodies and pass from place to place. According to Epicurus, the speed, at which these images travel, is very great and they arouse sensations in us whenever they strike our bodies. There is no need to discuss the details of Epicurus' theory of sensation, with its very primitive mechanistic approach. But, it is of interest to note the repeated emphatic assertion, that the structure, which the molecule has within the body, representing on a small scale all its properties, is preserved also after its emission.

Undoubtedly, it was Epicurus, who actually evolved the molecular theory and tried to define the physical characteristics of molecules. To say this is in no way to detract from the achievement of Leucippus and Democritus, who were the first to conceive the molecular idea, when they stressed the influence of the position and arrangement of the atoms. Indeed, it would appear to be Democritus, who was the author of an analogy, which was intended to exemplify the nature of the molecule and which is very characteristic of the synthetic approach of the Greeks. The analogy is mentioned by Aristotle in his *Metaphysics* [15].

In this passage of Aristotle [15], the use of an analogy from language to explain a physical theory is in itself most instructive. The common point is, in this case, the construction of more complex units, from units which cannot be broken down any further. This is also reflected in the Greek term «**stoicheion**», which is used both as a collective noun for «letter» and as one of the many Greek equivalents of «atom» and in a still more general sense of the ultimate elements of physical reality.

Democritus' picture is the aptest of all. Just as a word is more than the algebraic sum of its component letters, so the particular association of atoms in a molecule is something different from the geometrical combination of elements. An entity is formed, which, by force of its specific constitution, receives a specific quality, which we perceive as colour, taste or smell. Any shifting of one of the constituting units from one place to another, any alteration in a single one of the elements, produces a complete change in the characteristic quality of the whole.

To sum up, then, it would seem that the development of the atomic theory, from Leucippus and Democritus to Epicurus and his school, is more a matter of progress in the clarification of details than of advance in scientific ideas or principles. An exception is the concept of the molecule, the association of atoms: here Epicurus made a striking original contribution to scientific knowledge. But, with this one exception, it may be said that the later writings in this field were merely explanations and commentaries of what had been discovered by the originators of the theory. The greatest achievement of the atomists was to develop a new kind of scientific reasoning, based on evidence by analogy and inference of the invisible from the visible, by means of parallels and models as illustrations. We have seen that this achievement was no mere chance, but a logical consequence of the main principles of the theory, which set physical reality upon an infra-sensory basis.

A typical difference in conception between Democritus and Epicurus theories, which again reveals Democritus as being more cautious and critical, concerns their respective opinions about the nature of knowledge. **Galen,** in one of his writings, repeats the famous statement of Democritus with a very characteristic addition: «*After Democritus had attacked sensation by saying that colour exists by convention, sweet by convention, bitter by convention, atoms and void exist in reality, he lets the senses say the following words against the mind: "Miserable mind, you get your evidence from us and do you try to overthrow us? The overthrow will be your downfall*» [16]. Democritus was extremely doubtful about the value of the senses as tools of knowledge. Notwithstanding that his view of the world was absolutely rational, he realized that the mind has no choice, but to use that most imperfect and unreliable of instruments, the senses.

In Epicurus we find the opposite opinion. The philosophic scepticism of Democritus is replaced by a naive realism and an unquestioning faith in the senses. To Epicurus' mind, any questioning of a single one of the senses is likely to remove the solid ground from beneath our feet: «*If you fight against all sensations, you will have no standard by which to judge even those of them which you say are false*» [17]. It is not the senses that represent a danger to our knowledge, but the deductions made by the mind from our sensation.

In view of the gulf, which separates this opinion from the careful and balanced position taken up by Democritus, it is no wonder that, in the perspective of history, the later commentators linked together Democritus and Plato, one of them even comparing the «ideas» of the latter to the Atoms of the former: «*The schools of Plato and of Democritus say that there is no reality except that comprehended by the mind. Democritus says so, because in his opinion the fundamentals of nature are not perceptible to the senses, seeing that the atoms of which everything is composed are by their nature devoid of all sensory attributes; while Plato says so, since to his mind things perceptible to the senses are in a constant process of being created and are not permanent*» [18]. A few extant fragments of Democritus' writings confirm his critical stand, which was a logical outcome of his rationalism and a pessimistic view of the power of human knowledge: «*We know nothing about anything really, but Opinion is for all individuals an inflowing*» [19]. «*It will be obvious that it is impossible to understand how in reality each thing is*» [20]. «*We know nothing accurately in reality, but as it changes according to the bodily conditions, and the constitution of those things that flow upon the body and impinge upon it*» [21]. «*One must learn by this rule that Man is severed from reality*» [22]. The pessimism expressed here by one of the founders of the atomic theory reaches its climax in the following sentence: «*We know nothing in reality; for truth lies in an abyss*» [23].

The contemporary scientist is forcibly struck by the historical affinity between the science of Ancient Greeks and the modern science. Modern science goes back to the 17th century and its origin is usually associated with the names of Galileo and Newton. Despite its many transformations during the last 400 years and which in all propability will continue in the future, the character of modern science can be accurately and unambiguously defined as follows:

In **method** it is an interaction of the reciprocal processes of induction and deduction, while in purpose, it is an interplay of the comprehension and conquest of nature. This second characteristic synthesis of modern science finds expression in the interdependence of pure and applied science. However, Ancient Greeks throughout a period of 800 years made no recorded attempt at systematic experimentation. Then, induction for them was limited to the systematic observation and collection of such experimental material, as was offered by the study of natural phenomena. Nor was the deduction of the Grekes any better, since it lacked in general the mathematization of the fundamental concepts and the deduction of facts from laws expressed in terms of mathematical formulas.

However, a general overview of the achievements of the ancient world allows us to accept that the foundation of modern science is accomplished by the Greeks, since some basic principles of the scientific approach, which are still as valid as ever today, were discovered in Ancient Greece.

The independence of Greek science was brought about by the struggle of **logos** against **mythos**, something similar in many respects to the birth of modern science from the assault on petrified medieval scholasticism. The dawn of systematic scientific reasoning occurred at the beginning of the 6th century at Miletus, on the west coast of Asia Minor, by the Prosocratic philosophers. These scientists promulgated a series of principles:

i) The maximum of the phenomena should be explained by a minimum of hypotheses.

ii) The introduction of the law of the conservation of matter.

iii) A modification of the law of conservation of matter into the law of conservation of energy. This principle may result from the acceptance that nature is capable of a rational explanation, which reduces the number of variables and replaces some of them by constant quantities, independent of time, or the particular form of a given process.

iv) The first and basic matter is one and unlimited.

v) Motion is a basic fact, which does not need explanation. Then, it is motion which brings about the realization of the principle that quality can be reduced to quantity. With this principle, the Milesian school reached the summit of its achievements, since this brief sentence expresses the very essence of science from the time of Anaximenes to the present day.

Besides these basic principles, the Milesian school introduced successfully the notion of models and analogies and made extensive use of considerations of symmetry. They have established the distinction between matter and force. The force was defined as attraction and repulsion and their dynamic equilibrium conceived the existence of cosmos.

The whole process of evolution of science in Ancient Greece covers a long period of almost ten centuries. Indeed, the Greek civilization generated science, as we understand today, without, however, giving concrete elements of inter-connection of the scientific progress and achievements with technology.

The picture unfolded in the description of achievements of atomists in antiquity is a characteristic episode during the birth and death of a living organism. Indeed, we witness a period of germination in the sixth and fifth centuries, with the appearance of the Milesian School, the work of Pythagoras and his first pupils, and the teachings of Empedocles and Anaxagoras. This seed comes to fruition in the period from Leucippus and Democritus and the later Pythagorean School, in the second half of the fifth century, to the death of Archimedes, at the end of the third century. In the second century, after Hipparchus, the pace of creation becomes noticeably slower and the long-drawn decline of creative power begins. Its place is taken by the activity of compilers and commentators, beginning in the first centuries of the Christian era and continuing until the final eclipse of classical culture. The whole process covers a long enough period: about eight hundred years, if reckoned from Thales to Ptolemy, and more than a thousand, if we carry it down to the time of the later commentators.

In the modern world we have grown so accustomed to regarding science and technical progress as inseparable, that we cannot understand how the nation which, by discovering the scientific method, paved the way for modern science, failed to display worthwhile initiatives in the technical sphere. It can be said that the slow progress made by Greek science, apart from astronomy, completely belies the greatness of its vision and its original momentum, and that its few technical contributions fall far short of its scientific achievements. While the philosophical schools in antiquity became centers of scientific research, only after Aristotle, in the Hellenistic period, did there arise professional scientists in the modern sense, great investigators, mathematicians and astronomers, such as Euclid and Archimedes, Aristarchus and Apollonius of Perga, Eratosthenes and Hipparchus. Even so, Greek science was still overshadowed by philosophy, and for two reasons. First, because of the tremendous educational influence of Plato, who was the inspiration of adtronomical and mathematical research; and secondly, as a result of Aristotle's encyclopedic systematization and the great influence of the Stoic School in the centuries after him.

The Ancient Greek scientist believed fundamentally that the world should be *understood*, but that there was no need to *change* it. This remained the belief of subsequent generations, up to the Renaissance. Indeed, the real revolution which completely transformed human affairs, came with the change of man's attitude to nature, ushered in by the Renaissance. The Renaissance was the awakening of man's desire for conquest, the conquest and control of nature through science. Previously, the attitude to nature had been one of submissiveness, and the character of science had been theoretical and speculative. Now, all this was thrust aside by the thirst for knowledge, as the means of controlling the forces of nature and harnessing them to man's requirements. By understanding nature, the free man would be able to tame and exploit it, for the extension of his own power. This revolution, which took place over a long period of time, cannot be traced to any single cause. But the significance of its consequences is plain enough: the fear of the gods and the elements was replaced by the spirit of adventurous conquest which turned science into the handmaid of technical progress. The supreme expression of this transformation of values is found in the personality of Leonardo da Vinci. This active, aggressive attitude of man to nature and his desire to take a hand in natural processes opened up a new world to him, while the increasingly complex structure of society directed this desire into the channel of scientific discovery and technical invention.

This «**dissection of nature**» by experiment developed after the Renaissance, which was foreign to the Greek, was the beginning of the modern period to appreciate the decisive role in the rapid development of the natural sciences, played by the application of mathematics to them. In antiquity, the use of mathematics in physical problems was confined to static phenomena, where a mechanical question could easily be translated into geometrical or arithmetical terms, and simple kinetic phenomena, in which there exist simple relations between the distance covered and the time taken. The new era started after Renaissance, and developed especially during this century, has as a result the enormous progress of development of sciences. Indeed, systematic experiment and the mathematization of natural science, which began simultaneously in the modern era, are part of the revolution, which also brought technical development in its train. This development started, when man's attitude to nature became aggressive, when he was no longer content with just understanding nature, but was fired by the ambition to master it, and the desire to exploit for his own needs. «The dissection of nature» by experiment and mathematics was also the result of man's changed attitude to the cosmos.

Then, the civilization of Europe inaugurated the era of the progressive integration of science and technology. As participators in this era, we are in danger of suffering from a distorted perspective. Still, there can be no gainsaying the fundamental fact that this integration has become the mainspring of a creativeness and rapid progress, alike in the theoretical and practical spheres, which are unparalleled in earlier cultures.

The fructification of technology by science is plain for all to see; the converse effect is no less profound and many sided. Not only does technology give fresh impetus to pure science, but technical achievements have been harnessed to the service of fundamental science. In this connection, it is sufficient to mention the tremendous service rendered by the development of scientific instruments and scientific machines in extending man's knowledge of nature beyond the limits of his five senses, thus enabling him to overcome that «*weakness of the senses*» which Anaxagoras regarded as the chief obstacle to ascertaining the truth.

If the intellectual adventure of modern science is perhaps the greatest of all the adventures inaugurated by the modern era, this is due to the development of mathematics as the key to nature's laws. It is true that our cosmos has been drained of all the «*human*» content, which it contained in the Greek period; it is true that the naive world of the senses is separated from the world of science by an ever-widering chasm; it is true that understanding this world of science calls for enormous powers of abstraction and a professional and intellectual training, which is becoming ever more rigorous. But, on the other hand, this cosmos, from the nucleus of the atom to the distant galaxies, is being filled more and more with new and marvellous contents.

However, industrial development, on the other hand, especially during the initial phases of its revolutionary technical change, created profound socioeconomic effects and serious problems arose with respect to employment: for example in the early nineteenth century, skilled people sought to destroy the new machines being introduced into the textile industry, because they were afraid of the effect on their livelihoods, of labor displacement, and consequent unemployment.

During the second half of this century a new phenomenon has manifested itself: a continuously increasing flood of technology, taking the form of a revolution, which we may call the **Technological Revolution**, whose proportions are comparable with those of the Industrial Revolution. A process of rapid and deep-rooted technical change is growing up, quite dissimilarly from the innovative waves of the Indiustrial Revolution, which appeared at roughly fifty-year intervals. The Technological Revolution is drived forward by a whole group of emerging technologies, which are, evolving not only at high speed, but also in a highly interactive and diffusive way.

This Technological Revolution is leading our Societies away from the industrial age, towards a post-industrial society, dominated by new information processes, where a large part of employment will be found in a wide variety of service sectors, dominated by the activities of scientific research and including also cultural and leisure activities. Although this picture is much different from the typical pattern of activities of the Industrial Revolution, it should be stressed that industry and manufacturing are still just as important as before.

The Technological Revolution, however, aims principally to enhance productivity, efficiency, flexibility and the quality of production in industry, without any longer dominating the center stage as a job provider. Industry must become accustomed to this new pattern.

Therefore, research is now the key to international standing. Only those countries, that engage in scientific and technological research, will be able to play a role in the world to tomorrow. The importance of science and technology policy and of medium-to long-term research strategies is growing constantly.

It is of paramount importance for industry to collaborate with Universities and research institutions. Widening the scientific basis of a firm's research is becoming a vital factor in competitive strategies. Cooperative agreements take place in a great variety of patterns, and they are no longer national in scope. There are even areas demanding strong interdisciplinary and inter-institutional collaboration on a large scale.

The idea of developing appropriate technologies, simple and not capital intensive, but, rather labor-intensive, for the Third-World countries, was introduced and developed in the 1960's and 70's. This technologicaî appropriateness should be seen in the sense that grafting an advanced technology onto a traditional activity can generate formidable improvements in productivity and quality of product. Industrially developed countries must be ready to supply suitable technologies and to develop them in cooperation with the Third World countries.

These problems must be faced with a collective effort of all countries, including those of the Third World, but it is the prime responsibility of the

«North» to help develop solutions. Another highly important responsibility of the developed countries concerns the dramatic need for the Third World to reap the possibîe benefits from the Technological Revolution, by exploring unconventional paths of development, without repeating the energy —and material— intensive patterns of production, that have marked the history of industrial society. In this way, phenomena of deforestation and excessive reliance on fossil fuels will be avoided, factors which contribute to the «greenhouse effect» and pollution. But, in all these issues and particularly in energy efficiency, we Europeans are far from setting a good example: that environment and development are intertwined problems. We have to be concerned with a **«sustainable development»**, that is a development capable of satisfying the needs of the generations to come.

The fact that environment and development problems should be intertwined was stated clearly in the so-called Brundtland Report written by Gro Harlem Brundtland, then Prime Minister of Norway and published under the title: **«Our Common Future»** by the World Commission on Environment and Development (1987). In this report Ms Brundtland identified and defined the concept of **«Sustainable Development»**. This type of development is capable of satisfying the requirements of a well-devised program for the industrial and technological development of a country, without obstructing its natural — resource protection. The concept of «sustainability» refers to the limiting conditions of development, which are not rigid, but rather relate to the state of technology and social organization, resource-availability, and the carrying capacity of the biosphere, to absorb the impact of the activities of the man.

A great global effort will be required, and this is the field, where the scientific and technological prowess of the North can be used to best effect in mobilising existing capabilities in the rest of the world, in undertaking more sophisticated and expensive research, and in education and training.

Then science and technology will be able to help resolve the twin questions heaving over this planet: **its global development and the preservation of its global environment**.

This is particularly true in the proliferation of industries and other applications based no nuclear power, especially by the third world, where the scientific infrastructure is in general not well developed to ascertain the security of environment. It is the purpose of this collection of contributions by international authorities on the subject of sustainability of development gathered in this comprehensive volume, whose interest, suitability and timeliness is obvious.

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Ἡ γένεσις τῆς Ἀτομικῆς καὶ Μοριακῆς Θεωρίας τῆς ὕλης κατὰ τὴν ἀρχαιότητα.

Τὸ ὅλον περιεχόμενον τῆς ἀρχαίας ἀτομικῆς ὑποθέσεως εἶναι εἰδικῶς διδακτικὸν διὰ τὸν φυσικὸν ἐπιστήμονα τῆς περιόδου τῆς **συγχρόνου ἀτομικῆς θεωρίας**. Ἡ ἀτομικὴ δομὴ τῆς ὕλης ἔχει σήμερον ἀποδειχθῆ πειραματικῶς καὶ ἔχει γίνει παραδεκτή, ἀποτελοῦσα ἐπομένως ἀναμφισβήτητον γεγονός. Ἡ ἱστορία τῶν τελευταίων ἑκατὸν πεντήκοντα ἐτῶν καταδεικνύει, πῶς αὐτὴ ἡ βεβαιότης ἀνεδύθη προοδευτικῶς ἀπὸ τὰς γενικὰς παραδοχάς, ἡ πραγματικότης τῶν ὁποίων ἐθεωρεῖτο μὲ σκεπτικισμὸν ὑπὸ πολλῶν ἐπιστημόνων, καὶ ἀπὸ μακρὰν σειρὰν ἀλληλοσυνδεομένων πειραμάτων καὶ ἐπαγωγῶν, αἱ ὁποῖαι προοδευτικῶς ἐξειλίχθησαν εἰς ὁμοιόμορφον καὶ πλήρη θεωρίαν.

Εἰς τὸ φῶς τῆς συγχρόνου ἐξελίξεως τῆς ἐπιστήμης εἶναι ἐνδιαφέρον νὰ πληροφορηθῶμεν εἰς ποῖον βαθμὸν κατώρθωσαν οἱ ἀρχαῖοι Ἕλληνες νὰ προοδεύσουν σὲ μιὰν ἐποχήν, ὅπου κάθε συστηματικὸς πειραματισμὸς ἦτο οὐσιαστικῶς ἄγνωστος, ὅταν αἱ χρησιμοποιηθεῖσαι μέθοδοι κατὰ τὴν ἐποχὴν ἐκείνην συνίσταντο κυρίως εἰς παρατηρήσεις καὶ ὑποθετικὰς εἰκασίας, καὶ ὅταν αἱ ἐπιστημονικαὶ ἀρχαὶ καὶ τὰ συμπεράσματα ἐν χρήσει ἦσαν μόνον ὀλίγα τὸν ἀριθμὸν καὶ γενικωτάτης φύσεως. Δὲν πρόκειται ἐδῶ νὰ συγκρίνωμεν δύο θεωρίας ὅσον ἀφορᾶ τὴν ἀπόλυτον ἐπιστημονικήν των ἐπιτυχίαν: μία τοιαύτη σύγκρισις τῶν δύο θεωριῶν θὰ ἦτο προφανῶς ὄχι μόνον ἄσκοπος, ἀλλὰ καὶ ἄδικος. Ἀντ' αὐτοῦ, ὁ κύριος σκοπὸς τῆς τοιαύτης συγκρίσεως εἶναι μᾶλλον ἡ ἀνάγκη τοῦ καθορισμοῦ τῆς ἰσχύος μιᾶς μεθόδου, ὅπως αὐτὴ ἐμφανίζεται εἰς τὴν ἐσωτερικὴν λογικήν της, καὶ τῆς ἐκτάσεως εἰς τὴν ὁποίαν κατώρθωσε νὰ ἐπιτύχη διὰ τὴν πλήρη ἀνάπτυξιν τῶν βασικῶν της προτάσεων, καθ' ὃν χρόνον ἡ ἐπιστημονικὴ γνῶσις ἦτο κατ' οὐσίαν μόνον ποιοτική. Εἶναι πράγματι γνωστὸν ὅτι οἱ ἀρχαῖοι Ἕλληνες ἐγνώριζον ἀμυδρῶς τὸν πειραματισμὸν καὶ τὴν μαθηματικὴν ἐπαγωγήν, ὡς μέσα ἐφαρμογῆς τῆς ἐπιστημονικῆς ἐμπνεύσεώς των, διὰ τὴν περιγραφὴν τῆς πραγματικότητος: δι' αὐτοὺς ἡ μέθοδος τῶν ἀναλόγων καὶ τὰ ἐπιστημονικὰ πρότυπα (μοντέλα) ἦσαν ὁ μόνος σύνδεσμος μεταξὺ τοῦ ἀγνώστου καὶ τοῦ γνωστοῦ.

Ἡ ἱστορία τῆς ἀρχαίας ἀτομικῆς θεωρίας ἐκτείνεται εἰς μίαν περίοδον 400 ἐτῶν καὶ συνδέεται μὲ τέσσερα διάσημα ὀνόματα. Ὁ δημιουργός της ἦτο ὁ **Λεύκιππος ὁ Μιλήσιος**, ὁ ὁποῖος ἔζησε εἰς τὰ μέσα τοῦ 5ου π.Χ. αἰῶνος. Μαθητὴς τοῦ Λευκίππου ἦτο ὁ **Δημόκριτος ὁ Ἀβδηρίτης**, ἕνας ἀπὸ τοὺς περισσότερον γνωστοὺς παγκοσμίως σοφοὺς τοῦ ἀρχαίου κόσμου. Περαιτέρω, ἡ ἀτομικὴ θεωρία μετετράπη εἰς φιλοσοφικὸν σύστημα ἀπὸ τὸν **Ἐπίκουρον τὸν Σάμιον**, ὁ ὁποῖος ἔζησε ἀπὸ τὸ 341 ἕως τὸ 270 π.Χ., καὶ ὁ ὁποῖος κατέστησε τὴν θεωρίαν αὐτὴν παγκοσμίως γνωστήν. Τέλος, ὀφείλομεν νὰ ἀναφέρωμεν τὸν Ρωμαῖον ποιητὴν **Τίτον Λουκρήτιον Κάρον**, τοῦ ὁποίου τὸ διδακτικὸν ποίημα «*De Rerum Natura*» ἀποτελεῖ παιᾶνα ἐπαίνου, πρὸς τιμὴν τῆς Ἐπικουρίου φιλοσοφίας. Τὸ ποίημα αὐτὸ ἀποτελεῖ τὴν πλέον λεπτομερῆ πηγὴν γνώσεών μας περὶ τὴν ἀτομικὴν θεωρίαν τοῦ Ἐπικούρου, πέραν τῆς γνωστῆς ἐπιστολῆς τοῦ Ἐπικούρου πρὸς τὸν μαθητήν του Ἡρόδοτον.

Ἀπὸ τὰ πολυπληθῆ γραπτὰ τοῦ Δημοκρίτου μόνον ὀλίγα ἀποσπάσματα σώζονται, καὶ ἀκόμη ὀλιγώτερα τοῦ Λευκίππου, ἀλλὰ σημαντικὸς ἀριθμὸς τῶν λεγομένων τῶν δύο σοφῶν ἀναφέρεται ἀπὸ τὸν Ἀριστοτέλην καὶ τὸν Θεόφραστον, κατὰ τὴν πορείαν τῆς ἰσχυρᾶς πολεμικῆς των ἐναντίον τῆς ἀτομικῆς θεωρίας. Αἱ ἀναφοραὶ αὐταί, μαζὶ μὲ ἄλλας ἀναφορὰς ἀπὸ τὸν Πλούταρχον, καὶ τὴν δοξογραφικὴν φιλολογίαν, συμπληρώνουν τὴν εἰκόνα τῆς θεωρίας ποὺ ἐδημιουργήθη ἀπὸ τοὺς ἱδρυτὰς τῆς ἀτομικῆς σχολῆς. Αἱ ὀλίγαι λεπτομέρειαι, κατὰ τὰς ὁποίας ὁ Λεύκιππος, ὁ Δημόκριτος καὶ ὁ Ἐπίκουρος διαφέρουν μεταξύ των, χρειάζονται εἰδικὴν προσοχήν, ὡς δείγματα τῆς θεωρητικῆς ἀναπτύξεως ἑνὸς ἑκάστου εἰδικοῦ δόγματος. Ἐν τούτοις, γενικῶς, εἶναι δυνατὸν νὰ λεχθῆ ὅτι αἱ ἀρχαὶ τῆς ἀτομικῆς θεωρίας εἶναι αἱ αὐταὶ εἰς ὅλους τοὺς ὑποστηρικτάς της. Ὅλοι αὐτοὶ οἱ στοχασταὶ τονίζουν συχνὰ τὴν ἄποψιν ὅτι ὑπάρχει εἰς τὴν φύσιν μία γενικὴ συμμόρφωσις εἰς τὸν νόμον καὶ εἰδικῶς ὅτι ὑπάρχει νόμος, ὁ ὁποῖος δύναται νὰ ὀνομασθῆ **νόμος τῆς διατηρήσεως τῆς ὕλης**.

Ἡ ὑπόθεσις τῶν ἀτομικῶν περὶ ὑπάρξεως ἑνὸς κατωτέρου ὁρίου εἰς τὴν διαίρεσιν τῆς ὕλης ἀποτελεῖ **ἀξίωμα**, τὸ ὁποῖον δύναται νὰ ἀποδειχθῆ διὰ τῆς συλλογιστικῆς τῶν πιθανοτήτων. Πράγματι, ἂν ἡ ὕλη εἶναι δυνατὸν νὰ διαιρεῖται ἀπείρως, τότε ὑπόκειται σὲ πλήρη ἀποσύνθεσιν, ἐκ τῆς ὁποίας οὐδέποτε εἶναι δυνατὸν νὰ ἐπανασυνταχθῆ. Ἑπομένως, ἂν ἐπιθυμῶμεν νὰ διατηρήσωμεν ἐν ἰσχύϊ τὸν νόμον τῆς διατηρήσεως τῆς ὕλης καὶ νὰ παραδεχθῶμεν τὴν διαδικασίαν τῆς διαλύσεως καὶ τῆς ἐπανασυνδέσεώς της, ὡς ἀντιστρεψίμου διαδικασίας, πρέπει νὰ ὑποθέσωμεν ὅτι ἡ ἀποσύνθεσις ἢ ὁ κατατεμαχισμὸς σταματᾶ εἰς ὡρισμένον καὶ πεπερασμένον ὅριον. Μόνον τοιουτοτρόπως εἶναι δυνατὸν νὰ ὑπάρξη διαρκὴς πρωτογενὴς βάσις διὰ νέαν ἐπαναδημιουργίαν ἀπὸ τὰ ἀπειροστὰ σωματίδια, ἄνευ οὐδεμιᾶς ἀπωλείας τῆς ποσότητος τῆς ὕλης.

Ὡς πόρισμα διὰ τὴν ἐπίμονον παραδοχὴν τῆς ὑπάρξεως τῶν ἀτόμων, ὁ Ἐπίκουρος ἐπίσης ἐπιμένει εἰς τὴν ὕπαρξιν καὶ ἀνωτέρου ὁρίου εἰς τὸ μέγεθος τῶν ἀτόμων. Ἐν ἀντιθέσει πρὸς τὸν Δημόκριτον, ὁ ὁποῖος δὲν ἐδογμάτισε ἓν μέγιστον μέγεθος διὰ τὸ ἄτομον, ὁ Ἐπίκουρος προφανῶς ἀνέπτυξε τὴν θεωρίαν ὅτι τὸ συλληπτὸν καὶ τὸ ἀσύλληπτον εἶναι οὐσιαστικῶς δύο διάφοροι κατηγορίαι τῆς ὑπάρξεως τῆς ἐννοίας **τοῦ κενοῦ**. Τὸ κενὸν εἰσήχθη ἐκ τῆς αὐστηρᾶς παραδοχῆς εἰς τὴν εἰκόνα τοῦ κόσμου ὡς ἀνεξάρτητος πραγματικότης. Διὰ μίαν ἀκόμη φορὰν ἡ παραδοχὴ αὐτὴ βασίζεται εἰς τὴν πιθανότητα: *Δεδομένου ὅτι ἡ ὕλη ἀποτελεῖται ἀπὸ ἄτομα τὰ ὁποῖα καταλήγουν εἰς μὴ διαιρούμενα σωματίδια, κάθε ἀλλαγὴ ὀφείλει νὰ εἶναι ἀποτέλεσμα τῆς κινήσεώς των, καὶ ἡ προαπαίτησις τῆς κινήσεως εἶναι τὸ κενὸν τὸ ὁποῖον ἀποτελεῖται ἀπὸ ἕνα χῶρον πλήρως ἀπηλλαγμένον τῆς ὕλης, εἰς τὸν ὁποῖον ἓν σωματίδιον δύναται νὰ μεταβῇ ἀπὸ μιᾶς θέσεως εἰς ἄλλην.*

Ἐκ τῆς ἀπόψεως αὐτῆς ἀναγκαστικῶς συνάγεται ὅτι δὲν ὑπάρχει δυνατότης ὑπάρξεως κενοῦ ἐντὸς αὐτοῦ τούτου τοῦ ἀτόμου, διότι εἰς τὴν περίπτωσιν αὐτὴν τὸ ἄτομον θὰ ἦτο ὑποκείμενον εἰς μεταβολὰς καὶ εἰς τὴν φυσικὴν ἐπίδρασιν ἐκ τῶν ἔξω, καὶ κατ' ἀνάγκην θὰ ἠδύνατο πολὺ πιθανὸν νὰ διαχωρισθῇ. Ἑπομένως, ἀκολουθεῖ τὸ δόγμα τοῦ κενοῦ, ὡς προαπαίτησις τῶν κινήσεων τῶν ἀτόμων, πρᾶγμα τὸ ὁποῖον ὑποχρεωτικῶς ὁδηγεῖ εἰς τὸν καθορισμὸν τῆς ἀπολύτου δομῆς αὐτοῦ τούτου τοῦ ἀτόμου. Ἡ ὕλη καὶ τὸ κενὸν εἶναι ὁλοκληρωτικῶς χωρισμέναι ὀντότητες ἡ μία ἀπὸ τὴν ἄλλην. Αἱ φυσικαὶ συγκεκριμέναι ἰδιότητες τῶν μικροσκοπικῶν σωμάτων καθορίζονται ἑπομένως ἀπὸ τὸ εἰδικὸν εἶδος, ἢ τὸν συνδυασμὸν τῶν εἰδῶν τῶν συνιστώντων ἀτόμων, καθὼς ἐπίσης ἐξαρτῶνται ἐκ διαφόρων ἀρχῶν ρυθμιζουσῶν τὰς διατάξεις τῶν ἀτόμων εἰς τὸν χῶρον, ὁ ὁποῖος καταλαμβάνεται ἀπὸ τὸ σῶμα καὶ αἱ ὁποῖαι ὁρίζονται ὡς **θέσεις καὶ συνενώσεις.**

Τὸ σύμπαν τῆς ἀτομικῆς σχολῆς ἑπομένως ἀπετελεῖτο ἀπὸ κενὸν ἀπείρου μεγέθους, πλήρους μὲ στερεὰ σωματίδια, τὰ ἄτομα ἀπείρου ἀριθμοῦ. Ἐγένετο παραδεκτὸν ὅτι τὰ ἄτομα αὐτὰ διέφερον μεταξύ των, ὄχι ὡς πρὸς τὴν ὕλην ἡ ὁποία τὰ ἐπλήρου, διότι αὐτὸ θὰ εὑρίσκετο εἰς ἀντίφασιν μὲ τὴν μονιστικὴν βάσιν τῆς ἀτομικῆς θεωρίας. Πράγματι, ἡ πρωτογενὴς ὕλη ἀπὸ τὴν ὁποίαν τὰ ἄτομα ἐδημιουργήθησαν εἶναι ἑνιαία, ἀλλὰ ὑπάρχουν διάφορα εἴδη ἀτόμων ποὺ διακρίνονται ἀπὸ τὸ σχῆμα των: **τὰ ἄτομα διαφοροποιοῦνται ἀπὸ τὰ σχήματά των**: ἡ φύσις ὅλων αὐτῶν, λέγουν, εἶναι ἡ ἴδια, ὅπως ἀκριβῶς ἓν ἕκαστον ἐξ αὐτῶν χωριστὰ ἦτο ἓν μέρος τοῦ συνόλου.

Τὸ σχῆμα τοῦ ἀτόμου ἀντιστοιχεῖ πρὸς τὸ χημικὸν στοιχεῖον τῆς συγχρόνου ἀτομικῆς θεωρίας. Εἶναι τὸ σχῆμα τὸ ὁποῖον διαφοροποιεῖ τὰ ἄτομα, κατὰ τὴν αὐτὴν ἔννοιαν κατὰ τὴν ὁποίαν ὁ ἀτομικὸς ἀριθμὸς ὁρίζει σήμερον τὰ στοιχεῖα, ὁ ὁποῖος καὶ καθορίζει τὰς χημικὰς ἰδιότητας τοῦ ἀτόμου. Οὕτω, ὁ Λεύκιππος διεχώριζε μόνον τὸ μέγεθος καὶ τὸ σχῆμα τῶν ἀτόμων, ἐνῶ εἰς τὸν Δημόκριτον, ἐξάλλου, δὲν ἀναφέρεται τὸ βάρος, ὁπωσδήποτε ὄχι ὡς ἀνεξάρτητον τῆς ποιότητος, ἀλλὰ μόνον ὡς συνάρτησις τοῦ ὄγκου τοῦ ἀτόμου. Εἰς τὸ σημεῖον αὐτὸ ὑπάρχει βασικὴ μεταβολὴ εἰς τὸ δόγμα τοῦ Ἐπικούρου. Πράγματι, εἰς τὰ λεγόμενα τοῦ Δημοκρίτου περιλαμβάνεται ὅτι ὁ Ἐπίκουρος ἐθεώρει ἀναγκαῖον νὰ εἰσαγάγῃ τὸ βάρος, ὡς τὴν αἰτίαν τῶν κινήσεων τῶν ἀτόμων. Ἐν ἀντιθέσει, ὁ Δημόκριτος ἀπέκλειε ὅτι ἡ κίνησις ὠφείλετο εἰς τὸ βάρος.

Πάντως, ἡ εἰκὼν ποὺ δίδει ὁ Δημόκριτος σχετίζεται μὲ τὴν εἰκόνα τῶν συγχρόνων ἐπιστημόνων διὰ τὰ ἄτομα τῶν **ἰδανικῶν ἀερίων**, εἰς τὴν σύγχρονον κινητικὴν θεωρίαν τῶν ἀερίων, τὰ ὁποῖα εὑρίσκονται εἰς ἀέναον κίνησιν, χαρακτηριζομένην ἀπὸ σταθερὰς συγκρούσεις. Καθ' ὅλην τὴν ἔκτασιν τῆς φιλολογίας τῆς ἀτομικῆς σχολῆς παρατηρεῖται γενικὴ παραδοχὴ εἰς τὴν ὕπαρξιν τῆς ἀενάου κινήσεως τῶν ἀτόμων. Ἀντιθέτως, ὁ Ἀριστοτέλης κατακρίνει αὐστηρῶς διὰ τὴν τοιαύτην ἀπουσίαν τῶν αἰτιῶν δημιουργίας τῶν κινήσεων τῶν ἀτόμων, εἰς τὰς παραδοχὰς τοῦ Λευκίππου καὶ τοῦ Δημοκρίτου, εἰς τὰ βιβλία του *Περὶ Οὐρανοῦ*, καθὼς ἐπίσης καὶ εἰς τὰ *Μεταφυσικά*.

Ἐξάλλου, κατὰ τὴν γνώμην τῶν ἀτομιστῶν, ὄχι ὅλα ἀπὸ τὰ ἄτομα σχηματίζουν μέρος ἑνὸς συνθέτου σώματος, ἀλλὰ ὑπάρχουν πάντοτε μερικὰ ἄτομα ἐλεύθερα ἐκτὸς τοῦ σώματος, τὰ ὁποῖα κινοῦνται ἐλευθέρως. Ὁ Λουκρήτιος, εἰς τὸ δεύτερον βιβλίον τοῦ ποιήματός του, περιγράφει τὸ φαινόμενον αὐτὸ μὲ μεγάλην λεπτομέρειαν, τονίζοντας ὅτι τὰ ἄτομα μερικὲς φορὲς ξεφεύγουν ἀπὸ τὰ σύνθετα σώματα καὶ ἐπιτυγχάνουν τὴν ἐλευθέραν κίνησίν των εἰς τὸ κενόν. Διὰ τὰ ἄτομα τὰ ὁποῖα συμπλέκονται διὰ νὰ σχηματίσουν σύνθετα σώματα, οἱ ἀτομισταὶ ἐπιμόνως παρεδέχοντο ὅτι καὶ αὐτὰ συνεχίζουν νὰ κινοῦνται ἐπ' ἄπειρον. Ἕκαστον ἐκ τῶν ἀτόμων αὐτῶν συνεχίζει νὰ κινεῖται εἰς τὸν στενὸν περιβάλλοντα χῶρον, τὸν ὁριζόμενον ἀπὸ τὰ γειτονικά του ἄτομα, καὶ ὑφίστανται μεταξύ των συχνοτάτας συγκρούσεις, αἱ ὁποῖαι καταλήγουν εἰς εὐκάμπτους ταλαντώσεις εἰς τὴν περιωρισμένην περιοχήν των. Ἡ ἀρχὴ αὐτὴ σημαίνει ὅτι ἡ συμπλοκὴ τῶν ἀτόμων μεταξύ των δὲν τὰ μεταβάλλει εἰς συγκεκριμένην φυσικὴν ἑνότητα. Ἀκόμη καὶ μετὰ τὸν συνδυασμόν των, ἓν ἕκαστον τῶν ἀτόμων διατηρεῖ τὸν ξεχωριστόν του χαρακτῆρα, ὅπως οὗτος ἐμφανίζεται εἰς τὰς ἐπὶ μέρους κινήσεις των, αἱ ὁποῖαι, εἰς αὐτὰς τὰς περιπτώσεις, λαμβάνουν τὴν μορφὴν ταλαντώσεων.

Οἱ Ἀρχαῖοι Ἕλληνες δὲν εἶχον συλλάβει πλήρως τὴν ἀνάγκην τῆς χρησιμοποιήσεως τῆς στατιστικῆς διὰ τὸν προσδιορισμὸν τῶν νόμων τῶν φαινομένων, ὅπου συμμετέχει πολὺ μεγάλος ἀριθμὸς ἀπὸ εἴδη, ἢ μεγάλος ἀριθμὸς ἀπὸ ἐπαναλήψεις, ὡρισμένου συμβάντος. Πράγματι, δὲν εὑρίσκομεν μεταξὺ τῶν ἐπιστημονικῶν ἐπιτευγμάτων τῶν Ἀρχαίων, ὁ,τιδήποτε ὁμοιάζον μὲ τὸν **νόμον τῶν μεγάλων ἀριθμῶν** ἢ τὸν **νόμον τῶν μέσων**, ἢ παρόμοιον νόμον, ἀκόμη καὶ εἰς περιπτώσεις ἑρμηνείας παιγνίων τύχης, τὰ ὁποῖα ἦσαν εἰς κοινὴν χρῆσιν κατὰ τὴν ἀρχαιότητα καὶ παρεῖχον πολλὰς εὐκαιρίας διὰ τὴν μελέτην τῶν φαινομένων αὐτῶν. Τὴν μόνην ἐξαίρεσιν εἰς τὸν κανόνα αὐτόν, ἀποτελεῖ ἡ **ἀτομικὴ θεωρία**, ἡ ὁποία ἠσχολεῖτο μὲ μέγαν ἀριθμὸν ἐπὶ μέρους εἰδῶν.

Ἐπὶ τοῦ σημείου αὐτοῦ διαθέτομεν δύο ἐνδιαφερούσας περιγραφὰς ἀπόψεων τοῦ δόγματος τοῦ Ἐπικούρου καὶ τὰς δύο περιεχομένας εἰς τὸ δεύτερον βιβλίον τῆς Φύσεως τῶν Πραγμάτων. Εἰς τὴν πρώτην περιγραφὴν ὁ Λουκρήτιος ἐξετάζει τὴν περίπτωσιν πολλῶν σωματιδίων κινουμένων καθ' ὅλας τὰς διευθύνσεις, ἐντὸς καθωρισμένων συνόρων. Ἐὰν τοῦτο συμβαίνη, συμπεραίνει ὁ Λουκρήτιος, τὸ τελικὸν ἄθροισμα τῶν σωματιδίων θὰ εὑρίσκεται ἐν ἠρεμίᾳ, ὡς ἁπλῆ ἑνότης εἰς δοθέντα χῶρον, ἢ ἄλλως **τὸ σύνολον τῶν ταχυτήτων θὰ πρέπει νὰ εἶναι ἴσον μὲ τὸ μηδέν.**

Ἡ δευτέρα περιγραφὴ ἀφορᾶ πολυπλοκώτερον φαινόμενον, τὸ ὁποῖον ἐν συνεχείᾳ ἀνεκαλύφθη εἰς τὸ μικροσκόπιον κατὰ τὸ πρῶτον ἥμισυ τοῦ 19ου αἰῶνος. Τὸ φαινόμενον αὐτὸ εἶναι ἡ **κίνησις κατὰ Brown.** Παρατηρώντας μικροσκοπικὰ σωματίδια, αἰωρούμενα ἐντὸς ρευστοῦ ὑγροῦ ἢ ἀερίου, βλέπομεν ὅτι αὐτὰ κινοῦνται κατὰ τελείως ἄτακτον τρόπον, περιπλανώμενα κατὰ διαφόρους διευθύνσεις, ἄνευ κανόνων καὶ συγκεκριμένου σκοποῦ. Τὸ φαινόμενον αὐτὸ καταδεικνύει ἐμμέσως τὴν δραστηριότητα τῶν ἀτόμων ἐντὸς ὑγροῦ ἢ ἀερίου, ἡ ὁποία δὲν εἶναι ὁρατὴ εἰμὴ μόνον εἰς τὸ μικροσκόπιον. Ἡ κίνησις τῶν ἀτόμων αὐτῶν, κατὰ μέσον ὅρον λαμβανομένη κατὰ μακρὰς περιόδους χρόνου, δημιουργεῖ κρούσεις μεταξὺ τῶν ἀτόμων καὶ τῶν μικροσκοπικῶν σωματιδίων, αἱ ὁποῖαι ἀλληλοαναιροῦνται. Ἀλλὰ εἰς ἑκάστην χρονικὴν στιγμὴν αἱ συμβαίνουσαι στατιστικαὶ ἀποκλίσεις εἰς τὴν μέσην τιμήν, καταλήγουν ὥστε τὰ σωματίδια αὐτὰ νὰ δημιουργοῦν διαρκῶς ὠθήσεις κατὰ διαφόρους κατευθύνσεις, μεταβάλλοντας διαρκῶς κατευθύνσεις, καὶ ἡ τυχαία αὐτὴ ὤθησις εἶναι ἐκείνη πού δημιουργεῖ τὶς ἀδιάκοπες ταλαντώσεις τῶν σωματιδίων.

Τὸ φαινόμενον αὐτὸ εὑρίσκομεν περιγραφόμενον καὶ συγκεκριμένως ἐπεξηγούμενον εἰς χωρίον τοῦ Λουκρητίου, τὸ ὁποῖον εἶναι ἀξιοσημείωτον διὰ τὴν διαύγειαν καὶ τὸν τρόπον περιγραφῆς τῶν κυριωτέρων σημείων του. Εἰς τὴν ἀξιοσημείωτον αὐτὴν περιγραφήν, τὴν διδομένην ὑπὸ τοῦ Λουκρητίου, δὲν χρειάζεται νὰ προσθέσωμεν τίποτε, παρὰ μόνον τὴν παρατήρησιν ὅτι ὁ Λουκρήτιος περιγράφει τὴν κίνησιν κατὰ Brown μὲ λανθασμένον παράδειγμα. Ἡ κίνησις τῶν σωματιδίων σκόνης, ὅπως τὴν παρατηροῦμεν διὰ γυμνοῦ ὀφθαλμοῦ ἀπὸ τὰς ἀκτῖνας τοῦ ἡλίου εἰς κλειστὸν χῶρον, δημιουργεῖται ἀπὸ ρεύματα ἀέρος καὶ δὲν ἀντιστοιχεῖ πρὸς τὴν κίνησιν κατὰ Brown, ἐνῶ τὸ πραγματικὸν φαινόμενον πού περιγράφει ὁ Λουκρήτιος δὲν γίνεται ὁρατὸν παρὰ μόνον εἰς τὸ μικροσκόπιον.

Ἐν τούτοις ὅμως, ἡ ἐπίκρισις αὐτὴ οὐδόλως μειώνει τὴν σημασίαν τῆς ἀνακαλύψεως αὐτῆς καθ' ἑαυτήν. Εἶναι δυνατὸν νὰ ἰσχυρισθῆ τις ὅτι τὸ μέγιστον ἐπίτευγμα τῆς ἀτομικῆς σχολῆς τῆς Ἀρχαίας Ἑλλάδος ἦτο ἡ εἰσαγωγὴ καὶ ἡ καθιέρωσις εἰς τὴν ἐπιστημονικὴν ἑρμηνείαν τῶν φαινομένων τῆς **μεθόδου τῆς ἐπαγωγῆς**, ὅπως αὐτὴ παρουσιάζεται ἀπὸ τὸν **Λουκρήτιον**. Διὰ νὰ ἐκτιμήσωμεν τὸν συλλογισμὸν τοῦ Λουκρητίου, πρέπει νὰ ἐνθυμηθῶμεν πόσον ἐνδιαφέρουσα εἶναι ἡ διαδικασία διὰ τὴν ἐξήγησιν φαινομένου τινὸς ἢ τὴν ἑρμηνείαν ἑνὸς πειράματος, ἡ ἱκανοποιουμένη ἀπὸ αὐτὸ τὸ εἶδος τοῦ ἐπιστημονικοῦ διαλογισμοῦ, ἀκόμη καὶ κατὰ τὰς ἡμέρας μας, ὅπου ἡ πειραματικὴ ἐπιστήμη ἀφ' ἑνὸς καὶ ἡ μαθηματικὴ διαμόρφωσις καὶ ἔκφρασις ἀφ' ἑτέρου, ἀποτελοῦν βασικὰ ἐργαλεῖα μελέτης τῶν φαινομένων τῆς φύσεως. Ἡ μέθοδος αὐτὴ τῆς **ἐπαγωγῆς** εἰς τὴν ἐπιστημονικὴν μέθοδον ἔφθασεν εἰς τὴν κορυφὴν τῆς ἀναπτύξεώς της κατὰ τὴν ἑλληνικὴν περίοδον, ἡ δὲ συμβολὴ τῆς ἀτομικῆς σχολῆς ὑπῆρξεν ἀναμφιβόλως ἀποφασιστικῆς σημασίας.

Εἴδομεν ὅτι αἱ βασικαὶ προτάσεις, ἀπὸ τὰς ὁποίας ἐκίνησαν ὁ Λεύκιππος καὶ ὁ Δημόκριτος ἦταν ἡ ὕπαρξις τοῦ κενοῦ καὶ τῶν ἀτόμων, διαφοροποιουμένων ὡς πρὸς τὸ σχῆμα των, τὴν θέσιν των καὶ τὴν διάταξίν των. Καθίσταται τώρα ἀναγκαῖον νὰ ἐξετάσωμεν εἰς ποίαν ἔκτασιν οἱ στοχασταὶ αὐτοὶ ἐπεχείρησαν νὰ ἀναγάγουν ὅλες τὶς συνέπειες αὐτῶν τῶν προτάσεων καὶ νὰ οἰκοδομήσουν ἐπ' αὐτῶν τῶν φυσικῶν καὶ χημικῶν θεωριῶν τῆς ὕλης, τὴν λογικὴν ἑρμηνείαν τῶν φυσικῶν φαινομένων. Πρέπει νὰ ἀναφερθῆ ὅτι ἡ ἀντιμετώπισίς των, τῶν διαφόρων φυσικῶν φαινομένων, συμπεριλαμβανομένων καὶ τῶν βιολογικῶν καὶ ψυχολογικῶν φαινομένων, ἦτο αὐστηρῶς **μηχανιστική**, ἑρμηνεύουσα πάντα τὰ φαινόμενα ὡς ὀφειλόμενα εἰς τὴν κίνησιν τῆς ὕλης καὶ εἰς τὰς ἐπαφὰς τῶν μερῶν της.

Οὕτω, διὰ τῆς γενικῆς διαγραφῆς τῆς ὑπάρξεως πάσης μορφῆς δυνάμεων, ὁ Δημόκριτος καὶ οἱ μαθηταί του, ἀπηλλάγησαν ὅλων τῶν ἄλλων δοξασιῶν καὶ ἀφέθησαν μόνον μὲ μίαν αἰτίαν, διὰ τὴν ἑρμηνείαν κάθε φυσικῆς μεταβολῆς, ἤτοι τῆς **κρούσεως** ἢ τῆς **συγκρούσεως τῶν ἀτόμων** ἢ τῶν **ὁμάδων ἀτόμων**. Ἡ ἐφαρμογὴ τῆς ἀρχῆς αὐτῆς εἰς τὴν ἐπιστημολογίαν ὡδήγησε τοὺς ἱδρυτὰς τῆς ἀτομικῆς σχολῆς νὰ ὑποστηρίξουν τὴν αὐτὴν θέσιν, τὴν ὁποίαν πολὺ ἀργότερον ὑπεστήριξε καὶ ὁ Locke, μαζὶ μὲ τοὺς Ἄγγλους ἐμπειριστάς, κατὰ τὸν 18ον αἰῶνα.

Ἐν τούτοις, δυσκολίαι εἰς τὴν ἑρμηνείαν τῶν διαφόρων ἰδιοτήτων τῶν σωμάτων, ὅπως τὸ βάρος, ἡ σκληρότης των, ἡ ψαθυρότης των κ.ἄ. ἠγέρθησαν μεταξὺ τῶν ἀτομιστῶν. Ὁ Ἐπίκουρος ἦτο ὁ πρῶτος, ὁ ὁποῖος ἀποκατέστησε καὶ διετύπωσε σαφῶς ὅτι ἡ θέσις καὶ ἡ διάταξις τῶν θέσεων τῶν ἀτόμων εἶναι τοῦ αὐτοῦ ἐνδιαφέροντος διὰ τὴν ἑρμηνείαν τῶν ἰδιοτήτων τῶν σωμάτων, ἐκτελῶντας τοιουτοτρόπως τὸ πρῶτον βῆμα ἀπὸ τὴν ἀτομικὴν θεωρίαν εἰς τὴν **μοριακὴν θεωρίαν**. Ἐν τούτοις ὅμως, συμφώνως πρὸς τὸν Ἐπίκουρον, τὸ **μόριον** κατέχει ἕτερον χαρακτηριστικὸν γνώρισμα, ἤτοι τὴν συνεργασίαν τῶν κινήσεων τῶν ἀτόμων, τὰ ὁποῖα τὸ ἀπαρτίζουν, ἤτοι τὰς κινήσεις τὰς ὁποίας τὰ ἄτομα αὐτὰ ὑφίστανται καὶ ἀναλαμβάνουν. Ἔχομεν ἤδη ἰδεῖ ὅτι τὸ διηνεκὲς τῆς κινήσεως ἦτο μία τῶν βασικῶν προτάσεων τῆς ἀτομικῆς σχολῆς, ἐφαρμοσθεῖσα ἀκόμη καὶ διὰ σύνθετα σώματα, εἰς τὰ ὁποῖα τὰ ἄτομα εὑρίσκονται εἰς τοιαύτην στενὴν ἐπαφήν, ὥστε ἡ κίνησις ἐντὸς τῶν σωμάτων αὐτῶν λαμβάνει τὴν μορφὴν ταλαντώσεων προκυπτουσῶν ἐκ τῶν συχνῶν ἐπαναλαμβανομένων συγκρούσεων καὶ ἀναπηδήσεων. Τὸ ἁπλούστερον σύνθετον σῶμα εἶναι τὸ **μόριον**, τὸ ὁποῖον ἐκλήθη ὑπὸ τοῦ Λουκρητίου ὡς **concilium**, ὅρος ὁ ὁποῖος σημαίνει τὴν ἕνωσιν ἢ τὸν σύνδεσμον, καὶ ὡς ἔννοια εἶναι πολὺ πλησίον τῆς συγχρόνου ἐννοίας τοῦ **χημικοῦ συνθέτου σώματος**. Τὸ σύνθετον τοῦτο σῶμα εἶναι μονὰς ἀνωτέρας τάξεως ἀπὸ τὸ ἄτομον, καὶ ἡ δομή του εὑρίσκεται εἰς στενὴν σχέσιν μὲ τὴν φύσιν τῆς κινήσεως καὶ τῶν στοιχείων της.

Συντονισμὸς τῶν κινήσεων τῶν ἀτόμων εἰς τὸ μόριον, ἁρμονία μεταξὺ τῶν διαφόρων ταλαντώσεων τῶν ἀτόμων, κυριαρχουμένη ἀπὸ τὴν ἀρχὴν τὴν ρυθμίζουσαν τὰς ἀμοιβαίας κινήσεις, αὐτοὶ εἶναι οἱ κύριοι φυσικοὶ συντελεσταὶ οἱ χαρακτηρίζοντες τὸν συνδυασμὸν τῶν ἀτόμων, δηλαδὴ τὸ concilium, καὶ τὸ καθιστοῦν ἁπλῆν ἑνότητα.

Εἶναι ἄξιον θαυμασμοῦ τὸ γεγονὸς τῆς δυνάμεως ἐπινοητικότητος καὶ τῆς ἐπιστημονικῆς διαισθήσεως, ἐπιδεικνυομένης κατὰ τὴν ἔμφασιν τὴν παρουσιαζομένην ἐδῶ διὰ τὸν καθορισμὸν μιᾶς βασικῆς ἰδιότητος, χαρακτηριστικῆς τοῦ μορίου, δηλαδὴ τοῦ συνολικοῦ ἀθροίσματος ὅλων τῶν δυνατῶν ταλαντώσεων καὶ τῶν συνδυασμῶν των, πρᾶγμα τὸ ὁποῖον ὁ Ἐπίκουρος θεωρεῖ ἁπλῶς ὡς συνάρτησιν τῆς θέσεως καὶ τῆς διατάξεως καὶ οὐχὶ τῶν δυνάμεων.

Ἐφ' ὅσον ὁ Ἐπίκουρος ἐθεώρει τὰς δευτερευούσας ἰδιότητας τῶν σωμάτων ὡς προκυπτούσας κυρίως ἐκ τῶν μορίων, δὲν εἶναι δύσκολον νὰ κατανοήση τις τὴν ὑπόθεσίν του, ὅτι οἱαδήποτε μεταβολὴ ἐντὸς τοῦ μορίου, προκύπτουσα ἀπὸ τὴν μεταβολὴν τῆς διατάξεως τῶν ἀτόμων του, δημιουργεῖ ἀλλαγὴν τοῦ χρώματός του, ἢ τῆς γεύσεώς του, ἢ καὶ τῆς ὀσμῆς του. Ἀναμφιβόλως ὁ Ἐπίκουρος ἦτο πρῶτος ὁ ὁποῖος ἀνέπτυξε τὴν μοριακὴν θεωρίαν καὶ προσεπάθησε νὰ καθορίση τὰ φυσικὰ χαρακτηριστικὰ τοῦ μορίου. Ἰσχυριζόμενοι τὰ ἀνωτέρω δὲν προσπαθοῦμε νὰ ἀπομειώσωμεν καὶ ὑποβιβάσωμεν τὴν σημασίαν τῆς συμβολῆς τοῦ Λευκίππου καὶ τοῦ Δημοκρίτου, οἱ ὁποῖοι ἦσαν ἐπίσης οἱ πρῶτοι, οἱ ὁποῖοι συνέλαβον τὴν ἰδέαν τοῦ μορίου, ὅταν ἐτόνισαν τὴν ἐπίδρασιν τῆς θέσεως καὶ τῶν διατάξεων τῶν ἀτόμων. Πράγματι, φαίνεται ὅτι ὁ Δημόκριτος ἦτο ὁ πρῶτος ποὺ διετύπωσε **τὸ ἀνάλογον**, τὸ ὁποῖον σκοπὸν εἶχε νὰ ἑρμηνεύση τὴν φύσιν τοῦ μορίου, καὶ τὸ ὁποῖον εἶναι χαρακτηριστικὸν παράδειγμα τῆς συνθετικῆς ἀντιμετωπίσεως τῶν φυσικῶν προβλημάτων ἀπὸ τοὺς Ἕλληνας. Τὸ ἀνάλογον αὐτὸ ἀναφέρεται ἀπὸ τὸν Ἀριστοτέλην εἰς τὰ *Μεταφυσικά* του.

Τὸ ἀνάλογον τοῦ Δημοκρίτου διὰ τὴν σημασίαν τοῦ μορίου βασίζεται εἰς τὴν διαδικασίαν διαμορφώσεως τῶν λέξεων τῆς γλώσσης καὶ ἀποτελεῖ λίαν διδακτικὸν παράδειγμα ἀναλόγου εἰς τὴν Φυσικήν. Τὸ κοινὸν σημεῖον τοῦ ἀναλόγου εἶναι ὁ τρόπος δημιουργίας συνθετωτέρων ἑνοτήτων ἀπὸ ἁπλᾶς μονάδας, μὴ δυναμένας νὰ διαιρεθοῦν περαιτέρω. Τὸ ἀνάλογον βασίζεται ἐπὶ τῶν ἐννοιῶν τοῦ ὅρου: «**Στοι-**

χεῖον», ὁ ὁποῖος χρησιμοποιεῖται, εἴτε διὰ νὰ δηλώση τὰ γράμματα τοῦ ἀλφαβήτου, εἴτε διὰ νὰ περιγράψη κατὰ γενικωτάτην ἔννοιαν τὰ ἄτομα, εἴτε περαιτέρω νὰ περιγράψη, κατὰ ἔτι γενικωτέραν σημασίαν, τὰ βασικὰ στοιχεῖα τῆς φυσικῆς πραγματικότητος. Τὸ ἀνάλογον τοῦ Δημοκρίτου ἀποτελεῖ τὸ προσφιλέστερον ἐξ ὅλων, διατυπώνεται δὲ συνοπτικῶς ὡς ἑξῆς: *«Ὅπως ἑκάστη λέξις εἶναι κάτι περισσότερον ἀπὸ τὸ ἀλγεβρικὸν ἄθροισμα τῶν συνιστώντων αὐτὴν γραμμάτων, οὕτω καὶ ὁ εἰδικὸς συνδυασμὸς ἀτόμων εἰς τὴν φύσιν δημιουργεῖ τὸ μόριον, τὸ ὁποῖον εἶναι τελείως διάφορον ἀπὸ τὸν γεωμετρικὸν συνδυασμὸν τῶν στοιχείων τῶν ἀτόμων. Τὸ μόριον εἶναι ἑνότης σχηματιζομένη ἀπὸ ἄτομα, ἡ ὁποία, δυνάμει τῆς εἰδικῆς διαμορφώσεώς της, δέχεται ἐπὶ πλέον εἰδικήν τινα ἰδιότητα, ὅπως τὸ χρῶμα, τὴν ὀσμὴν ἢ τὴν γεῦσιν, ἀνεξαρτήτους ἀπὸ τὰ στοιχεῖα της. Οἱαδήποτε μεταβολὴ καὶ μετακίνησις ἁπλοῦ στοιχείου τοῦ μορίου δημιουργεῖ πλήρη μεταβολὴν τῶν χαρακτηριστικῶν ἰδιοτήτων τούτου»*.

Ἀνακεφαλαιοῦντες, παρατηροῦμεν ὅτι τὸ μέγιστον ἐπίτευγμα τῶν ἀτομιστῶν, ἐκτὸς τῶν ἄλλων, ἦτο νὰ δημιουργήσουν ἓν νέον εἶδος ἐπιστημονικοῦ λογισμοῦ, βασιζομένου εἰς τὴν ἀπόδειξιν, διὰ τοῦ ἀναλόγου, τῆς δημιουργίας τοῦ ὁρατοῦ μορίου ἐκ τοῦ ἀοράτου ἀτόμου, τῇ βοηθείᾳ ἐπαλλήλων εἰκόνων καὶ προτύπων, ὡς ἀπεικονίσεων. Τὸ ἐπίτευγμα αὐτὸ δὲν ἐγένετο ἀπὸ ἁπλῆν καὶ μόνον τύχην, ἀλλὰ ἦτο ἡ λογικὴ συνέπεια καὶ τὸ τελικὸν συμπέρασμα, τὸ προκῦπτον ἐκ βασικῶν ἀρχῶν τῆς θεωρίας, τὸ ὁποῖον ἔθετε τὴν φυσικὴν πραγματικότητα ἐπὶ μὴ καταληπτῆς βάσεως.

Ὁ σύγχρονος φυσικὸς ἐπιστήμων ἀνακαλύπτει, κατὰ πειστικὸν τρόπον, τὴν ἱστορικὴν συγγένειαν μεταξὺ τῶν φυσικῶν ἐπιστημῶν τῆς Ἀρχαίας Ἑλλάδος καὶ τὴν σύγχρονον φυσικὴν ἐπιστήμην. Ἡ ἀρχὴ τῆς συγχρόνου φυσικῆς ἐπιστήμης δημιουργεῖται κατὰ τὸν 17ον αἰῶνα καὶ ἡ ἀρχὴ αὐτὴ συνδέεται μὲ τὰ ὀνόματα τοῦ Γαλιλαίου καὶ τοῦ Νεύτωνος. Παρὰ τὰς πολλαπλὰς μεταπτώσεις καὶ ἐξελίξεις τῆς Ἐπιστήμης κατὰ τὴν διάρκειαν τῶν τελευταίων 400 ἐτῶν, αἱ ὁποῖαι κατὰ πᾶσαν πιθανότητα θὰ ἐξακολουθήσουν νὰ ὑπάρχουν καὶ εἰς τὸ μέλλον, ὁ χαρακτὴρ τῆς συγχρόνου ἐπιστήμης δύναται νὰ καθορισθῇ ἐπακριβῶς καὶ ἀναμφιβόλως ὡς ἑξῆς: «*Εἰς τὴν μέθοδον κυριαρχεῖ ἡ ἀλληλεπίδρασις τῶν ἀντιστρόφων διαδικασιῶν τῆς* **ἀναγωγῆς** *καὶ τῆς* **ἐπαγωγῆς**, *ἐνῶ, ὡς πρὸς τοὺς σκοποὺς ἀποτελεῖ ἓν* **συνεχὲς παίγνιον ἀντιλήψεως** *καὶ* **κατακτήσεως τῆς φύσεως**». Πράγματι, οἱ Ἀρχαῖοι Ἕλληνες, καθ' ὅλην τὴν περίοδον τῶν 800 ἐτῶν συμβολῆς των εἰς τὴν γένεσιν τῶν ἐπιστημῶν, ἐπέτυχον νὰ δημιουργήσουν διὰ πρώτην φορὰν συστηματικὰς καὶ βασικὰς ἀρχὰς τῶν ἐπιστημῶν, ὥστε νὰ θεωροῦνται σήμερον ὡς **οἱ κύριοι ἱδρυταὶ τῆς συγχρόνου φυσικῆς ἐπιστήμης.**