The Atomic View of Matter in the XVth, XVIth, and XVIIth Centuries

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§ 1. *Introduction.*

It is generally conceived that atomic philosophy was in abeyance, from the time when the authority of ARISTOTLE displaced it, until the days of DALTON. Those who have looked further into the matter are aware of the atomic leanings of GASSENDI about the middle of the seventeenth century, and those of BOYLE and NEWTON which quickly followed. It is, however, seldom realised that there was a continuous chain of atomic thought from the fifteenth century to the time of DALTON. Our purpose here is to trace this thought as far as BOYLE in the works of some of its more striking exponents, not neglecting some of its opponents. The consideration of BOYLE, of NEWTON and of their successors in the eighteenth century demands separate treatment.

The current attitude may be illustrated by a statement made by NERNST that DALTON's Atomic Theory « arose, by one effort of modern science, like a phoenix from the ashes of the old Greek philosophy. » (1)

§ 2. *Atomism in the middle ages. The Recovery of Lucretius.*

An examination of the works of many of the Church Fathers and early Christian writers reveals an undercurrent of atomistic tradition. (2) The idea is still there, though it is frequently misunderstood. Thus, ISIDORE OF SEVILLE (560-636), (3) the Venerable

(1) W. NERNST, *Theoretical Chemistry*, English translation of 10th German edition, London 1923.

(2) J. PHILIPPE, *Lucrèce dans la théologie chrétienne de III^e^ et XIII^e^ siècle*, Paris, 1896.

(3) ISIDORE OF SEVILLE, *Etymologia*, Lib. XIII.1.11.

BEDE, (672-735), (4) and HRABANUS MAURUS (776-856), (5) all speak of the « atom », referring to discontinuity in bodies, in time and number. WILLIAM OF CONCHES (1080-1154) (6) and VINCENT OF BEAUVAIS (d. about 1268), (7) two of the most distinguished mediaeval scholars, display some knowledge of atomic philosophy, and the former openly taught the atomistic doctrine of DEMOCRITUS and EPICURUS. It may be asked how this knowledge came to mediaeval thinkers. The matter is explained firstly by their copying from each other, and secondly by the fact that a few copies of LUCRETIUS were scattered among the libraries of various churches during the Middle Ages. Thus the 9th century MS. of LUCRETIUS now at Leyden was formerly at St. Martin's at Mainz, the see of HRABANUS. A 10th century MS. also at Leyden was once in the abbey of St. Bertin, near St. Omer. There was a copy at Corbie, near Amiens, about 1200, which has since been lost. Other copies certainly existed. Fragments of some which have survived are now at Copenhagen and Vienna.

POGGIO BRACCIOLINI (1380-1459), one of the early promoters of classical literature in Italy, undertook the task of searching the monasteries for ancient manuscripts, and discovered, among other works, a copy of LUCRETIUS. In 1414 he brought it to Italy from Germany. This MS. of POGGIO is now lost, but a copy of it survives. From such a copy was prepared the first printed edition, which appeared in Brescia in 1473. It was reprinted in Verona in 1486, and attracted much attention.

§ 3. *Nicholas of Cusa.*

But even prior to the appearance in print of the work of LUCRETIUS there was some revival of atomic thought. Notably NICHOLAS OF CUSA (1401-1464) recalled the basic ideas of the atomists from the theoretical point of view.

NICHOLAS OF CUSA, whose real name was KHRYPFFS, CHRYFFTZ or KREBS, was the son of a fisherman and was born at Cues, on the

(4) BEDE, *Opera*, Cologne 1688, Vol. i. page 90.

(5) HRABANUS MAURUS, *Opera a Jac. Pamelio collecta*, Cologne 1626, Vol. I, page 145, Book IX, Chap. i.

(6) *Elementorum philosophiæ libri IV* bound up in the Cologne (1688) edition of BEDE's works. Vol. II, pages 206-230.

(7) VINCENT OF BEAUVAIS, *Speculum major*, Venice 1591, Chap. 2. Book 2,p. 14.

Moselle not far from Trèves. He ran away from home while a boy to escape ill-treatment, and took refuge in the service of a neighbouring nobleman. This man saw in him evidence of exceptional ability, and sent him to study at the school of the « Brothers of the Common Life » at Deventer. NICHOLAS afterwards went to the University of Padua, where he took a degree in law in his twenty-third year. He became one of the most distinguished intellects of his time and takes an important place in the history of thought. In philosophy he was one of those who broke with the scholastic system while it was still orthodox. In mathematical and physical science, he was much in advance of his age, and he was certainly a pioneer of the experimental method. He was one of the earliest thinkers to develop a system of religious toleration. He can be said to have placed himself at the head of nearly all kinds of progressive movements in the Church, in Science, in Letters and in Philosophy. He was in sympathy also with the Humanism.

At Deventer, NICHOLAS had learned to know and love the Latin classics. At Padua, he found himself in the company of the keenest intellectuals, and he became secretary to Cardinal ORSINI, one of the learned princes of the Church, who showed a love for ancient literature. NICHOLAS himself became a keen and successful seeker for ancient MSS., and his library, which still exists, almost intact, is of the greatest interest. With such tastes it was natural that NICHOLAS should meet POGGIO, and the discovery of the work of LUCRETIUS would thus be known to him.

With a knowledge of LUCRETIUS, it is easy to understand why NICHOLAS introduces in his *De Mente Idiotae* the question : « What dost thou understand by an atom? » (8). To that question, he replies : « Under mental consideration that which is continuous becomes divided into the ever divisible, and the multitude of parts progresses to infinity. But by actual division we arrive at an actually indivisible part which I call an atom. For an atom is a quantity, which on account of its smallness is actually indivisible. »

NICHOLAS was, moreover, but one of a school of Renaissance thinkers who were influenced by LUCRETIUS. Of these, FRACASTORO is the most prominent.

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(8) NICOLAS OF CUSA, *Opera*, Basel 1555, «De Mente Idiotae», Book III, Chap. 9, p. 162.

§ 4. *Girolamo Fracastòro.*

Very soon after the first printing of the work of LUCRETIUS there was born GIROLAMO FRACASTORO, a man who was deeply stirred by the awakening of atomistic ideas. He was born in Verona in 1478 and died near that city in 1553. He came of a stock which had produced many distinguished physicians, and he received the most complete education available in his day. He attended the University of Padua, where he occupied himself with medicine, mathematics and philosophy. FRACASTORO thus associated with many brilliant men, and there is no doubt that several of them exercised great influence upon him. Among them were GIAMBATTISTA RHAMNUSIO (1485-1587), the Italian HAKLUYT, who inscribed to FRACASTORO his *Viaggi e Navigazioni*, and ANDREA COTTA and ANDREA NAVAGERO (1483-1529), two excellent Latin poets. The latter was well versed in Greek and Latin Literature and edited for the Aldine press the works of QUINTILIAN, VIRGIL, OVID, TERENCE, HORACE, the Speeches of CICERO, as well as LUCRETIUS. With such companions FRACASTORO early developed facility as a writer of elegant verse. The atomic theory of LUCRETIUS was quite familiar to him, and the conception of the « seeds of disease » or *seminaria hypothesis* which has become attached to his name has its basis in LUCRETIUS. In the *De rèrum natura* of LUCRETIUS are, in fact, actual references to seeds that are helpful to life and seeds which cause disease and death. (9)

FRACASTORO in his *De Contagionibus* (10) in dealing with infection by means of fomites (11) supposes the existence of minute invisible particles which convey the infection. These can lurk in the recesses of a porous substance. To them he applies the term *semina*. When dealing with infection at a distance (12) he elaborates a suggestion as to how the seeds of contagion may be carried to a distance and on to the world at large — the idea being that all bodies, especially moist and volatile ones, constantly give off small particles, which may be perceived as vapours or odours.

In his *De sympathia et antipathia* FRACASTORO actually puts

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(9) LUCRETIUS, *De Rerum natura*, Book VI, pages 257 and 272. Clarendon Press. (Trans. BAILEY).

(10) HIERONYMO FRACASTORO, *Opera Omnia*, Venice 1555, page 105, *et seq.*

(11) *Op. cit. De Contagione*, Book 1, Chap. 4, page 106 B.

(12) *Op. cit. De Contagione*, Book 1, Chap. 7, page 108 C.

forward a corpuscular point of view to explain actions of a chemical order, (13) and he expresses assent to the atomic theory of EPICURUS, DEMOCRITUS and LUCRETIUS.

§ 5. *Ramus.*

In the second half of the 16th century began a definite agitation against the old Aristotelian physics. The most vigorous opponent of ARISTOTLE was perhaps PETER RAMUS (PIERRE DE LA RAMÉE, 1515-1572), one of the most learned humanists of the time. He was born at Cuth, near Soissons in Picardy, and went to Paris about 1523, when but 8 years old, and became a lackey in the Collège de Navarre.

RAMUS early developed the strongest inclination for learning. Soon he broke with scholastic Aristotelianism, pushing his opposition to revolutionary extremes. Without discretion or restraint, he attacked the great idol, and when scarcely 21 he presented a thesis, the subject of which was the audacious proposition that « all that ARISTOTLE has said is false ». His disputants being unable to appeal to the authority of ARISTOTLE without begging the question, were unable to make any headway. As a result, after assailing his thesis for a whole day and having their arguments refuted with great spirit, subtlety and directness, they were at length obliged to admit him to the degree with honours. Such was the way in which academic distinction was earned in those days !

RAMUS dreamt of compassing a thorough regeneration of dialectic. He expounded his plans in 1543 in his *Dialecticae Institutiones* and *Animadversiones in Dialecticam Aristotelis*. The works provoked violent opposition ; their publication was prohibited and they were ordered to be burned. Their author was silenced by order of FRANCIS I. On the death of FRANCIS in 1544, RAMUS resumed the teaching of philosophy at Presles, and re-edited his works. In 1551 he was appointed regius professor of rhetoric and philosophy at Paris. His spirit of inquiry ultimately led him to embrace the Reformed faith and he was obliged to flee Paris. His house was pillaged and his library burned. In 1563 he was restored to his chair, but in 1568 affairs were again so threatening

(13) *Op. cit. De sympathia et antipathia*, Book 1, Chap. 5, page 82 B. C.

that he found it advisable to ask permission to travel. Returning to France, he fell a victim to his opponents in the massacre of St. Bartholomew at Paris in 1572.

§ 6. *Giordano Bruno.*

Some twenty years later, in 1583, GIORDANO BRUNO (1548-1600), now 35 years of age and long in rebellion against the scholastic system, presented himself in Paris as an antagonist of the Aristotelian philosophy. BRUNO made a definite stand for a finite state of matter. His atomism or doctrine of *monads* is put forward in his difficult poem *De Triplici Minimo et Mensura* published at Frankfurt in 1591, though an idea as to ultimate particles is seen in his *Acrotismus* of 1588. In that work he says, « The division of natural things has a limit; an indivisible something exists. The division of natural things attains the smallest and last parts which are not perceptible by the aid of human instruments. » (14)

His *De Triplici Minimo* is both metaphysical and geometrical, and in it geometrical considerations and metaphysical explanations are almost inextricably mingled. In the second chapter, BRUNO puts forward his doctrine of « the Minimum » which, being the indivisible unit, is not only the element from which all is made up, but is also the principle, the germ of all existence. (15) The views of BRUNO do not submit of ready analysis, but we may say that the title of the book is taken from his view that there are three minima : (16)

(*a*) A general metaphysical minimum or monad, which means primarily the unit at the base of all existence, and secondarily the limit at the base of number — the minimum as the principle of quantity.

(*b*) A physical minimum or atom — the minimum as the principle of the size of bodies.

(*c*) The geometric minimum or point.

BRUNO declares his belief in discontinuity, holding that there is a minimum that is the basis of all things. « Thus the minimum

(14) BRUNO, *Camoeracensis acrotismus seu rationes articulorum physicorum.* Wittenberg 1588. Book VI, Art. 42.

(15) BRUNO, *De triplici minimo,* Frankfurt 1591, Page 9, line 5.

(16) *Op. cit.* page 10.

is found in all things, and if it were not underlying, things would be aught. Without the monad, there would be no number, for it constitutes the species, which determines each genus. It is indeed the ultimate foundation in all things. It is God and fruitful nature, and art interprets it as that which persists beyond, and wich is common to, every genus » (17) « The minimum remains as a constant in all things being above the confines of finiteness : it attains to infinity, causing, uniting, renewing and propagating eternally all creatures, both composite and simple. » (18)

BRUNO reduces all knowledge of nature to a knowledge of the « minimum », and he concludes that « if contemplation pursues the form of nature, it ought to begin at the minimum, it ought to consist in the examination of the minimum, and it ought to stop with the apprehension of the minimum ». (19) He deduces that the knowledge of the minimum is absolutely necessary as a foundation for natural science, mathematics and metaphysics. (20) He holds that without this principle neither physicist nor mathematician nor philosopher could work. (21) He seeks to refute current proofs of divisibility to infinity, and states the origin and base of all errors in physics as in mathematics to be the conception of a division of a continuous whole to infinity. Thus all error can be reduced to ignorance of the minimum. (22)

BRUNO has a lengthy argument in opposition to ARISTOTLE's conception of continuity, (23) but although he postulates empty space and atoms, 'as do LEUCIPPUS and DEMOCRITUS,' his atomism differs from their materialistic philosophy which considered life and soul as products of union of the atoms. The minimum of BRUNO is the « primodial force », the creating germ and the divine spark by which all things exist. Each kind of substance must possess a definite minimum from which it is established and into which it could be reduced. (24)

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(17) *Op. cit.* page 9, lines 11-17.
(18) *Op. cit.* page 9, lines 18-22.
(19) *Op. cit.* page 18, note 79.
(20) *Op. cit.* page 20, note 1.
(21) *Op. cit.* page 16, lines 79-82.
(22) *Op. cit.* page 23.
(23) *Op. cit.* pages 24-31.
(24) *Op. cit.* Book IV, c. 2. Heading and notes on p. 102.

§ 7. *Bacon and Descartes.*

BRUNO sojourned for a time in England where a contemporary opponent of Aristotelianism was FRANCIS BACON (1561-1626).

To BACON, all that we now call the natural sciences was the soundest philosophy, and while he bitterly attacked the principles and practice of the Peripatetics, (25) and deplored the condition to which natural philosophy had fallen owing to the want of proper appreciation, (26) he promulgated a new method by which all knowledge should be collected and arranged. The evidence of the senses was to form the starting point, and experiments were to be performed to check any information obtained. « Axioms » were to be framed as a result. These were to be examined for the discovery of additional implied facts, and the existence of such facts was to be determined by further experiments.

In considering the ultimate constitution of matter, he was evidently attracted by the atomic doctrine of DEMOCRITUS (27) but he considered the hypothesis of a vacuum and that of the unchangeableness of matter as false assumptions, while the actually existing ultimate particles as conceived by him were not atoms proper but were always capable of further division. (28) His idea was that there was only one kind of primitive matter capable of transmutation into the different kinds that may be perceived. (29)

In his attempt to propound a new method, he was joined by by RENÉ DESCARTES (1596-1650) whose standpoint, however, was fundamentally different. The object of DESCARTES was to found a system which should be solid, clear and convincing. It was to be based on first principles whose validity was beyond doubt, and from these everything was to be explained deductively. The validity of any inference was tested by its approximation to a mathematical demonstration. It was his ambition to apply the geometrical method to universal science and to make it the method of metaphysics. (30)

In his search for his clear first principles, he attempted to divest

(25) BACON, *Novum Organum*, London 1620, I. 63.
(26) BACON, *The Great Instauration, Plan of the work.*
(27) BACON, *De Principiis atque Originibus.*
(28) BACON, *Novum Oragnum*, II, 9 and 48.
(29) BACON, *Thoughts on the nature of things*, II.
(30) DESCARTES, *Discourse on Method*, (Ed. EVERYMAN's Lib.), pages 7 and 16.

himself of every preconceived notion, and as a result he concluded that the most clearly apprehended of all truths was summed up in his famous dictum, *Cogito, ergo sum*. Taking this as a basis and applying his method, DESCARTES was led to the conception of the evolution of the material universe and to his view of the ultimate constitution of matter. His systematic work, *Principia Philosophiae* (1644), treats in successive sections of the principles of human knowledge, of the principles of material things, of the visible world and of the earth, and after recapitulating the principles laid down in the *Meditationes*, his philosophical system — and especially his natural philosophy — is developed. The aim of his natural philosophy is to give an account of all that can be discovered of nature by thought. He holds that the one essential attribute of bodies is extension (31) in length, breadth and depth, and other attributes and qualities are secondary when considering the nature of matter. (32)

In a further development of his Physics the conclusions that are of importance from the standpoint of the atomists are the following :

(a) He denies the existence of a vacuum ; (33) holding that in the philosophical sense a space, in which there is no substance, cannot exist, as the extension of space is no different from that of a body.

(b) The absence of a vacuum had to be reconciled with the existence of motion, and this leads him to conclude that matter could be infinitely divided. (34)

(c) Allowing no limit to the divisibility of matter, he denies the possibility of the existence of atoms. (35)

DESCARTES is thus far from being an atomist, for although he regards all matter as made up of particles so small as to be imperceptible by our senses, (36) yet these particles are not, in his opinion, indivisible, nor is there any void. (37)

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(31) DESCARTES, *Principia Philosophiae*, I, 53, II. 4.
(32) *Op. cit.* II, 4.
(33) *Op. cit.* II. 16.
(34) *Op. cit.* II. 34.
(35) *Op. cit.* II. 20.
(36) *Op. cit.* IV. 201.
(37) *Op. cit.* IV. 202.

§ 8. *Early seventeenth century atomists.* (a) *The Germanic School.*

The influence of DESCARTES during the seventeenth century was enormous. Nevertheless, the atomic view of matter was very far from lacking supporters of a humbler order. An able exponent of the corpuscular theory during this period was DANIEL SENNERT (1572-1637), a native of Breslau, who studied philosophy and medicine in Wittenberg, in Leipzig, Jena and Frankfurt. He became Professor of Medicine at Wittenberg, and as a physician he was one of the first to take up a physical atomistic view. His fame as a practitioner and teacher received universal acknowledgment. He died of the plague in 1637.

SENNERT first shows his adherence to atomism in his *De chymicorum cum Aristotelicis et Galenicis consensu ac dissensu* published at Wittenberg in 1619. In his *Hypomnemata Physica*, (Wittenberg in 1636), SENNERT seeks to set forth atomic doctrine in relation to the old teaching concerning the four elements. He writes that « in considering natural things, subject to generation and corruption, one must necessarily suppose simple bodies of a particular kind, from which the composite bodies arise and into which they are resolved. These simple bodies are physical, not mathematical minima, and are so small that they cannot be perceived by the senses, and these « minima » are the smallest indivisible particles to which all natural bodies owe their existence. » (38) SENNERT holds that there must be atoms of more than one type — atoms of elements and atoms of composite bodies (secondary atoms), (39) and in connection with the different kinds of elements he gives four types of elementary atoms, viz : atoms of fire, atoms of air, atoms of water and atoms of earth.(40) He also supposes that living things, such as plants and animals, are composed of atoms (41) and he illustrates the smallness of atoms by comparing them with the smallest animals, of which he knows « Acari » and « Sirones» the insects of the « Itch » (42)

(38) D. SENNERT, *Hypomnemata Physica,* Wittenberg 1636, Hypomnema III, Chap. 1, p. 90.

(39) *Op. cit.* p. 94.

(40) *Op. cit.* p. 96-97.

(41) *Op. cit.* page 112.

(42) *Op. cit.* page 114.

The observation of these minute creatures frequently awoke atomic thought and language among his contemporaries.

SENNERT points out that chemical operations are capable of explanation when the existence of atoms is supposed, and that a consideration of certain operations shows how small these atoms must be. (43) For example, in evaporation, the vapour from spirits of wine penetrates four thicknesses of writing paper : in distillation, a large volume of vapour containing myriads of atoms yields scarcely a small drop : in melting a mass of gold and silver, the atoms run together and in the resultant mass the different metals cannot be detected, yet each may be obtained again from the mass in its original state.

He further holds that the essential form of a substance is retained in its atomic parts, (44) and quotes the experiment of melting gold and silver so that the atoms of each are thoroughly mixed, and the individual metals cannot be distinguished, though each retains its own form, for on treating the mass with nitric acid the silver is dissolved and the gold remains. Also if mercury be sublimed, dissolved, or suffer other changes by a variation of the atoms into which it is resolved when it becomes mixed with others, it always retains its essential form, and can be readily separated from bodies with which it is mixed, and it may be obtained in its pristine form of running mercury.

In the year following the publication of SENNERT's *De chymicorum consensu ac dissensu* and in the same year as the publication of BACON's *Novum Organum* (1620), a book appeared at Leyden by one DAVID GORLAEUS (van Goorle) entitled *Exercitationes philosophicae quibus universa fere discutitur Philosophia Theoretica*, which is of some interest for our theme. GORLAEUS of Utrecht, in this and in his other works, ranged himself against the followers of ARISTOTLE, though he approached somewhat the philosophical outlook of DESCARTES. He points out in a chapter dealing with Atoms (45) that if an entity be given and the body has material parts, then these parts must be indivisible, or the body would have no material being when such parts come together. Further, if atoms of a definite size be granted, then all quanti-

(43) *Op. cit.* p. 108.
(44) *Op. cit.* pp. 114 and 115.
(45) D. GORLAEUS, *Exercitationes philosophicae*, Leyden 1620, pages 235-239.

ties are divisible into these atoms, and the end of the division of a body is not « non-existence » but only the separation into other parts. Following this he argues the impossibility of an endless number, and the necessity of the atoms having size and weight. He also discusses the shape of the atoms, and questions whether they are round or cubical, and concludes the section with the statement that « whatever the shape may be, the atoms are so small that they cannot be perceived by the senses and scarcely apprehended by the mind. » (46)

Another Dutch philosopher, JOHANNES PHOCYLIDES HOLWARDA (1618-1651) also takes sides with the atomists, and declares that « atoms are nothing more than the smallest corpuscles possible and incapable of further division ». (47) He considers that their movement proceeds from a Creator, (48) but that their different effects result from their shape and their « sympathy and antipathy » (49). He also accepts the existence of a vacuum. (50)

That a corpuscular theory held some place in the thought of the time is further shown by the use of the term « Atom » by the chemist VAN HELMONT (1577-1644). He often employs the term (51) but he does not seem to mean Atoms in the strict sense, but only minute particles. He speaks of the odours, smells and seeds which rise in the air, and states that « a vapour is a cloud of atoms of water rent asunder from each other ». (52)

In 1647, JOHANNES SPERLING (1603-1658) published his *Institutiones Physicae* at Lubeck. His work is borrowed largely from SENNERT. It does not go as far as MAGNEN as to the « atoms » of living creatures and mixtures being divisible, but considers atoms of fire, air, water, earth, mixtures, plants and animals. He writes that « Atoms are the most minute *effluvia*, particles of the utmost smallness, which may be seen when in groups but are invisible when alone. » (53)

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(46) *Op. cit.* p. 243.
(47) J. P. HOLWARDA, *Philosophia naturalis*, Franeker 1651, Chap. III, p. 6-8.
(48) *Op. cit.* Chap. V, p. 12-14.
(49) *Op. cit.* Chaps. VI and VII, p. 15-20.
(50) *Op. cit.* Chap. XI. p. 27-40.
(51) J. B. VAN HELMONT, *Oriatrike or Physick refined*, London 1662, Chap. 8. para. 15 ; Chap. 13, para 21 & 22 ; Chap. 15, para 27 ; Chap. 11, para 7.
(52) *Op. cit.* Chap 15, para 27.
(53) J. SPERLING, *Institutiones physicae*, Lubeck 1647, p. 787.

In considering the German School of Atomists of this period, mention must be made of JOACHIM JUNGE (1587-1657). He is best known for his botanical work, and he also made some mark as an atomist. According to WOHLWILL, (54) who has had access to all known existing manuscripts relating to JUNGE, his corpuscular ideas were already formed in 1622, and had been built up before he knew SENNERT or BASSO.

In 1629, as Rector and Teacher in a school at Hamburg, he was supposed to teach Aristotelian Physics. Nevertheless, he always pointed out its untenability, and maintained and emphasised the superiority of the corpuscular theory. The notes of his lectures, chiefly of the years 1629-1631, are preserved, and were the basis of a posthumous publication (55). In various discussions he defended the atomic standpoint. On March 23rd, 1633, he opposed « the substantial forms » ; in 1634, he dealt with « chemical elements », and the views he then expressed exhibit remarkable similarity to those later expressed by BOYLE. In this connection, we may note that on May 15th, 1654, HARTLIB sent to BOYLE a « rude draught of JUNGE's philosophy » adding that « as it lyes in a pack bound about with such coarse expressions and terms as he uses, it makes no great show, but if it were fully opened, a great deal would appear to be rich cloth of Arras ».

The detailed treatment of his corpuscular theory is seen in the published accounts of two discussions of March 30th, and April 2nd, 1642. These had very little circulation at the time but they establish the claim of JUNGE as an independent atomist and a scientific ancestor of BOYLE.

§ 9. *Early Seventeenth Century Atomists.* (b) *The Italian School.*

The renaissance of the corpuscular theory was not confined to Germany and Flanders. In Italy GALILEO led the van of the forces arrayed against ARISTOTLE. GALILEO was no atomist but his associate CLAUDE BERIGARD had atomist leanings. He published two works, *Dubitationes in dialogum Galilaei pro terrae immobilitate* (Florence, 1632), and *Circulus Pisanus* (Udine, 1643) in which he comments upon the Physics of ARISTOTLE.

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(54) E. WOHLWILL, *Joachim Jungius und die Erneurerung atomischer Lehren in 17 Jahrhundert*, Hamburg 1887.

(55) J. JUNGE, *Doxoscopiae physicae minores* (Ed. M. VOGEL), Hamburg 1662.

BERIGARD was a French physician, who was born at Moulins probably in 1578. He successfully studied literature, philosophy, medicine and mathematics, and after having lived for some time in Paris, went to Pisa in 1628, where he was known to GALILEO. Here he taught philosophy until 1640, when he was invited to occupy the chair in that subject at the University of Padua, where he died in 1664.

His *Circulus Pisanus* is in dialogue form, and in the section headed *In Aristotelis libros de ortù et interitu* he shows a very definite partizanship towards a corpuscular theory, and an antagonism to ARISTOTLE, although no decision is reached in the dialogue. His ideas are rather hazy, but there is approbation of the conception, ascribed to ANAXAGORAS, of the foundation of the universe from an endless number of qualitatively different substances, though he inclines to an atomic composition of these basic substances.

Three years later, 1646, JEAN CHRYSOSTOME MAGNEN (1590-1679) published at Pavia an elaborate work (56) which shows the awakening that had taken place in atomic thought. He commences his *Democritus reviviscens* with a long preface dealing with the life and character of DEMOCRITUS, and then gives a short summary of what he supposes to have been his atomic teaching. He opens by discussing the four elements, (57) which he considers must be reduced to three, viz : earth, water and fire. (58) After this disquisition, he continues his propositions in connection with atoms. (59) He regards the elements as atomic, and he develops the idea « that all things are built up from atoms ». (60) One of his propositions states that « the *continuum* is made up of atoms or an infinite number of corpuscles, adequately distinct amongst themselves and of certain determinate extent ». (61)

In the earlier propositions (62) in which he deals with the atomic composition of things, he reviews reasons why the continuum cannot consist of mathematical points, whether the number

(56) MAGNEN, — *Democritus reviviscens sive de atomis*, Pavia 1646.
(57) *Op. cit.* Prop. IX, page 59.
(58) *Op. cit.* Prop. XI, page 70.
(59) *Op. cit.* « De compositione rerum ex atomis », p. 94.
(60) *Op. cit.* Chap. II, page 104.
(61) *Op. cit.* Prop. XIX, p. 104.
(62) *Op. cit.* Props. XIV-XVIII, pp. 98-103.

be finite, indeterminate or absoluty infinite. In the introduction to Prop. XIX, he states that the atoms are not mathematical points, as these have no dimensions as the atoms have, for the atoms are physically indivisible particles.

He puts forward eight fundamental reasons for the existence of atoms, among which are the following :

(a) Nature shrinks from the endless. (63)

(*b*) « Minima » under different names appear in nearly all Physics. (64)

(*c*) In the building up of bodies, there must be the definite indivisible parts, otherwise one would get matter without form. (65)

(*d*) Decomposition would yield « nothings ». There must be a smallest form. Division does not give an endless number of parts, but quantitative physical parts. (66)

(*e*) The acceptance of an atom rests upon certain chemical experiments, (67) for which he refers to SENNERT's *Hypomnemata Physica III*, chap. 2, and also to some wonderful tales of JACQUES GAFFAREL (1601-1681) as recorded in his *Curiositez inouyes*. (68)

In attempting to define the atom, (69) he states that it is material, simple, purely homogenous, and by its very nature, indivisible. (70) He speaks of atoms of fire, water and earth (71) and says the smallest parts of living creatures and mixtures are not atoms, but are susceptible of division into atoms. In discussing their properties he considers that they have a triple movement,(72) and that « sympathy » exists between atoms. (73) He deals, moreover, with the different conjectures as to the shape of the atoms. (74)

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(63) *Op. cit.* p. 105.
(64) *Op. cit.* p. 106.
(65) *Op. cit.* p. 108.
(66) *Op. cit.* p. 109.
(67) *Op. cit.* pp. 109, 110.
(68) J. GAFFAREL, *Curiositez inouyes*, Hamburg, 1629.
(69) *Op. cit.* p. 113. Prop. XX.
(70) *Op. cit.* p. 114.
(71) *Op. cit.* p. 114.
(72) *Op. cit.* Chap. III, p. 116, Prop. XXI.
(73) *Op. cit.* Prop. XXII.
(74) *Op. cit.* Props. XXIII-XXX pp. 122-154.

Another resolute adversary of Aristotelianism in this period was SEBASTIAN BASSO. In his book *Philosophia Naturalis adversus Aristotelem* published at Geneva in 1621, he suggests a return to Atomism. (75) He attempts to give what he regards as the ideas of DEMOCRITUS, ANAXAGORAS, PLATO and EMPEDOCLES with regard to « the Atom ». He points out that these philosophers differed as to the « prima principia » but that all agreed that it was suitable to explain the cause and reason of natural change. The postulate was that all things arose from very small and very different particles, which possessed a different nature in the divided state and also retained it when in combination. BASSO calls the particles « atoms » and holds that they must be understood as having been created by God in the beginning .

§ 10. *Gassendi.*

PIERRE GASSENDI (1592-1655) of Champtercier, near Digne, in Provence, is usually considered as the reviver of Epicureanism. He certainly adapted that system of thought to the exigencies of the philosophy of his time, yet it is clear from what has gone before that Atomism had never ceased to have partisans. GASSENDI is, indeed, only the most prominent member of a flourishing school, which existed before him and persisted after him.

The Epicurean doctrine as understood and modified by GASSENDI is embodied in his *Syntagma philosophiae Epicuri* (Lyons, 1649) a work on which at least twenty years of labour were expended. The *Syntagma* (76) is divided into three parts : Logic, Physics and Ethics. In the first section of his *Physics* he deals with space, time, movement, the *materia prima*, the properties of things, generation and corruption. The question of the existence of a vacuum is fully discussed (77) before mention is made of atoms. The importance which he attaches to the existence of the void is shown by the fact that he gives three long chapters to the demonstration of its necessity.

In considering the Prima Materia (78) his point of view is that there must be something which serves as a concrete principle,

(75) S. BASSO *Philosophia naturalis,* Geneva 1621, Arts. 4 and 5, pp. 10-12.
(76) P. GASSENDI, *Opera Omnia,* Lyons 1658, Vol. 1.
(77) *Op. cit.* Section 1, Book II, pp. 192-216.
(78) *Op. cit.* Section 1, Book III, pp. 229-282.

and upon which the things in the universe are built, (79) and he lays down the conditions that must be satisfied by it. He then reviews the opinions of the ancient philosophers. Taking in turn first Homoiomerae, then the elements Water, Earth, Fire and Air, and next the Alchemical principles Salt, Mercury and Sulphur, he analyses these conceptions and thus shows what the *Prima Materia* is not. (80) He then deals with the Epicurean school (81) and reaches the conclusion that the *Prima Materia* must be represented by Atoms.

GASSENDI develops the fundamental properties of the atoms along Epicurean lines, holding that they cannot be created or destroyed ; (82) that they are solid (83) ; and that they cannot be divided into any smaller parts. (84) He makes it clear that this indivisibility does not mean that they are without size like a geometrical point, (85) but that they are real entities of extremely small dimensions and must not be conceived merely as mental concepts. His arguments are turned against the confusion of what he calls the *punctum physicum* and the *punctum mathematicum*.

In discussing the properties of atoms, (86) GASSENDI notes that DEMOCRITUS gave the atom only magnitude and figure, while EPICURUS added weight. (87) He would retain all three attributes. To give some idea of their size, he draws attention to the extremely small animals which, despite their minuteness, are equipped with their essential organs. These may be seen by means of a microscope, (88) and he points out that from such observation, some conception of the minuteness of the atom may be obtained. In connection with the form of the atoms, (89) his opinion is that it is very varied. Among other reasons for this belief he points out that no two grains of wheat, no two leaves of the same tree, etc., are identical. (90)

(79) *Op. cit.* Section 1, Book III. Chap 1, pp. 229-234.
(80) *Op. cit.* Section 1, Book III, Chaps. 2, 3 and 4, pp. 234-256.
(81) *Op. cit.* Section 1, Book III, Chap. 5, pp. 256-266.
(82) *Op. cit.* Section 1, Book III, Chap. 5, p. 259.
(83) *Op. cit.* Section 1, Book III, Chap. 5, pp. 260, 261.
(84) *Op. cit.* Section 1, Book III, Chap. 5, p. 261.
(85) *Op. cit.* Section 1, Book, III, Chap. 5, pp. 263 *et seq.*
(86) *Op. cit.* Section 1, Book III, Chaps. 6 and 7, pp. 266-279.
(87) *Op. cit.* Section 1, Book III, Chap. 6, p. 266.
(88) *Op. cit.* Section 1, Book III, Chap. 6, pp. 268-269.
(89) *Op. cit.* Section 1, Book III, Chap. 6, pp. 269-272.
(90) *Op. cit.* Section 1, Book III, Chap. 6, p. 270.

The last attribute of the Atom discussed by GASSENDI is its weight. (91) Unless the atom have this quality he considers that it would be impossible to give an explanation of things. (92) It is by reason of their weight that atoms are able to move among themselves, and he considers it as a property, or power, or innate permanent tendency which pushes the atoms into action. (93) This ability to move on the part of the atoms is considered of great importance, and is examined at length. (94)

GASSENDI, in opposition to EPICURUS, denies that atoms are eternal, unproduced, and moving of their own accord through infinite space. For him, the world is an organised whole ; God the creator and « first cause », above and beyond the physical world. (95) The self movement of the atoms is not « a se ipsis » but only « Dei gratia ».

§ 11. *Charleton.*

The system of GASSENDI is the basis of an English work (96) by WALTER CHARLETON (1619-1707), physician to King CHARLES II and one of the early Fellows of the Royal Society.

His *Physiologia* is divided into four books. Book I deals with the Universe, Time, Eternity, Place and a Vacuum : Book II deals with Atoms, their properties, size, shape and motion : Book III deals with the manner and reason of vision ; the nature of colours, light, sound, smells and taste ; the physical characteristics of substance, softness, hardness, ductility, fluidity, etc. ; an explanation of the behaviour of the loadstone and a most amusing chapter wherein « occult qualities are made manifest » : Book IV deals with Motion and Generation and Corruption. Each book is sub-divided into chapters, sections and articles, and the opening chapter in Book II is styled « The existence of Atoms, evicted ». (97) An early article (98) in the chapter claims that

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(91) *Op. cit.* Section 1, Book, III Chap. 7, pp. 273-279.
(92) *Op. cit.* Section 1, Book III, Chap. 7, p. 273.
(93) *Op. cit.* Section 1, Book III, Chap. 7, p. 273.
(94) *Op. cit.* Section 1, Book V, p. 338, *et seq.*
(95) *Op. cit.* Section 1, Book IV, pp. 287-295.
(96) W. CHARLETON, *Physiologia Epicuro-Gassendo-Charltoniana or a fabrick of science natural upon the hypothesis of atoms,* London 1654.
(97) *Op. cit.* Book II, Chap. 1, p. 84.
(98) *Op. cit.* Book II, Art. 3, p. 85.

atoms have the attributes of the First Matter, and contains the following statement in support of the claim : « Nothing can be the Root or beginning of Material or Physical extension, but something so minute and solid, that nothing can be conceived more exiguous and impatible in nature ».

He tells us « that there are such things as Atoms or Insectile Bodies, in Rerum Natura cannot be long doubted by any judicious man, who shall thus reason with himself — Nature can produce Nothing out of Nothing, nor reduce anything to Nothing, is an Axiom, whose tranquility was never yet disturbed », (99) and « that Nature in her dissolution of concretions doth descend to insensible particles, that she cannot run on to Infinity, but must consist in Atoms, the term of exsolubility » (100).

He then seeks to show (101) that no physical continuum is infinitely divisible, and discusses fully the question of Atoms being « the first and universal matter ». (102) The fact that the number of elements had been a point of dissension among the ancients is brought forward, and it is claimed that while all the earlier ideas « are made equally plausible by a parity of specious arguments, it cannot appear either a defect of judgment, or an affectation of singularity in DEMOCRITUS and EPICURUS to have suspected them all of incertitude, and founded their physiology on an hypothesis of one single principle, Atoms ». (103) Then follows the statement of a number of reasons why « though the four vulgar elements may be the father, yet they cannot be the grandfather principle to all concretions » (104) and an explanation as to the difference between Atoms and Homoiomerae of ANAXAGORAS. (105) The section is concluded with a long dialogue between atomist and anti-atomist in which the difficulties of an atomic view-point are elucidated. (106)

The essential properties of the atoms are further dealt with. (107) « All atoms being equally corporeal and solid, must be

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(99) *Op. cit.* Art. 7, p. 87.
(100) *Op. cit.* Arts. 8, 9 and 10, pp. 88 and 89.
(101) *Op. cit.* Chap. II, pp. 90-98.
(102) *Op. cit.* Chap. III, pp. 99-110.
(103) *Op. cit.* Book II, Chap. III, Art. 4, p. 101.
(104) *Op. cit.* Book, II Chap. III, Art. 6, p. 102.
(105) *Op. cit.* Book II, Chap. III, Art. 7, p. 102.
(106) *Op. cit.* Book II, Chap. III, Art. 8, pp. 103-106.
(107) *Op. cit.* Book II, Chap. IV, pp. 111-126.

substantially identical, or of one and the same nature, knowing no disparity of essence. » (108) The question of their « figure » is also discussed, (109) as « an essential adjunct of their quantity. For, insomuch as atoms are most minute bodies... they must have real dimensions and .... a determinate figure ». The atoms not only have a plain figure, but a solid one, whilst they also possess gravity or weight. With respect to the last three properties, it is admitted that there may be a difference between the atoms as to size, shape and weight. The question of the magnitude of the atoms comes under notice, (110) and it is made clear that the assumption of magnitude as the first essential property of atoms does not mean that they possess any sensible bulk, but that they are entities, realities endowed with certain corporeal dimensions, and not mathematical points. (111) A calculation as to the number of « elemental » atoms in a grain of frankincense is attempted, based on the result of its vaporisation, and the conclusion arrived at is that it contains at least 777,600,000, 000,000,000, « and so we may guess at the exiguity of a single atom ». (112) Futher conjecture as to the size of the atoms is made based upon the diffusion of a grain of vermillion dissolved in water : upon the small quantity of oil consumed by the flame of a lamp in a quarter of an hour, and upon the use of the microscope in discerning the minute particles of bodies, the smallest of which, according to ARCHIMEDES (*in arenario*) consists of ten hundred thousand millions of insensible particles. (113)

In treating of the Figures of Atoms (114) he tells us that « the atoms of the vulgar », seen in a sunbeam viewed through a microscope, are found to have « many irregular and dissimilar appearances » as have the real atoms. The variation of « Figures in Atoms » is substantiated by comparison with natural substances of the same species, in which case no two are found to be exactly alike. (115)

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(108) *Op. cit.* Book II, Chap. IV, Sect. 1, Art. 2, p. 111.
(109) *Op. cit.* Book II, Chap. IV, Sect. I, Art. 2, pp. 111 and 112.
(110) *Op. cit.* Book II, Chap. IV, Sect. II, pp. 113-116.
(111) *Op. cit.* Book II, Chap. IV, Sect. II, Art. I, p. 113.
(112) *Op. cit.* Book II, Chap. IV, Sect. II, Art. 4, p. 114.
(113) *Op. cit.* Book II, Chap. IV, Sect. II, Arts. 7, 8 and 9, p. 11 .
(114) *Op. cit.* Book II, Chap. IV, Sect. III, pp. 117-121.
(115) *Op. cit.* Book II, Chap. IV, Sect. III, Art. 4, p. 118.

The final section to this book (116) is concerned with the motions of atoms and the material Epicurean standpoint is replaced by the idea that the atoms were created by God, given an internal energy by him and that « their internal motive virtue necessitates their perpetual commotion among themselves ». (117)

The date of the publication of CHARLETON's work (1654) brings us to the age of the foundation of the Academies and the work of ROBERT BOYLE. The atomic theory now emerges into fuller light, but its discussion must be postponed. Here we have only sought to demonstrate a continuous atomic tradition from the first half of the fifteenth to the second half of the seventeeth century.

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(116) *Op. cit.* Book II, Chap. IV, Sect. IV, pp. 121-126.
(117) *Op. cit.* Book II, Chap. IV, Sect. IV, p. 126.