NICOLE ORESME AND THE MEDIAEVAL ORIGINS OF MODERN SCIENCE[1]

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Historians of culture are chronically vexed by what may be called the Renaissance Problem.[2] In 1860 Jakob Burckhardt established the classic concept of the period as a unique moment of creative vitality, emerging spontaneously, flourishing in isolation and disappearing without having thrust permanent roots into the soil of European culture. For two generations scholars have struggled to reconcile Burckhardt's brilliant affirmation with their own faith in the continuity of history. This effort has led in two directions, backward into the Middle Ages and forward into the sixteenth and seventeenth centuries. The discovery of unmistakable lines of continuity in either direction has encouraged numerous attempts to redefine the Renaissance as an organic part of Western culture.[3]

In attempting to deal with this problem, especially in determining the nature of the transition from the Middle Ages — it might well be called the Burckhardt Problem — the student of cultural history may derive valuable assistance from specialists in various branches of his field. Historians of art, of political theory and of the vernacular literatures have perhaps been more successful than others in redefining that transition. Historians of philosophy and political economy are rapidly reaching new formulations. Gradually the findings of these groups of specialists are dissipating the confusion which perplexes the student of *Kulturgeschichte*. The outlines of a new and more acceptable synthesis are beginning to emerge.

In this general reconsideration of the Renaissance one important subject has frequently been neglected, the history of science. In part this oversight reflects the immature state of a relatively new field. To a larger extent, however, it derives from the nineteenth-century conviction that the history of science may be reduced to the chronicle of advance in the experimental and mathematical disciplines. To this advance of 'positive' knowledge, it has generally been supposed,

[1] This article is based upon a paper delivered at the joint meeting of the History of Science Society and the American Historical Association, Chicago, Dec. 29, 1938. In preparing it I have received helpful suggestions from my student, W. S. Gifford, Jr, and my colleague, Dr G. de Santillana.

[2] Among the numerous recent articles summarizing the status of research on this problem it will be sufficient to cite the following: H. Baron, 'Renaissance in Italien,' *Archiv für Kulturgeschichte*, xvii (1927), 226–256, and xxi (1931), 95–128, 215–239, 340–356; F. Chabod, 'Il Rinascimento nelle recenti interpretazioni,' *Bulletin of the International Committee of Historical Sciences*, v, ii (1933), 215–229.

[3] For the rôle played by the Italian Renaissance in the formation of modern philosophy, cf. R. Hönigswald, *Denker der italienischen Renaissance: Gestalten und Probleme* (Basel, 1938) especially Ch. xvii, 'Zum Problem der philosophischen Renaissance.' In the other direction J. Nordström, *Moyen-âge et Renaissance* (Paris, 1932) has attempted to destroy the Burckhardtian thesis. Nordström in turn has been scornfully attacked by I. Siciliano, *Medio evo e Rinascimento* (*Biblioteca della Rassegna*, xix: Milan, 1936), pp. 36–50. Siciliano emphasizes the miraculous fertility of the Renaissance in exceptional personalities, and the profound scope of its civilizing influence; 'il Rinascimento italiano uscì dall'Italia per conquistare il mondo e . . . esso è per la civiltà e l'arte moderna quello che per l'antichità fu la civiltà greco-latina' (p. 147).

the Middle Ages — and for that matter Burckhardt's Renaissance — made no contribution.[1]

The inadequacy of this conception will be apparent to anyone who examines the second volume of George Sarton's monumental *Introduction to the History of Science*.[2] As a result of Dr Sarton's industry, we now possess a detailed and comprehensive picture of scientific achievement during the Middle Ages in both the Christian and the non-Christian worlds. Unfortunately Dr Sarton has advanced only to 1300 in his published work; it is to be hoped that his volume on the fourteenth century will appear in the near future.

Besides Sarton's *Introduction* there have been two other attempts at a large scale survey of the field: the work of Pierre Duhem and Lynn Thorndike. The historian of culture may profitably turn to each of these to further his understanding of the transition from the Middle Ages to the Renaissance.

The full scope of Duhem's achievement cannot yet be measured. Twenty years after his death five of the ten volumes of his imposing *Système du Monde* still remain unpublished.[3] Presumably these volumes constitute the most extensive treatment in existence of cosmological thought during the two centuries before Copernicus. Even without them, however, it is clear from his other writings that Duhem was the true pioneer in this field. All future work will consist, in large measure, in working intensively the veins which he has opened. This work has already proceeded with considerable success. Critical scrutiny, indeed, has revealed that Duhem was frequently a careless, hasty searcher, over-enthusiastic in announcing some of his discoveries, and blind to the significance of others.[4] Apart from flaws of detail, inevitable in a work of such magnitude, the chief defects in Duhem's survey may be derived from a single complex bias emerging from three aspects of his personality.[5] We see in him a patriotic Frenchman, jealous of the

[1] A trivial illustration of this view may be found in H. S. Williams, *The great astronomers* (New York, 1930). Book I, 'The Old Heaven' occupies pp. 31–96; Book III, 'The slow dawn of a new era' begins on p. 103. Between the two is inserted Book II, 'Astronomy in the medieval period.' It consists of the following: Chapter VI, *The Christian world—12 centuries of progress (325–1543 A.D.)*, 'From the Council of Nicaea at which the Emperor Constantine made Europe safe for Athanasian theocracy, to the time of Copernicus, whose great work, teaching that the earth is not the centre of the universe, was to remain under ban of the Council of the Inquisition until fifteen centuries after the Nicene victory, the record of astronomical progress in all Christendom may most charitably be expressed in the following terms:' whereupon follow four blank pages!

[2] *Introduction to the history of science:* Vol. I, *From Homer to Omar Khayyám* (*Publication of the Carnegie Institution*, 376: Baltimore, 1927); Vol. II, i, ii, *From Rabbi ben Ezra to Roger Bacon* (Baltimore, 1931).

[3] *Le système du monde, histoire des doctrines cosmologiques de Platon à Copernic* (Paris, 1913–1917). In March 1937 George Sarton issued an 'Appel pour l'achèvement du *Système du Monde* de Duhem,' with the joint signature of M. P. Tannery (*Isis*, XXVI, 302–303). It appears that in the meantime arrangements had already been concluded with the firm of A. Hermann to publish the integral works of Duhem, including the remaining volumes of the *Système du Monde*. It is difficult to foretell the effect which these volumes will produce. They may well have lost much of their significance and originality through the delay.

[4] Cf. B. Ginsburg, 'Duhem and Jordanus Nemorarius,' *Isis*, XXV (1936), 341–362; S. Moser, *Grundbegriffe der Naturphilosophie bei Wilhelm von Ockham* (Innsbruck, 1932), pp. 123–127.

[5] Cf. the biography of her father by Mlle Hélène Pierre-Duhem, *Un savant français, Pierre Duhem* (Paris, 1936); also the laudatory passages devoted to him in *Archeion*, XIX (1937), 121–151.

achievements of the English, the Germans and the Italians, even as far back as the Middle Ages. We sense the animus of a Catholic frustrated in his academic ambitions by a hostile educational machine, eager to vindicate the scientific traditions of his Church. Finally we recall that he was a brilliant physicist in his own right, who approached the history of science primarily to establish the background, and to discover 'precursors' of his own discipline. And yet when this bias has been corrected, we are left with the realization that Duhem deserves the enormous credit of having opened a new field of scholarship. He was the first to fray an unbroken vista backward into the mediaeval antecedents of modern science.

The other important survey of this field, Professor Thorndike's *History of Magic and Experimental Science*, is animated by a different spirit.[1] Professor Thorndike is primarily an historian. He is less concerned than Sarton or Duhem with chronicling the advance of positive scientific knowledge. He is interested rather in the quasidialectical process by which the two elements indicated in the title of his book have gradually converged. For him, alchemy, astrology and the search for occult virtues — which others might regard as superstition rather than science — are the principal avenues through which man has gradually, and often obliquely, approached his present knowledge and mastery of Nature. Philosophy and mathematics recede to a secondary plane. In contrast with Duhem, Thorndike's sound training as an historian has led him to a cautious interpretation of fourteenth and fifteenth century science. His insistence on replacing the 'isolated geniuses' and the 'precursors' back into the context of their age, at times approaches close to 'debunking,' but on the whole his distrust of unfounded generalization has proved a healthful scepticism.[2]

It would be incorrect to state that Duhem and Thorndike have consistently presented opposing views. Nevertheless one might well affirm that between them they have established a sort of thesis-antithesis interpretation of late mediaeval science. It seems inevitable that future workers in the field will be tempted to use their investigations as the basis for a new synthesis. It would be presumptuous in the present paper to lay down the lines which such a synthesis must follow. I shall limit myself to a single instance of the way in which a fourteenth-century man of science may be used to illustrate the transition from mediaeval to modern thought. For methodological reasons I have selected a figure who has been treated in some detail by both Thorndike and Duhem.

[1] *A history of magic and experimental science.* Vols I, II (New York, 1929); III, IV (New York, 1934). Professor Thorndike has prepared continuation of his work into the sixteenth century. In addition to the wealth of manuscript citations, especially in Vols III and IV, the fruit of Professor Thorndike's extensive research in European libraries is also available in *A catalogue of Incipits of mediaeval scientific writings in Latin* (*The Mediaeval Academy of America*, Publication No. 29: Cambridge, Mass., 1937) which was prepared with the collaboration of Pearl Kibre. This *Catalogue* is an indispensable tool for investigation in this field.

[2] Cf. his chapters on Nicholas of Cusa and on Peurbach and Regiomontanus in *Science and thought in the fifteenth century* (New York, 1929). Thorndike's criticism is rejected by E. Zinner, *Leben und Wirken des Johannes Müller von Königsberg, genannt Regiomontanus* (*Schriftenreihe zur bayerischen Landesgeschichte*, XXXI: Munich, 1938), p. 209. Dr Sarton also feels that the criticism is too severe, *Isis*, XIV (1930), 238.

Nicole Oresme, Bishop of Lisieux, friend and adviser of King Charles v, was unquestionably one of the most talented and versatile men of the later Middle Ages. Although highly regarded in his own day, the reputation which he now enjoys has largely been established since the middle of the nineteenth century. In 1867 Francois Meunier published what still remains the only full length portrait of the man.[1] Oresme's fame grew rapidly. Historians discovered in his *De origine, natura, jure et mutationibus monetarum* an apparent anticipation of Gresham's law.[2] Subsequent criticism has gradually whittled away most of the substance of this 'precursorship,' but there were other claims to be made. In the late 1860's Maximilian Curtze — whom we might describe as the 'precursor of Duhem' — initiated the study of Oresme's mathematical writings.[3] He was able to establish the fact that Oresme was the first writer systematically to develop an equivalent of our modern fractional exponents; so far as I know the credit for this innovation has not been impaired. Curtze also called attention to a *Tractatus de latitudinibus formarum* which described a method of representing quasi-functional variations by means of simple geometrical diagrams.[4] On the strength of this treatise Curtze proclaimed Oresme as the 'precursor of Descartes' in the invention of analytical geometry. This has proved, on the whole, the most viable of Oresme's 'precursorships.'

The consolidation of Oresme's reputation as a scientist was the work of Pierre Duhem. In 1909 Duhem published a long extract from Oresme's French commentary on Aristotle's *De Caelo* in which the commentator had advanced arguments in favor of a diurnal rotation of the earth.[5] This notion, which goes back to classical antiquity, is based upon a geocentric, not a heliocentric universe.[6]

[1] *Essai sur la vie et les ouvrages de Nicole Oresme* (Thèse: Paris, 1857). I am grateful to Dr Sarton for permission to use his unpublished note on Oresme; this note will appear in the fourteenth-century volume of the *Introduction to the History of Science.*

[2] The standard work is E. Bridrey, *La théorie de la monnaie au XIV^e siècle: Nicole Oresme* (Paris, 1906); cf. also H. Laurent, *La loi de Gresham au moyen âge. Essai sur la circulation monétaire entre la Flandre et le Brabant à la fin du XIV^e siècle* (*Travaux de la Faculté de Philosophie et Lettres de l'Université de Bruxelles*, v: Brussels, 1933), pp. 87–94.

[3] *Die mathematischen Schriften des Nicole Oresme* (*circa 1320–1382*). *Ein mathematisch-bibliographischer Versuch* (Berlin, 1870). This general survey was preceded by *Der Algorismus Proportionum des Nicolaus Oresme* (Berlin, 1868) and 'Über die Handschrift R. 4°. 2, *Problematum Euclidis explicatio* der Königl. Gymnasialbibliothek zu Thorn,' *Zeitschrift für Mathematik und Physik*, XIII (1868), suppl., pp. 45–104. Cf. also H. Wieleitner, 'Zur Geschichte der gebrochenen Exponenten,' *Isis*, VI (1924), 509–522; VII (1925), 490–491.

[4] For a description of the manuscripts and printed editions of this work see H. Wieleitner, "Der *Tractatus de latitudinibus formarum* des Oresme," *Bibliotheca Mathematica*, 3. Folge, Bd. XIII (1913), 115–145.

[5] 'Un précurseur français de Copernic: Nicole Oresme (1377),' *Revue générale des sciences pures et appliquées*, XX (1909), 866–873. The French works of Oresme are being edited by Prof. A. D. Menut of Syracuse University and some of his students. One volume has already appeared, *Maistre Nicole Oresme, Le livre de Ethiques d'Aristote* (New York, 1940). The forthcoming publication of *Du Ciel et du Monde*, text and commentary, will be a welcome addition to our limited supply of fourteenth century scientific texts. Cf. also Prof. Menut's article 'Nicole Oresme's first work in French,' *Romanic Review*, XXVI (1935), 12–17.

[6] Cf. G. McColley, 'The theory of the diurnal rotation of the earth,' *Isis*, XXVI (1937), 392–402.

Moreover the character of Oresme's entire discussion is very close to paradox. Yet in spite of these two serious limitations Duhem took the bold step of labelling Oresme 'précurseur de Copernic.'

Following this, Duhem attempted in the third of his brilliant *Études sur Léonard de Vinci* (1913) to reinforce Curtze's claim that the 'latitude of forms' diagrams constituted an anticipation of Descartes.[1] He then added the final crown. On the basis of a detailed analysis of fourteenth-century theories of motion — particularly the concept of *impetus* — Duhem affirmed that Oresme had clearly foreshadowed the principle of inertia and the law of falling bodies.[2] He was the precursor not merely of Copernicus and Descartes, but also of Galileo. To Duhem, eager to diminish the reputation of the great Italian whom his Church had reproved, this was a felicitous climax!

For twenty years subsequent work on Oresme as a scientist very largely took the form of footnoting Duhem. Sometimes, indeed, the tenor of this work was distinctly critical. In 1914 Heinrich Wieleitner published excerpts of the manuscript transcriptions which Duhem had used in his *Études*.[3] He rejected the claim that Oresme's graphic representation of 'functions' constituted an equivalent of analytical geometry, and denied that it could have exercised a decisive influence on Descartes, whose inspiration came rather from a more intensive study of the Greek mathematical classics.[4] On the other hand Wieleitner also examined the scholastic theories of falling bodies, and in this case was able to substantiate the importance which Duhem had attached to the pre-Galilean tradition.[5] Wieleitner was followed by Ernst Borchert whose monograph on Oresme's concept of motion (1934) presented the first thoroughly critical examination of the subject.[6] Although he shades the picture more conservatively than Duhem, Borchert also affirms that Oresme arrived at a conception of *impetus* remarkably close to the modern theory.[7]

[1] *Études sur Léonard de Vinci:* 3e série, *Les précurseurs parisiens de Galilée* (Paris, 1913), pp. 375–387, 'Nicole Oresme, inventeur de la géométrie analytique.'

[2] *Études sur Léonard de Vinci*, 3e série, *passim*, especially pp. 389–398.

[3] Über den Funktionsbegriff und die graphische Darstellung bei Oresme,' *Bibliotheca Mathematica*, 3. Folge, Bd. XIV (1914), 193–243. Wieleitner's first article on the *Tractatus de latitudinibus formarum* had been published before he was aware of Duhem's investigations in the subject.

[4] *Ibid.*, pp. 241–243; the evidence of Isaac Beeckman's scientific journal which was discovered in 1905, forced Wieleitner to concede that the scholastic tradition of graphic delineation of 'latitudes' was still alive in the seventeenth century, and was probably known to Descartes.

[5] 'Das Gesetz vom freien Falle in der Scholastik, bei Descartes und Galilei,' *Zeitschrift für mathematischen und naturwissenschaftlichen Unterricht aller Schulgattungen*, XLV (1914), 209–228. Cf. also E. J. Dijksterhuis, *Val en Worp. Een Bijdrage tot de Geschiedenis der Mechanica van Aristoteles tot Newton* (Groningen, 1924) which presents a comprehensive survey substantially along the lines laid out by Duhem.

[6] *Die Lehre von der Bewegung bei Nicolaus Oresme* (*Beiträge zur Geschichte der Philosophie und Theologie des Mittelalters*, XXXI, 3: Münster i. W., 1934) with a good bibliography.

[7] *Ibid.*, pp. 100–111; cf. 'Wie schon bei allen eben erörterten Fragen die Spannungen in ihm zwischen den Lehren der Tradition und der eigenen Überzeugung immer grösser wurden, so steht in dieser letzten Teilfrage, die zugleich die Gesamtfrage unserer Untersuchung bedeutet, Oresme in dem fühlbaren Gegensatz des ihm dargebotenen unvollkommenen Schwerebegriffs und seiner klaren Formulierung des Impetus als der Qualitas des bewegten Körpers, für dessen Bewegung sie sein inneres reales

The year 1934 also marked the appearance of another important study of Oresme, presenting him, this time, from an entirely different angle. We have seen that for a period of seventy-five years — from Curtze to Borchert — scholars in this field had been primarily interested in Oresme's activity as a precursor of scientific discoveries ordinarily attributed to the sixteenth and seventeenth centuries. Professor Lynn Thorndike in the third volume of his *History of Magic and Experimental Science* devoted three chapters to an aspect of Oresme which had generally been neglected, *viz.;* his attitude toward esoteric science, astrology and natural magic.[1] From Thorndike's account Oresme emerges less as a 'precursor,' more as a typical, though indeed outstanding 'man of his age.' We see him as one of the shrewdest among mediaeval critics of astrology, and yet himself astonishingly credulous of much of the pseudo-science which had been current for centuries.[2]

Thorndike's characterization of Oresme goes far to neutralize the enthusiastic claims of Duhem. And yet it is by no means necessary to suppose that the two interpretations are contradictory. It would be more accurate to regard them as constituting two dimensions of the man — as Oresme might have put it, a 'qualitas superficialis.' It is natural to wonder whether a third dimension might not be added, constituting a 'qualitas corporalis.' I shall attempt to indicate in summary fashion the direction in which such a dimension might be imagined to extend.

Although each of the numerous 'precursorships' attributed to Oresme invites our scrutiny, I shall limit myself to one, the alleged anticipation of Descartes. The case for this 'precursorship' rests largely on two texts, the *Tractatus de latitudinibus formarum* investigated by Curtze, and the *Tractatus de configuratione qualitatum* studied by Duhem, Wieleitner and Borchert. Of the two the latter is by far the more important. Although it exists in at least a dozen manuscripts the *De configuratione qualitatum* has never been published as a whole.[3] What is perhaps

Fundament darstellt.' (p. 111). — A somewhat different interpretation is presented by A. Koyré in a group of important articles: 'À l'aurore de la science moderne (la jeunesse de Galilée),' *Annales de l'Université de Paris*, x (1935), 540–551; xi (1936), 32–56; 'La loi de la chute des corps; Galilée et Descartes,' *Revue Philosophique*, lxii (1937), 149–204. Koyré divides the history of physical theory into three periods: 1) Aristotelian physics, 2) physics of *impetus* (Buridan, Oresme), 3) mathematico-experimental physics (Galileo). This last phase, which was precipitated by the sixteenth-century Renaissance of Archimedes, constitutes in Koyré's opinion an 'intellectual mutation,' non-continuous with mediaeval physics; 'A l'aurore de la science moderne,' pp. 544–545.

[1] Ch. xxv, 'Oresme on astrology,' xxvi, 'Oresme on magic,' xxvii, 'Oresme on nature.' Cf. also by the same author 'Coelestinus' summary of Nicholas Oresme on marvels,' *Osiris*, i (1936), 629–635 which shows the survival of his ideas in the sixteenth century.

[2] *Magic and experimental science*, iii, 470, 'We should like to have been able to present Nicolas Oresme simply as a critic of magic and astrology and as battling against superstition and the occult. But in his expeditions against what seemed to him error we sometimes find him on the side of theology in what looks very much like a warfare with science.'

[3] To the manuscripts cited by Borchert, *op. cit.*, pp. 19–20 we may add Florence, Biblioteca Laurenziana, *Ms. Ashburnham 210*, fols. 101^{v}–129^{r}. This Ms., which contains writings of Henry of Hesse and Oresme, has been described by Thorndike, *Magic and experimental science*, iii, 744–745. I have utilized it as the basis of my own study of the treatise, supplementing the manuscript followed by Borchert

more remarkable is the fact that it has apparently not been used in its entirety even by those scholars who have consulted it in manuscript form. Duhem, Wieleitner and Borchert have confined their attention to those sections which contain material of clearly defined scientific character — about half of the total work. Professor Thorndike cites only from the section dealing with magic and the occult — about one quarter of the treatise. We are left then with as much as a fifth or a quarter of the *De configuratione qualitatum* which no serious student has found useful.[1] We see that this work which Oresme, himself, clearly regarded as one of his major achievements, has apparently never been studied as a whole. It will be worth our while to enquire whether any essential part of Oresme's total thought has been sacrificed by this concentration on partial aspects.

The *Tractatus de configuratione qualitatum* is divided into three parts. Part I commences with a careful account of the method by which Oresme proposes to represent the variations of qualities through geometrical diagrams. It is this section which has chiefly attracted the attention of those interested in Oresme as a mathematician. Although the method itself has been satisfactorily described by Wieleitner, Duhem and Borchert, the precise nature of Oresme's innovation has been imperfectly set forth. Fortunately an earlier writing, which appears to have been overlooked hitherto, enables us to penetrate into the process of thought by which Oresme arrived at his new conception. This text, a set of *Questiones* on the *Geometria* of Euclid, deals with a number of topics current in fourteenth-century scholastic mathematics, notably proportion, incommensurability and irrationality.[2] It differs from other works of similar character, however, in that it

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(Paris, Bibliothèque Nationale, Fonds Latin, *Ms. 14579*) and that which Duhem transcribed and Wieleitner published (B. N., *Ms. lat. 7371*). — I am at present engaged in preparing a critical edition of the *Tractatus de configuratione qualitatum*.

[1] It is indeed true that this and other sections of the *Tractatus de configuratione qualitatum* were examined even before the publication of Meunier's biography; cf. Abbé Picard, 'Dissertation sur un traité philosophique de Nicolas Oresme,' *Précis analytique des travaux de l'Académie des Sciences, Belles-lettres, et Arts de Rouen* (1851–1852), 456–475. The essentially antiquarian character of this account is sufficiently indicated by the laudatory remarks on p. 458: 'La matière, au premier aspect, est abstraite et aride, mais j'ose espérer qu'elle ne vous paraîtra pas sans intérêt, soit parce que l'auteur appartient à notre province soit parce qu'on aime revenir, du moins de temps en temps, sur ce qui autrefois préoccupa vivement nos pères, soit enfin parce que, dans les choses du passé, on trouve souvent des rapports assez piquants avec les choses présentes.'

[2] Vatican, *Ms. lat. 2225*, ff. 90r–98v, 'Incipiunt questiones super Geometriam Euclidis per Magistrum Nicolaum Oresare (!) probum philosophum et solempnem disputate Parisius, etc.' It was doubtless the mistake of a fifteenth-century Italian scribe and an eighteenth-century cataloguer which led to the appearance of this work in Thorndike's *Catalogue of Incipits* under the authorship of 'Nicholas of Cusa (?),' (col. 94). The text of these *Questiones* is extremely corrupt. Nevertheless I shall attempt to edit it in connection with the *De configuratione qualitatum*. — Questions 6 to 9, dealing with the commensurability of the side of a square with the diagonal closely resemble a text published by H. Suter, 'Die Quaestio "De proportione dyametri quadrati ad costam ejusdem" des Albertus de Saxonia,' *Zeitschrift für Mathematik und Physik*, hist.-lit. Abt. XXXII (1887), 41–56. The doubtfulness of the attribution was noted by Duhem, *Études sur Léonard de Vinci*, 1 ère série (1906), 341–344. Had Duhem not been intent on proving that this *Questio* was the work of an inferior author, he might not have overlooked a passage (p. 51) in which two 'caliditates' are imagined after the form of geometrical surfaces, a strong indication that it is in fact by Oresme.

attempts to combine the study of geometrical figures with elaborations of the non-geometrical *latitudo formarum*, such as had become commonplace through the subtle *Calculationes* of Richard Suiseth.[1] In a confused and haphazard form these *Questiones* present a number of ideas and principles which are identical with those developed more systematically in the *De configuratione qualitatum*.

The method by which Oresme proposes to fuse the mathematical and the logical approach to the study of 'forms' may be summarized as follows: a given base line, drawn horizontally, is taken to represent the extension, either in time or in space, of a subject whose properties, e.g., whiteness, density, luminosity, are to be determined. This line is divided into equal units called degrees. For each degree of extension or *longitudo* a certain degree of intensity or strength in the subject may be measured. This is represented by a vertical line generally called a *latitudo*.[2] When all the latitudes have been plotted on a uniform scale, a line may be drawn connecting their summits. A geometrical figure is thus obtained which Oresme calls the *linear* configuration of the quality or 'form' in question. A similar construction projected horizontally into the third dimension yields the figure of a *qualitas superficialis*. We need not follow Oresme in his ingenious development of this conception, which leads him to an implied regret that he has no fourth dimension at his disposal in order to represent the *qualitas corporalis*.[3]

The theoretical discussion of the technique of graphing the latitude of forms, as we have summarized it, occupies the first twenty-one chapters of Part I in the *Tractatus*. The rest of Part I (chapters 22 to 40) contains applications of the technique to the study of 'permanent' or, as we might say, static phenomena. It is this section of the *De configuratione qualitatum* which no one appears to have used, and which we must presently return to examine. Part II, the next division of the *Tractatus*, like Part I, falls into two main sections. Chapters 1 to 10 continue the theoretical discussion with reference to the study of motion and velocity; they have been used by Duhem, Wieleitner and Borchert. Then follow some thirty chapters detailing the application of the configuration principle to 'res succesivas'

[1] On the 'Calculator' Richard Suiseth see Thorndike's chapter in *Magic and experimental science*, III, 370–385. Thorndike states that a critical edition of this influential work is to be desired. The *Calculationes* have been studied by Carl Boyer, *The concepts of the calculus; a critical and historical discussion of the derivative and the differential* (New York, 1939), pp. 69–79.

[2] How the terms 'latitudo' and 'longitudo' came to be used in this connection is by no means clear. The suggestion that they may have been derived from geographical coördinates is rejected by Wieleitner, 'Der *Tractatus de latitudinibus formarum*,' p. 135. Wieleitner seems to favor a derivation through the purely philosophical tradition. It seems to me, however, that the possibility of an influence from scientific terminology is not excluded, if not from geography, at least from astronomy. Thus we find that 'degrees' and 'minutes' were used in the measurement of qualities and virtues by Walter of Odington early in the fourteenth century; cf. Thorndike, *Magic and experimental science*, III, 130–131, 683–684. Another possible influence on Oresme may be seen in the so-called *mensula Pythagorae* or multiplication table from one to ten, shown as a square with sides labelled 'longitudo' and 'latitudo.' A facsimile of such a table, emphasizing the diagonal formed by the square numbers (1, 4, 9, etc.), is published from the 1488 edition of Boethius' *Arithmetica* by Dr Sarton in 'The scientific literature transmitted through the Incunabula,' *Osiris*, V (1938), 138.

[3] Part I, ch. 4; cf. Duhem, *Études*, III, 388. There is a passage on the same point in the *Questiones super Geometriam Euclidis*, *Ms.Vat. lat. 2225*, f. 94r. Cf. also H. Wieleitner, 'Zur Frühgeschichte der Räume von mehr als drei Dimensionen,' *Isis*, VII (1925), 486–489.

such as sound and the production of magical effects. It is from this section, very largely, that Professor Thorndike derives his important chapter on Oresme's view of Nature. Part III, concluding the *Tractatus*, comprises only thirteen chapters, but since they deal with scientific topics such as measurement and infinity, they have been transcribed and studied by Duhem and Wieleitner.

From this analysis, then, it is apparent that the *Tractatus de configuratione qualitatum*, despite the seeming irrelevance of the section on magic, presents a definite unity. It is devoted to the establishment of a new graphic method of representing 'qualities,' and to the development of a number of possible applications.

Now what is the contribution of the neglected chapters at the end of Part I? In large measure they are devoted, as we have seen, to the application of the new diagrammatic principle to the study of 'res permanentes.' There are a number of curious and original ideas scattered through this section. For the moment, however, we shall confine our attention to a single point raised in chapter 22, which follows immediately after the close of the section transcribed by Duhem and published by Wieleitner.

It is manifest, Oresme declares, that bodies in their natural actions (using the term in the Aristotelian sense) may differ 'according to the variety of their figures, wherefore the ancients, supposing bodies to be composed of atoms, stated that the atoms of fire were pyramidal by reason of their strong sharpness; and hence, according to the diversity of the pyramids, bodies are able to pierce in greater or less degree . . . '[1] What is the significance of this allusion to the atomism of classical antiquity?

The persistence of atomistic notions in mediaeval thought was pointed out nearly 50 years ago by Kurd Lasswitz.[2] The principal source from which they were derived was undoubtedly the Aristotelian corpus. For although Aristotle was a firm opponent of atomism, his thorough intellectual habits, led him to present a reasonably detailed — if not quite fair — account of the view which he was undertaking to destroy. It was largely through passages in the *Physics*, *De Caelo*, *De Generatione et Corruptione* and *De Anima*, that the notions of Democritus and Leucippus were preserved — embalmed, one might say, like bees in amber — for future ages to consider. The fascination which they exerted on the schoolmen is apparent in numberless discussions of such problems as the *horror vacui*,[3] the persistence of the elements in substantial change,[4] and the infinite divisibility of the continuum.[5]

[1] Florence, Biblioteca Laurenziana, *Ms. Ashb. 210*, f. 108r, 'Manifestum est corpora in actionibus suis diversimode posse (a word is obviously missing here, possibly imaginari) secundum varietatem figurarum corporum eorundem, propter quod antiqui ponentes corpora componi ex athomis dixerunt athomalia ignis fore piramidalia propter eius acuitatem fortem, unde secundum diversitatem piramidum possunt corpora magis aut minus pungere . . . '

[2] *Geschichte der Atomistik vom Mittelalter bis Newton*, 2 vols (Hamburg and Leipzig, 1890). This work is certainly one of the most brilliant and original attempts at synthesis in the field of the history of science. Despite its age it has suffered little from subsequent research; it was deemed worthy of re-edition without benefit of revision in 1926. [3] *Ibid.*, I, 201–208. [4] *Ibid.*, I, 235–254.

[5] *Ibid.*, I, 186–201. Cf. also E. Stamm, '*Tractatus de continuo* von Thomas Bradwardina,' *Isis*, XVI (1936), 13–32.

Although nearly all the scholastic philosophers, including such august figures as Aquinas and Scotus, were thus fully acquainted with classical atomism, with few exceptions they agreed in rejecting the doctrine. In part this rejection was motivated by respect for the authority of the Philosopher and for the cogency of his arguments. In part it sprang from dread of the materialistic implications of the Democritean physics, and of the heterodox conclusions to which it inevitably led.

The force of both of these restraining considerations was greatly weakened during the fourteenth century. It was natural that the critical and skeptical bias of nominalism should incline Occam and some of his followers to a sympathetic scrutiny of the arguments for atomism which Aristotle had undertaken to refute.[1] In Occam himself this tendency was only implicit. The keen edge of his 'razor' by slicing away the distinction between substance and accident laid bare an inner core of materialism which was eventually to prove fatal to Christian philosophy. Bold minds did not hesitate to draw perilous conclusions, and these in turn were swiftly met with the defensive weapon of ecclesiastical condemnation. In 1346 Nicolas d'Autrecourt, the worst offender, was compelled to burn his writings publicly, and to recant his radical theses of which more than one was tainted with atomism.[2]

The impact of this condemnation might well have discouraged further traffic in such dangerous notions. And yet there is evidence that atomism continued to attract attention at the University of Paris, and precisely in the intellectual circles where Oresme must have moved. We learn from Jean Buridan, twice rector of the University, and a close associate of Oresme, that there were those in his day who held an ancient opinion of the pre-Aristotelians, viz., that there was no such thing as an 'accident,' and that matter, 'taliter et taliter figurata vel formata,' constituted the whole entity of natural things.[3]

Is it possible that this reference to atomism by Buridan, who was himself hostile

[1] K. Michalski, 'La physique nouvelle et les différents courants philosophiques au XIV^e siècle,' *Bulletin international de l'Académie Polonaise des Sciences et des Lettres*, classe de philologie, classe d'histoire et de philosophie (1927), pp. 158–164. This, and other studies by Michalski, constitute perhaps the most important recent contribution to the history of fourteenth-century philosophy.

[2] J. Lappe, *Nicolaus von Autrecourt, sein Leben, seine Philosophie, seine Schriften* (*Beiträge zur Geschichte der Philosophie des Mittelalters*, IV, 2: Münster, 1908), pp. 29–31. Cf. also the article 'Nicolas d'Autrecourt' by P. Vignaux in the *Dictionnaire de théologie catholique*, XI, i (Paris, 1933), cols 561–587. — The influence of Democritean atomism on the development of the notion of *impetus* in the fourteenth century is stressed by F. Enriques, *Il significato della storia del pensiero scientifico* (Bologna, 1936), pp. 56–63. Enriques, in a criticism of Duhem's 'objectivity, declares that the latter has misinterpreted the origins of the *impetus* concept, and as a result has been led to a false evaluation of the achievement of Galileo.

[3] Michalski, *op. cit.*, p. 161; the passage occurs in Book III, chapter 7 of a commentary on the *De Anima* (*Ms. Bruges 477*, fol. 293^r). The entire text of Michalski's quotation is as follows: 'Unde fuit una opinio antiqua, quae posuit, quod nullum esset accidens . . . et ista opinio fuit ante Aristotelem . . . Unde ista opinio imaginabatur, quod ipsa materia taliter et taliter formata vel figurata et etiam ista opinio tenebat, quod entium naturalium materia esset tota entitas. Unde istam opinionem quidam post tempore Aristotelis resumpserunt et hodierno tempore adhuc tenent, quod nullum accidens et res distincta a substantia.'

to the doctrine, was occasioned by the writings of Oresme? Or was Oresme merely echoing a tradition which had persisted at the University despite the condemnation of 1346? Unfortunately the evidence at hand does not permit of a positive answer. We shall confine ourselves, therefore, to the relation between the passage quoted above, and the general context of the *Tractatus de configuratione qualitatum*.

We may begin with a note of caution. The reference to classical atomism at the beginning of chapter 22 stands in isolation. Although the same notion is applied to the study of natural 'passion' in chapter 23, there is no other direct allusion to atoms in the treatise. This reticence may indicate either that Oresme attached little importance to the discussion, or else that he was wary of ecclesiastical censure.[1] On the other hand it is difficult to escape the impression that Oresme regarded the matter as of more than casual interest. For it is precisely at this point, I believe, that the real novelty of his whole approach may be detected.

Taking our cue from Buridan's statement that there were those who believed matter to be 'figured or formed thus and so' on the basis of views held prior to Aristotle, we may turn to the text of the *De Generatione et Corruptione* (I, 2, 315b, 6–16).[2] Aristotle is discussing the views of his predecessor concerning growth, alteration, action and passion. For the most part, he declares, these earlier explanations have been unsatisfactory. Only one deserves serious consideration:

> Demokritos and Leukippos, however, postulate the 'figures' and make 'alteration' and coming-to-be result from them. They explain coming-to-be and passing-away by their dissociation and association, but 'alteration' by their 'grouping' and position. And since they thought that the truth lay in the appearance, and the appearances are conflicting and infinitely many, they made the 'figures' infinite in number. Hence — owing to the change of the compound — the same thing seems different and conflicting to many people; it is 'transposed' by a small additional ingredient, and appears utterly other by the 'transposition' of a single constituent. For Tragedy and Comedy are both composed of the same letters.

Two passages from the *De Caelo* also merit attention: According to the same thinkers, 'the atoms differ in figure, and all figures are composed of pyramids, rectilinear in the case of rectilinear figures, while the sphere has eight pyramidal parts' (III, 4, 303a, 30–303b, 2). 'Those who start from fire as the single element, while avoiding this difficulty, involve themselves in many others. Some of them give fire a particular shape, like those who make it a pyramid . . . The reason given may be — more crudely — that the pyramid is the most piercing of figures as fire is of bodies' (III, 5, 304a, 8–13).

There can be little doubt that these passages must have been in Oresme's mind when he wrote the two chapters on the influence of 'configuration' in natural actions and passions. In any study of Oresme, whether as a scientist or as a politi-

[1] On this point cf. Thorndike, *Magic and experimental science*, III, 469–471.

[2] The three passages cited are taken from the *The works of Aristotle translated into English*, edited by W. D. Ross: Vol. II, *De Caelo*, translated by J. L. Stocks; *De Generatione et Corruptione*, translated by H. H. Joachim (Oxford, 1930).

cal and economic theorist, we must keep in mind the fact that his intellectual foundations were deeply embedded in the Aristotelian corpus. At least half of his writings take the form of commentaries on Aristotle's works, among them the two which we have just cited.[1] We must also recall that Oresme belonged to a generation which had mastered virtually the entire substance of the Stagirite's teaching. The commentator of this late period, therefore, was either reduced to the sterile repetition of familiar points, or impelled to wrest new and subtler interpretations from his text. To a thinker as fertile and ingenious as Oresme the second alternative was naturally the more attractive.[2]

We may say, then, that the atomistic explanation of the structure of natural things was suggested to Oresme primarily through his study of Aristotle. To a large extent it partook of the character of paradox, a notion to be played with, like the diurnal rotation of the earth, 'par esbatement.'[3] And yet we may suspect that there was something more. The genius of Oresme's mind lay in its facility for combining ideas, for detecting inter-relations between fields of thought which more pedestrian thinkers had failed to note. It is this impulse toward the unification of scattered fragments in the study of nature which led Oresme to compose the *Tractatus de configuratione qualitatum.*

The term 'configuration' itself gives us, I believe, the key to Oresme's intuition. We see that it came to him from two main sources. First, the study of various mathematical works, especially Euclid, had led him to imagine a means of representing concretely that 'latitude of forms' which in earlier and contemporary writings had been essentially logical and abstract. In this sense 'figure' constituted a graphic pattern which aided the student to visualize the order and intensity of properties in natural objects, and the character of the process by which they underwent variation. 'Figure' in this sense, however, bore no direct relation to the actual distribution of parts, or to the causal mechanism by which change took place. It was an aid to the study of nature, not a rationale of its inner structure.

The other sense of the term 'figure' appears to have been that which was sug-

[1] Oresme prepared a Latin commentary on the *De Caelo*, also a French translation and commentary; Borchert, *op. cit.*, pp. 18, 20. Borchert also lists a commentary on the *De Generatione et Corruptione* as among the lost works of Oresme. I have found a manuscript copy of this work in the Biblioteca Nazionale, Florence, *Ms. conventi soppressi H IX 1628*, fols. 1r–76v. It is unfortunate for our understanding of Oresme's scientific development that no copy of his commentary on the *Physics* appears to be known.

[2] This tendency is particularly apparent in the development of Oresme's views on the immobility of the earth. Step by step from his early commentaries on Aristotle's *Meteorica* and Sacrobosco's *Sphera* to the Latin and the French *De Caelo* we see him pass from a conservative to a radical attitude toward the arguments for a diurnal rotation of the earth; cf. Borchert, *op. cit.*, pp. 66–76, and Michalski, *op. cit.*, pp. 140–155, giving the views of Buridan, Albert of Saxony and other fourteenth-century scholastics, who on the whole adhered to the traditional position of Aristotle.

[3] The cautious, and perhaps ironical tone which Oresme adopted when treading on perilous theological ground may be illustrated from his apology for defending the thesis of the diurnal rotation of the earth: 'Et toutes voies ce semble de prime face autant et plus contre raison naturèle comme sont les articles de notre Foy, ou tous, ou plusieurs. Et ainsi ce que j'ay dit par esbatement en ceste matère peut valoir à confuter et reprendre ceuls qui vouldroient notre Foy par raisons imputer,' Duhem, 'Précurseur de Copernic,' p. 872.

gested in the passage from the *De Generatione* quoted above. Whether or not the original atomism of Democritus was in fact both 'geometrical' and 'physical' — a point which is still in dispute — to Oresme it certainly suggested the possibility that the two orders might be combined, a possibility which Aristotle had denied.[1] The opening lines of the *Tractatus* appear to warrant such an interpretation: 'Every measurable thing except numbers is imagined in the manner of a continuous quantity. Therefore it is fitting to imagine for its measurement points, lines, and surfaces or the properties of those things, in which, as the Philosopher says, measure or proportion is immediately to be found . . . And whether or not there be such things as indivisible points, nevertheless it is appropriate to imagine them in mathematical fashion, in order to know the measure of things and their proportions.'[2]

The problem of interpreting this passage is rather delicate; there are significant differences among the manuscripts as to the precise wording, which further shade its meaning in the direction of ambiguity.[3] Nevertheless when these lines are taken together with those quoted from chapter 22, it seems that they assume a very broad significance. Without forcing, I believe we may say that they represent a conception, which, however limited and confused, is substantially novel. What Oresme is groping toward is a theory of the relation between the actual order, shape and disposition of the imperceptible particles which make up natural objects, and the geometrical figures which will be obtained when their active and passive qualities are represented according to their extension and intension. In other words the shape and pattern of the diagram bear an immediate one-to-one correspondence, not only to the actual shape of the object in question and its constituent parts, but also to the various properties which it possesses.

Oresme's theory of configuration is indeed halting and obscure. Although supported by specific instances, these are hardly of a nature to compel our assent. They are either conjectural and abstract, or fanciful and remote. They fail to provide any sanction of experimental verification according to modern conceptions. Moreover Oresme himself concedes that he has presented nothing more than an hypothesis. Natural phenomena, he admits, may well be explainable in other terms than the 'configuration' of particles and velocities. It is sufficient for him if such an explanation be possible.[4]

[1] Cf. S. Luria, 'Die Infinitesimaltheorie der antiken Atomisten,' *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik*, Abt. B, Bd. II, Heft 1 (1933), pp. 106–185. Luria maintains that Aristotle did not understand the essential character of Democritean atomism.

[2] Florence, *Ashb. 210*, f. 102^{r}, 'Omnis res mensurabilis exceptis numeris ymaginatur ad modum quantitatis continue, ideo oportet pro eius mensuracione ymaginari puncta lineas et superficies aut istarum proprietates in quibus, ut vult Philosophus, mensura seu proporcio per prius reperitur . . . Et si nichil sint puncta indivisibilia aut linee, tamen oportet ea mathematice fingere pro rerum mensuris et earum proporcionibus cognoscendis.'

[3] Thus Paris, *Ms. lat. 14579*, f. 18^{v} as quoted by Borchert (p. 93) gives the word 'vel' instead of 'nichil' in the passage quoted above. In my translation the phrase 'whether or not there be such things' appears to take account of both these readings.

[4] *De configuratione qualitatum*, I, 23 (*FL Ashb. 210*, f. 108^{v}): 'Si autem per istam vel cum ista causa aliquis velit in similibus aliam causam vel alia assignare, de hoc non contendo; sufficit enim mihi quod ista quandoque possit habere locum.'

Now if our analysis is correct, it is apparent that it is susceptible of a fairly radical interpretation. If we were in the mood of Duhem, looking for a precursor, we might say, here is the forerunner of Descartes indeed, not merely as the inventor of analytical geometry, but as the initiator of the conception that all natural phenomena may be mathematically reduced to magnitude, figure and motion![1]

So far as I am aware, no such claim has ever been made for Oresme, and I have no intention of advancing it myself. Nevertheless a claim of almost equal scope has recently been asserted. In a brief but thoughtful passage of his *Geschichte der Naturphilosophie* (1932) Hugo Dingler has assigned to Oresme a position of pivotal significance in the history of science.[2] According to Dingler the speculative tradition of the Greeks had achieved one outstanding triumph; it had succeeded by a tremendous intellectual effort in establishing a solid, rational basis for knowledge of the constant, eternal and unvarying principles of Being. In spite, or because of their success in this endeavor the Greeks had never succeeded in mastering the other fundamental aspect of reality, the sphere of Becoming. It remained for modern science to perfect and exalt the conception of the dynamic and the variable in Nature. And according to Dingler it was Oresme with his reduction of all phenomena to a successive flux — *formae fluentes* — measured against the invariant coördinate of time, *primum omnium successivorum*, who took the decisive step.

Substantially this thesis is derived from that of Kurd Lasswitz, as Dingler himself indicates. Lasswitz had seen the process by which modern causal-mechanistic science overcame Greek teleology, as the substitution of the principle of 'variability' for that of 'substantiality.'[3] The precipitating cause of that successful transformation he ascribed to the convergence of atomistic and corpuscular notions of matter with certain aspects of Neoplatonic philosophy during the fifteenth century.[4] The pivotal figure from which this new orientation took its start was Nicholas of Cusa. Lasswitz did, indeed, assign a rôle in this process to Oresme, but having at his disposal only the fragmentary material assembled by Curtze, he was restricted to the consideration of Oresme primarily as a mathematician.[5]

[1] Cf. E. A. Burtt, *The metaphysical foundations of modern physical science* (New York, 1927), Ch. IV, 'Descartes.'

[2] *Geschichte der Naturphilosophie* (*Geschichte der Philosophie in Längsschnitten*, VII: Berlin, 1932), p. 75; also 'Über die Stellung von Nicolaus Oresme in der Geschichte der Wissenschaften,' *Archeion*, XI (1929), suppl. pp. xv–xxiii. So far as I am aware Dingler's interpretation of Oresme is not based upon original research, but rather upon a synthesis of existing secondary material; it is nonetheless remarkable as an attempt to interpret the history of science through the history of philosophy.

[3] Lasswitz, *op. cit.*, I, 269–274; cf. such passages as the following with the view of Dingler, 'In allen Erscheinungen besteht das Reale derselbe in ihrer Tendenz zur Fortsetzung in der Zeit' (271).

[4] The importance of Neoplatonism in producing the modern mathematical physics is stressed by Burtt, *op. cit.*, Ch. II. Against this may be set the criticism of E. W. Strong, *Procedures and metaphysics; a study in the philosophy of mathematical-physical science in the sixteenth and seventeenth centuries* (Berkeley, California, 1936). Strong sees the advance of mathematical science in sixteenth-century Italy as being inspired by the study of Euclid, rather than of 'metamathematics' of the Pythagorean type. Both Burtt and Strong, I believe, have weakened their accounts by failure to examine the fourteenth-century mathematical tradition, e.g., such works as the *Geometria Speculativa* of Bradwardine and the treatise of Oresme.

[5] Lasswitz, *op. cit.*, I, 281–282.

Had Lasswitz been able to study the *Tractatus de configuratione qualitatum*, he might well have been led to an estimate fully as flattering as that of Dingler.

We see, then, that there is substantial authority for crediting Oresme with an outstanding scientific achievement. It is noteworthy that even Professor Thorndike concedes that he may have occupied a pivotal position between the Greeks and modern science.[1] The dimension of Oresme's thought which Duhem has indicated is seen to possess reality, even though its precise extent must be revalued. We may now enquire whether the second dimension — the quasi-magical view of Nature which Thorndike has outlined — can also be given further specification.

We have seen that the graphic technique and the corpuscular conception of matter, taken in isolation, invest the *Tractatus de configuratione qualitatum* with a singularly modern appearance. If we return to the treatise with an eye for the concrete applications, we are immediately struck with a different impression. We have seen that Oresme was wont to illustrate most of his general points with specific examples. As in other contemporary treatises of similar nature, these are usually selected from the conventional scholastic repertory — alteration in whiteness, luminosity, degree of rarefaction, resistance or velocity.[2] These in turn are largely derived from Aristotle himself. For the most part they are of a naïve character, invested with a specious affectation of mathematical precision; they are not based upon what we should call experiment designed to check and verify an hypothesis. What is remarkable in Oresme's treatise is the contrast between the boldness and ingenuity with which he extends the applications of his method, and the generally trivial or far-fetched character of his examples. As we watch him push forward, inspired by a restless imagination and an insistent logic, we realize that the second dimension of his thought is fully as subtle and complex as the first.

The curious penumbra of pseudo-science which permeates the *Tractatus de configuratione qualitatum* is particularly noticeable in the later chapters of Part I. In chapter 24 Oresme discusses the variations of 'natural virtues' according to their configurations. As examples he cites the contrasting activity and virtue of the natural heat in the lion and the ass, or the particular configuration which makes conception possible in the female womb.[3] In the following chapter he in-

[1] *Magic and experimental science*, III, 492, '. . . the attempt of Oresme and Henry of Hesse to apply the current fourteenth century "art of latitudes," theoretical as it was, to the solution of natural problems must be regarded, like the *Calculationes* of Richard Suiseth, as an important first step towards the development of modern mathematical method and its application to scientific questions.'

[2] Illustrations of this type abound in the so-called 'sophismata physicalia' of the fourteenth century. These logical exercises which grow out of the study of the 'syncategoremata' were particularly popular at Oxford; Suiseth's *Calculationes* are closely related to the type. C. Prantl, who pioneered this field in his *Geschichte der Logik im Abendlande*, Vol. III (Leipzig, 1867), saw in it nothing but barren waste. Michalski, who is gifted with greater historical perception, suggests that these sophistical discussions, originating in mere grammar, lead through such conceptions as the 'de incipit et desinit,' and 'maxima' and 'minima' to the actual study of physical phenomena; 'Le criticisme et le scepticisme dans la philosophie du XIV^e siècle,' *Bulletin international de l'Académie Polonaise*, cl. de philol., cl. d'hist. et de philos. (1925), pp. 59–62.

[3] *FL Ashb. 210*, f. 108^v, 'Rursus oportet huiusmodi qualitatem secundum alias et alias figuraciones predictas habere diversas virtutes et varias actiones . . . verbi gracia calor naturalis leonis est aliter

troduces the familiar instances of mandragora and the human fear of snakes. These may be better explained through configuration of occult but strictly natural virtues, than through the incorporeal spirits of the necromancers.[1] In chapter 26 Oresme develops still another consequence of his theory. Figures, in addition to possessing active and passive virtues, also display the quality of beauty or its opposite.[2] Precisely as some musical intervals are more consonant than others, so the pattern of natural qualities within a given species is susceptible of intension and remission in the degree of pulchritude and nobility. We have thus approached an aesthetic conception of nature strongly reminiscent of Pythagoreanism and Platonism. But Oresme does not leave us here. Not only are configurations variable in their approximation to perfect harmony, rationality and beauty; they are also subject to a principle of attraction and repulsion, or as Oresme puts it, natural 'amicitia' and 'inimicitia.'[3] Through the configuration of the due proportion of qualities in each species, we may explain the enmity between the wolf and the sheep, or the friendship between man and dog!

By this point Oresme's theory has swept him far beyond the corpuscular materialism implied in chapters 22 and 23. The infinite variety of 'figures,' which, as we have seen, was impressed upon him with the notions of Democritus, now serves as an explanation of psychological phenomena such as the relativity of pleasure and pain.[4] The same principle is used to account for the 'difformity' of the sensitive and the cognitive faculties, and ultimately even for the soul's capacity to behold visions and see into the future as in a mirror, clearly or darkly, in true or in distorted aspect.[5]

We must not suppose that these discussions of configuration in the 'res permanentes' are of an accidental or subordinate nature. As we have noted the second half of Part II contains an even more extensive application of the principle of configuration to the study of 'res successivas.' In chapters 11 and 12 the 'pulchritude of velocities' and the commensurability of celestial motions are discussed.[6]

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activus et alterius virtutis quam calor naturalis asini vel leonis (?), non solum quia est intensior vel remissior vel aliqua tali differencia, sed quia secundum intencionem aliter et dissimiliter figuratur . . . Et est possibile quod hec sit una de causis quare nullo artificio potest alius calor quam seminalis taliter temperari quod inde possit homo sine propagacione seminis generari, quia videlicet non solum ad hoc requiritur temperamentum secundum intencionem et remissionem, sed cum hoc etiam secundum configuracionem predictam que solum in mulieris utero non potest facere.' I have cited this passage *in extenso* as a typical example of the way in which Oresme advances his conjectures.

[1] *Ibid.*, f. 109^{r}.

[2] *Ibid.*, 'Quamvis Vitulo in 4^{0} sue Perspective multa de pulcritudine dicat et pauca de pulcritudine figurarum, dico tamen pro nunc, sicud in theorica musice demonstratum est, quod quedam consonancie sunt aliis perfectiores et nedum in sonis, sed eciam in aliis, ymo quedam sunt simpliciter pulcre et secundum theorice, licet pauce ut vult Aristoteles in *De sensu et sensato*, sic eciam certum est quasdam figuras corporeas alias excellere in pulcritudine et esse simpliciter nobiliores et perfectiores . . . '

[3] *Ibid.*, f. 109^{v} 'Iste scilicet due cause, scilicet habitudo proporcionum qualitatum naturalium et habitudo configuracionum, concurrunt ad amiciciam vel ad inamiciciam naturalem unius speciei ad alteram, cum quibusdam aliis causis que sunt preter propositum presens.'

[4] *Ibid.*, f. 110^{r}, Part I, ch. 30, 'De causis delectacionis sensus et ymaginacionis.'

[5] *Ibid.*, ff. 110^{r}–112^{v}, Part I, chs 31–40, especially ch. 33, 'De causis visionum anime.'

[6] *Ibid.*, f. 115^{v}. The problem of commensurability appears to have fascinated Oresme. The *Ques-*

A group of eight chapters (15 to 22) outlines a theory of musical aesthetics in terms of configuration.[1] This leads by a not illogical transition to the lengthy discussion of magic which Professor Thorndike has summarized. Part II, like Part I, concludes on a psychological theme, the 'difformity' of spiritual pleasures and pains. Configurations of consonance, harmony and concord determine the pattern of joy and delectation eternally experienced by the blessed angels, precisely as the disposition of particles determines the degree of receptivity to heat in a tin basin![2]

This, then, is the second dimension of Oresme's thought. It is a bewildering agglomeration of optics, music, aesthetics, occult virtues, demonology, natural magic and psychology. It is pieced together from the most disparate sources, from Boethius and Vitelo, from Platonic and Neoplatonic texts, from Avicenna and Algazel, from occult literature, and even from Aristotle himself.[3] How are we to regard this second dimension in comparison with the first? May we say that the one represents the 'man of his age,' the other the 'precursor'? If so, where shall we look for a third dimension which will integrate and give relief and substance to the other two?

A full answer to these questions cannot be given in a paper of this scope. The complexity of the problem to which we have directed our attention — the transition from mediaeval to modern science — forcibly suggests that no unitary solution is now possible. A satisfactory conception of that particular process — and in all probability of similar transitions in other ages — can only be achieved by simultaneously following a number of separate, non-converging types of approach. One of these types is that of *Ideengeschichte*, the isolation by a subtle analysis of irreducible components of thought which persist through various ages and cultures.[4] Another approach is that of the sociologically trained historian who sees

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tiones super Geometriam Euclidis, as we have seen, devote considerable attention to the proportion of the side of a square to the diagonal. Oresme also wrote a *Tractatus de commensurabilitate* (or *incommensurabilitate*) *motuum celestium* which resolves itself into an allegorical debate between Arithmetic and Geometry in which the latter stresses the beauty of the irrational proportion and the cosmic plenitude which it implies; cf. Thorndike, *Magic and experimental science*, III, 404–406.

[1] *FL Ashb. 210*, fols. 116^{r}–119^{r}; this discussion appears to have taken its inspiration from Boethius.

[2] *Ibid.*, f. 125^{v}, '. . . habet itaque creatura beata simul duas delectaciones vel plures, quarum una est principalior et simpliciter uniformis et quasi gravior sicud tenor in cantu. Alia vero vel alie sunt difformes difformitate pulcerrima consonancia armonica et concordi, sive igitur sit alia melodia sicud tactum est capitulo 24, sive non.'

[3] It lies beyond the scope of the present paper to trace the influences of these sources. We may content ourselves with pointing out the influence of Vitelo, not only on the optical and aesthetic side of Oresme's discussion, but also on the demonological; cf. A. Birkenmaier, 'Studya nad Witelonem,' *Archiwum do Badania Historji Filozofji w Polsce*, II, i (1921), 1–149. It is unfortunate that the ordinary scholar can derive little profit from this important study, apart from the Latin texts which it contains, e.g., Oresme's *Questiones Meteororum*, III, 19 (pp. 53–70). Tantalizingly brief résumés of Birkenmaier's studies are given under the heading 'Etudes sur Witelo' in *Bulletin international de l'Académie Polonaise*, cl. de philol., cl. d'hist. et de philos. (1918), 4–6; (1919–1920), 354–359, 359–360; (1922), 6–9.

[4] This approach is illustrated with singular brilliance in A. O. Lovejoy, *The Great Chain of Being; a study of the history of an idea* (Cambridge, Mass., 1936).

in the cumulative weight of statistics the best assurance for valid generalizations about the past.[1]

The approach which Oresme offers to us is of a different character. Because of the complexity, the heterogeneity and indeed the pervading obscurity of his thought, he baffles the analyst who would reduce him to a single term. Because of the magnitude of his talent, he deserves heavier weighting than the statistician is prepared to give. For Oresme may be said to belong to a special category of mankind, to that select group which we are tempted to characterize as the 'virtuosos.'

Now it is a serious weakness in the modern historian's equipment that he has no satisfactory technique of coping with individuals of this type. He flutters between the old 'transcendental genius' conception — which really underlies Burckhardt's Renaissance man — and the Procrustean-bed technique of the statistician. It is this fact which accounts for the constant guerrilla warfare between the historian who seeks 'precursors' and his colleague the 'debunker.'

We have seen this dichotomy in the two dimensions of Oresme, on the one hand a man deeply rooted in the traditional philosophy, the science and the pseudoscience of the Middle Ages, on the other hand the holder of an astounding number of 'precursorships.' The third dimension which I am proposing stresses neither his dependence on the age nor his transcendence. It emphasizes rather the importance of a special kind of intuition or 'bright idea' which we may properly call a 'hunch.'[2] Oresme's scientific achievement is a texture of 'hunches' with all the good and bad that the term implies, shrewd common-sense, a knack of focussing the dispersed ideas of other minds, a certain prophetic vision, and a considerable arbitrariness in disposing of facts. Men of this type have always existed in limited numbers; they were relatively abundant in the age which we have been considering. Roger Bacon, Ramon Lull, Nicholas of Cusa, Leonardo, Paracelsus, Bruno and Francis Bacon establish an almost unbroken chain of 'virtuosos' from the Middle Ages to modern times: and of course there were others. What is common to them all, and with them Oresme, is the passion with which they strove to reduce man's search for knowledge to a principle of unity leading to mastery of Nature.[3]

[1] Cf. L. Rosenfeld, 'Remarques sur la question des précurseurs,' *Archeion*, XXI (1938), 74–83. According to Rosenfeld a new idea can be imposed upon society only as the result of a strenuous conflict with an existing tradition. No matter how brilliant and original he may be, a thinker who fails of success in this struggle is merely a 'precursor.' He is without significance in the history of social progress which is governed ultimately by statistical laws.

[2] The significant rôle of the 'hunch' was also stressed by my colleague G. de Santillana in a paper on Machiavelli's conception of history which was presented at the same session of the History of Science Society as my own.

[3] It is inevitable that striking parallels will be found in these attempts. Thus we may detect in Oresme's whole conception of natural action through 'configuration' a close dependence on the so-called 'light metaphysic' of Grosseteste and Roger Bacon. Bacon's favorite theory, the *multiplicatio specierum*, leads through Vitelo to a sort of optical mechanics, a science of the 'modus actionum formarum et omnium virtutum caelestium et naturalium,' which undoubtedly influenced Oresme; cf. Birkenmaier, 'Etudes sur Witelo,' (1919–1920), p. 356. Cf. also the parallel to Oresme's 'amicitia' and 'inimicitia' to be found in Nicholas of Cusa's *De staticis experimentis*. In this case the existence of these principles is to be discovered not through a study of 'configuration' but through measurement of weight! The parallel is sufficiently striking to warrant quotation. 'Immo generaliter omnes har-

It is through this striving that their place in the history of science comes to bear a close correspondence to their place in the history of culture. I have singled out Oresme because he is the least known, though not the least important member of this select group. Coming precisely at the critical point where the linkage between mediaeval and modern philosophy must be sought, he invites further study from the specialist and from the general historian.

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monicae concordantiae per pondera subtilissime investigantur. Immo pondus rei est proprie harmonica proportio ex varia combinatione exorta. Immo amicitiae et inimicitiae animalium et hominum eiusdem specei ac mores, et quidquid tale ex harmonicis concordantiis et ex contrariis dissonantiis ponderatur. Sic et sanitas hominis harmonia ponderatur atque infirmitas; immo levitas et gravitas, prudentia et simplicitas et multa talia, si subtiliter advertis,' *Nicolai de Cusa, Opera omnia, jussu et auctoritate Academiae Litterarum Heidelbergensis ad codicem fidem edita*: T. V. *Idiota de staticis experimentis, edidit Ludovicus Baur* (Leipzig, 1937), p. 137.