Notes to Chapter I

(1) This very loose cover phrase, meaning little enough without further qualifications, is selected here for its negative virtue of avoiding a too-precipitate definition of a movement — some of the complexities of which it is the purpose of this study as a whole to explore — which would in its narrowness be inevitably misleading. The terms used may, in a general way, be justified, however, by some expansion. The intellectual current referred to, and in which Dee has his place, was, it is true, hardly a "philosophy" in the sense that would imply that it flourished as any uniformly regarded, explicitly forumalated, isolable and complete, systematic body of doctrine. Rather, it exhibited itself in the main, and only so as a whole, through a multitude of partial and particular — frequently idiosyncratic — expresssions by individual thinkers active in numerous, seemingly disparate fields; hence it seems to take on a bewilderingly protean variety of forms as a consequence of such differing selections of and the accompanying changes of emphasis on elements from this philosophy (that is, which organically pertain to it viewed as a whole), and the widely differing types of subject matter with which it was brought into conjunction and applied as a more or less concealed organising framework. At the same time such manifestations have a unity in that there may be traced in them certain characteristic guiding cannons, and they are frequently to be found informed by characteristic, constantly recurring themes. Some of these the present introduction is designed to elucidate, and subsequent chapters, intended to illustrate as they functioned in a number of spheres. The increasing frequency of works in Dee's day that may properly be so analysed testifies to the way in which a number of their common basic assumptions were gaining currency in contemporary culture — though what were perhaps the fundamental reasons ultimately responsible for the directional unity discernable in such particular endeavours, was to find historically only gradual clarification or conscious recognition.

The movement is described as new, not in order to discount the importance of its very obvious classical or mediæval roots, or in disregard of such facts as that many of its exponents were largely obsessed with such themes as the discovery of the secret wisdom of the ancients, but only in respect of the wide extent, and previously unexampled fruitfulness, it attained at this time, and because it would seem to have been so regarded by the majority of those who adhered to it in any way; even when believing it to be a "revival" they proclaimed it as "new" in relation to contemporary thought. Dee and other such participants in it professedly and proudly looked upon themselves as "moderns" — in their novel opposition to many accepted teachings of the day, and seem to have consciously thought of themselves as reformers; they are on occasion as confident and enthusiastic as Francis Bacon in envisaging a new era of social, scientific, and often religious progress, which the innovations they advocate will contribute to, or initiate. (A good example of the general spirit is provided by Hakewell, who sometimes quotes Dee in support of his views; especially his laudatory account of the "Renaissance" and its various stages from Paulus Jovius and Boccacio, whom he takes as its initiators onwards — an historical analysis curiously resembling that of nineteenth century historians — with his conclusion, "if we descend to a particular examination of the several professions, *Arts*, *Sciences* and *Manufacturies*, wee shall surely finde the prediction of the *Divine Seneca* accomplished; Multa venientis ævi populus ignota nobis sciet," and then quotes a pronouncement of Ramus — whose relations with Dee will be detailed later — "Majorem doctorum hominum & operum proventum soeculo uno vidimus, quam totis antea 14 Majores nostri viderant." *A Discourse Apologeticall* (p. 261). Its "vigour," to be gathered from its rapid spread and thw swift historical realization of its fruitful potentialities, which become ever increasingly apparent, was assisted by this attitude, but is chiefly due to the related factor that as a "philosophy" it proved sufficiently flexible to absorb and adapt itself tot he requirements of a number of contemporary features of the highest importance for the development of science — such as a relatively sudden, renewed interest in mathematical studies, and novel or unorthodox types of physical speculation — of these it was prepared to offer an adequate theoreticaly account, and one commensurate with the high value that individual specialists might attribute to them, and offered a congenial intellectual setting for their practise, while towards these older, more rigid systems showed themselves, at best, indifferent. Its "vigour" is also to be seen in the way such thinkers as Dee show themselves as acutely conscious of what they seem quite unequivocally to look on as a general development taking place in intellectual and more material fields, and put forward their doctrines as those best capable of keeping abreast of, or valuably

enriching, this process. Many schemes of educational reform can be associated with this particular current of ideas, and of the highest significance are the constant efforts it encouraged, as those of Dee and others, to convert as far as might be possible, what had hitherto been neglected as mere "craft" into "applied science" and to establish mutually beneficial relations between the speculative theoretician and the uninstructed practise of the artisan and others engaged in technical and constructive spheres.

(2) How quickly in some respects is graphically illustrated by Campanella's reception in France after his long imprisonment. Preceeded by a considerable reputation as the defender of Galileo, opponent of Aristotle, martyr to reform, on closer acquaintance a new generation of scientists found little worthy of respect in him. Both DesCartes and Cassendi so opposed in many respects, frankly despised him; Mersenne wrote of his disappointing meeting with him "ou j'ay appris qu'il ne nous apprendre rien dans les sciences" — and he was soon consigned to intellectual exile — socially feted and casting horoscopes — at the French court (Lenoble, *Mersenne où la Naissance du Mécanisme* p. 41 et seq.).

(3) See particularly E.G.R. Taylor *Tudor Geography* (1930); F.R. Johnson *Astronomical Thought in Renaissance England* (1937).

(4) F.R. Johnson reviewing *Tudor Geography* (Isis. XXIII. 1935 p.291).

(5) Huygens has been usually credited with the origination of this significant — since rapidly popularised analogy. Boyle writes (*Works* 1672. Vol. 5, p. 163) that the Universe is "like a rare clock such as may be seen at Strasbourg, where all things are so skilfully contribed that the engine eing once set amoving all things proceed according to the artificer's first design." However, the comparison would seem to have a much longer history; Mersenne developed the idea of God as the Watchmaker — in connection with proofs of his existence drawn from apparent cosmic design (Lenoble *Mersenne* p. 250 nl); Ralegh describes "Nature" as that system of laws infused by God into matter "having no other selfe ability than a Clocke after it is wound up by a mans hand hath" (*History of the World* I, 1, 10 p. 11), and the analogy makes an early and suggestive appearance in the opening chapter of a popular work of Christian Platonism by de Mornay that Philip Sydney translated (also in connection with the argument from design) (Sydney *Works* vol. 3, pp.267-8). Early uses are possibly not unrelated to the considerable interest shown by sixteenth century scientists and philosophers in the possibility of constructing a mechanical model of the Universe, based on accounts of Archimedes' "sphere." (References to this as one of the fruits of mathematical studies are almost innumerable. Dee quotes Cicero on this work of "Thaumaturgike," "For when Archimedes (sayth he) did fasten in a sphere, the mouynges of the Sonne, Mone and of the five other Planets, he did, as the God, which (in Timaeus of Plato) did make the world. That, one turnyng should rule motions most unlike in slownes, and swiftnes." *Preface* Aj^{v}). It is not the mere metaphor or the implied relations of God to the world that is distinctive and important about its use in the generation of Boyle and Huygens. These might equally well pertain to any ordered cosmology — such as that of the Averroists — which aimed to exclude the element of the miraculous, the irregular, the irrational, from nature, and indeed many attacks on physical astrology in Dee's day were made from the theological position that this science aimed to exhibit the universe as just such a fully determined system, such a self-sufficient machine as Boyle describes, leaving God no essential part to play in its general processes and operations (vide infra Ch. 3). But significant changes occur as regards the type of causation, the "intelligibility" and accessibility of the "mechanism" that is supposed to maintain his His cosmic system. The causal links in the Aristotelian picture — the transmissionof motion from the primum mobile — remained inevitably of an "occult" kind, unobservable, incalculable in detail, unknown, if not inconceivable in principle. Only in the mid-seventeenth century, if gravity were accepted as a physical force, able to act at a distance, which could be given exact mathematical expression, could such an analogy be regarded as holding good in a strictly "mechanical" sense, and the chain of causes and effects be thought of as exactly measurable in kind, and the whole system as mathematically representable, and throughout analysable and intelligible. (Descartes' plenum with its vortices provided another pattern of a similar kind, whose entire materiality made it even more preferable to many.) But this ideal is already significantly adumbrated in the systems of

mathematical neo-Platonists in an earler age. Dee, for example, in the *Aphorisms* of 1558 represents the universe as a closed mechanical system, its processes governed by the "emissionof species" from all entities, but particularly the heavenly bodies in it; these however he conceives of as physical forces, which may be if only indirectly, exactly measured, and their propagation is strictly geometrical, and he looks forward to a time when scientists might be able, combining theory and observation, exhaustively to describe the world in terms of mathematical law.

(6) Bolton: *Follies of Science at the Court of Rudolph II,* p.2.

(7) While it remains true that "the verification of a rationalistic scheme is to be sought in its general success, and not in the peculiar certainty or initial clarity of its first principles" (Whitehead: *Process and Reality* p. 10) such verification is frequently a lengthy historical process, distinct from and always subsequent to the original formulation and acceptance, though it too often intrudes on, and colours, the examination of the original motives and conditions which produced such schemes.

(8) Subsequent chapters will explore some of these interconnections, see also Lenoble's discussion; its theme, his comment after listing a number of the sciences considered almost as on equal level in the Renaissance — Mathematics, Theology, Physiognomy, Cabalah, Argyropeia etc. "Pour les hommes de ce temps ces 'connaissances' ne sont pas juxtaposées mais impliqueés, les unes dans les autres" (*Mersenne* p. 84).

(9) Hardin Craig: *The Enchanted Glass*, p. 14.

(10) Whitehead: *Process and Reality,* Pref. X.

(11) The argument of Strong's *Procedures and Metaphysics*, that science and mathematics developed even in the Renaissance entirely methodologically, and were only stifled and impeded by any contacts they made with the Platonism of the day, which is said to have no direct kinship with philosophies generated later when the implications of a successful mathematic were perceived, will be considered in detail in a subsequent study of Dee's *Preface*. The present introduction is designed only to set out and illustrate the point of view from which this study has been made, but for which, it is believed, later chapters provide much supporting evidence.

(12) *Vision of Piers the Plowman* ed. S. Keat, Oxford 1886 vol. 1, p. 300. B. Passus 10 p. 207-210 (omitted in 3rd version).

(13) *Advice to a Son* (1658) ed. Parry, London 1896, p. 14. "My Memory reacheth to the time," he says of Mathematics, "when the generality of People thought her most useful *Branches, Spells,* and her *Professors, Limbs of the Devil*."

(14) Blanché: *La Science Physique et la Realité* p. 11.

(15) *Essays* II, 12 "Et m'a l'on dict qu'en la Géometrie (qui pense avoir gagné le haut point de certitudes parmy les sciences). Il se trouve des demonstrations inevitables subvertissant la verite de l'experience, comme Jacques Peletier me discrit chez, moq qu'il avoit trouvé deux lignes s'acheminans l'une vers l'autre pour se iondre, qu'il verifioit toutefois ne pouvoir iamais, iusques à l'infinité, arriver à se toucher et les Pryrrhoniens ne se servent d leurs argumens et de leur raison que pour ruiner l'apparence de l'experience" (quoted Brunschvicg *L'Expérience Humaine et la Causalité Physique,* p. 170).

(16) B. Jowett, *The Dialogues of Plato,* trans. with analyses and Introductions (3rd, ed. Oxford 1892) vol. 3 Introd. to *Timaeus* ch. 8, p. 416. See also ch. 2, p. 388 et seq for his rejection along these lines of Whewell's criticism of the ancients, that they had plenty of ideas and

plenty of facts, but their ideas did not accurately represent the facts with which they were acquainted" which Jowett stigmatises scornfully as the crude mistake of an uneducated person!

However, it should be noticed that whatever the defects of Whewell's interpretation of particular points, not the least of the merits of this first great historians of science, is the striking initial analysis he makes of the conditions of scientific knowledge (to which he was led by a neo-Kantian epistemology) in which the "facts" on which all induction bases itself are presented as artificial constructs, already intellectually characterised by the observer's mind. (*History of Scientific Ideas*, p. 38 et req). "Senstation" he terms the "matter", "Idea" the "Form of Knowledge," and therefore decides that that which is admitted as theory, and that which is accepted as fact, differ merely in the degree to which Ideas are absorbed to the material, the ease and inevitability with which they are felt to organise senstation — i.e., a psychological criterion that prohibits any general and absolute differentiation — "In a Fact, the Ideas are applied so readily and familiarly, and incorporated with the sensation so entirely that we do not see *them*, we see *through them*." (Ibid p. 44)

(17) See especially Metzger: *Les Concepts Scientifiques*, a detailed examination of the process of "conceptualisation" — by which differing "objects" come to be ranged under the same class heading and a study of the shifting "Analogical criteria that, controlling this activity, are to be detected in present and past scientific systems. (It is stressed that the claim that organising class concepts come spontaneously from the objects themselves, is an undemonstrable metaphysical assumption; if some appear inevitable, the ultimate ground for maintainting this is merely "psychological," "et c'est en raison de la satisfaction qu'il donne à notre intelligence et à notre imagination que nous avons déclaré *naturel*") and that although certain "concepts," considered only as terms designating some particular group of "objects" ("metal" is an example) superficially seem to have acquired a stability amounting to permanence through time, yet they have nonetheless given rise to, or figure essentially in, hypotheses of such widely divergent characters at different epochs that it is clear that in a more fundamental sense which in turn determines any view of the objects they describe, they undergo striking metamorphosis. Hence the prime difficulty, and perhaps the major task of the historian of science faced with a particular period, even though its terminology has obvious overt similarities with others is "qu'il lui faudra diviner le cortège de penseés non exprimées que chaque système de concepts évoquait à telle époque." (pp. 12-14)

(18) Edgar Wind: *Experiment and Metaphysics* (Proceedings of the Sixth International Congress of Philosophy, 1926, p. 609-614 [Offprint p. 221]).

(19) Dingle: *Through Science to Philosophy* p. 113 cp. Carmichael: *The Logic of Discovery* (a full discussion of the problem of the interaction of theory and observation from a "postulationist" standpoint) p. 191. "There is much to be said in favour of the thesis that natural science should be considered a construct of the mind rather than a paraphrase of nature wrought out by the mind" etc.

(20) Brunschvicg *L'Expérience Humaine* p. 426 quotes an assertion of du Bois-Raymond, "Les propositions de la mécanique sont mathematiquement demonstrables, et portent en elles la même certitude apodictique que les propositions de la mathématique."

(21) *From Euclid to Eddington* p. 17.

(22) *New Pathways in Science*, C.U.P. 1947 ed., pp. 232-233. The passage continues "But theory is advancing, and we are beginning to ask, Are these four constants irreducible, or will a further unification of physics show that some or all of them can be dispensed with?" (or again, W.V. Quine comments apropos of the reduction of empirical sciences to "logic": "Carnap has pursued this program with such amazing success as to provide grounds for expecting all the expressions to be definable ultimately in terms of logic and mathematics, plus just one `empirical' primitive, representing a certain dyadic relation described as `recollection of resemblance'" (*Truth by Convention* p. 116 n. 20 in *Philosophical Essays for A.N. Whitehead*, N. York, 1931).

(23) Dr. Seth Demel comments: "Der mathematische Gedanken indem er unter der unmittelbaren Wirkung seiner Gestaltung bei Platon den Konkreten Niederschlag in den des Eukleides findet, wird zu einen mächtigen Kompenente der abendländischen Geistesbildung. Der *Ordo Geometricus* ist das Leitmotiv des Denkens der Renaissance er erweist in unmittelbarer Orientierung an Platon seine Tragkraft an der Engfaltung der exakten Naturwissenschaften" (*Platons Verhältnis sur Mathematik* p. 143).

(24A) *On the Originality of the Renaissance* J.H.I. vol. 4, 1943, p. 51.

(24B) Taylor: *Platonism and its influence*, p. 27.

(25) e.g., Sarton, in the Second Preface to vol. XXII of Isis 1935 *The History of Science versus the History of Medicine*, p. 317: "Even as the fundamental explanation of the universe, so far as any is possible is necessarily mathematical and cannot even be uttered in non-mathematical language, even so the fundamental explanation of human progress must necessarily be focussed on the history of science, itself focussed upon the history of mathematics....Mathematics forms the very core of human thought and hence of human life" etc.

(26) Since it can be held that even general empirical statements of the kind "food nourishes," "water drowns," "fire burns" are significant communications only because they make implicitly recognised reference to approximate measures of quantity. Discussed Brunschvicg: *L'Experiénce Humaine* p. 569.

(27) See Borel: *L'Espace et le Temps*, p. 13.

(28) Poincaré: *La Valeur de la Science*, p. 7.

(29) Whitehead: *Process and Reality*, p. 465.

(30) Its theoretical completeness, its capaciousness and flexibility is testified to by Mach's assertion: "The principles of Newton suffice by themselves without the introduction of any new laws to explain thoroughly every mechanical phenomenon practically occurring whether it belongs to statics or to dynamics, difficulties arise only of a mathematical or formal character." *The Science of Mechanics*, p. 257.

(31) See Brunschvicg: *L'Experience Humaine*, p. 53.
(32) E.g., in *The Grammar of Science*. Thus "an organism or form of life" Pearson remarks is "quantitatively described by the numerical values of the types and variabilities of its several organs, and by their interrelationships as expressed by the coefficients of correlation." (op. cit. London, 1900 ed. p. 418).

(33) *The Mathematical Way of Thinking* in *Studies in the History of Science* 1941, University of Pennsylvania bi-centenary Conference, p. 123.

(34) "Since the dread is considered to be a complete thing and to comprise the whole essential nature of the numerical system they assert that the bodies that revolve in the heavens are ten and there being only nine that are visible they make the anticthon the tenth." (Aristotle: *Metaphysics* I. 5.) It remained unobservable since, having a motion complementary to the earth's, it remained always on the opposite side of the central fire.

(35) The striking material success of Galileo's work, for instance, obscured even for his immediate successors and some of his contemporaries, the real nature of his position and grounds of his methods. On various later occasions, aspects of his "Platonic mathematicism," his impatient disregard of the "experience," his opponents were continually invoking against his conclusions will be relevantly noted. Yet the completeness of misunderstanding of that was able to arise among

seventeenth century scientists who no longer felt it necessary to associate their practise with any such metaphysic is illustrated by Mersenne. Lenoble describes his pragmatic phenomenalist view of science — that its function was only to search for laws expressing regular connections between "accidents," but was powerless to establish any relations between its "true cause" and any phenomena this being inevitably a metaphysical question. From this attitude sprang his inordinate admiration for Hobbes and Gassendi, and with them and without apparently any sense of disparity he associated Galileo, regarding him as the model of "the philosopher" as one who merely patiently investigated facts and avoided all unnecessary discussion (*Mersenne,* p. 314).

(36) *Metaphysical Foundations of Modern Physical Science* p. 223 et seq. cp also Boutroux on the transformation of metaphysical notions into mere essential canons or conventions of procedure, who observes that on the one hand many scientists declare themselves indifferent to "the philosophy of science" as having no possible repercussions on their work, "Et d'autre part ils se montrent si attachés à leurs propres idées sur la science qu'ils supportent avec paine de les voir mises en cause; c'est qu'en effet ces idées auxquelles ils n'attribuent aucune valeur absolue, sont cependant les conditions indispensables de leur activité scientifique" (*L'Idéal Scientifique* p. 7). From similar reasons, Collingwood has argued that "any attack on metaphysics is an attack on the foundations of science: any attack on the foundations of science is an attack on science itself." (*An Essay on Metaphysics* Oxford 1940, p. 170).

(37) cp Whitehead, *Process and Reality*, p. 13. "In their later stages, apart from occasional disturbances, most sciences accept without question the general notions in terms of which they develop. The main stress is laid on the adjustments and direct verification of more special statements. In such periods scientists repudiate philosophy."

A relevant, if restricted, illumination is provided by Metzger's detailed tracing of the history of the changing attitude adopted in various periods to one particular scientific concept — the theme of *Attraction Universelle et Religion Naturelle*. The "existence" of Universal gravitation was established for its advocates "non par des raisonnements rigoureux la déduisant a priori de la nature de notre esprit ou de la nature des choses, mais par le succès de calculs basées sur l'existence de cette force," for which Newton had produced the formula (p. 5) and it was bitterly resisted, as inconceivable, a violation of the character science must attribute to nature, and mechanical principles by the Cartesian school. These sentiments were in some sense shared by its supporters since its existence was extensively invoked by Newtonians for religious purposes, against a mechanical atheism, as demonstrating the continual operation of God, or the necessity of supposing that he had infused this force into matter by special decree, since it was of a kind that could not be admitted as an intrinsic property of matter, and properly pertaining to its nature. Increasing familiarity, the disappearance of rival theories, led eventually, however, to universal gravitation appearing to astronomers with no religion at all, such as Laplace and professing materialists, merely by this progressive assimilation of it to habits of thought, with no increase or alteration in kind of the evidence for its existence as entirely "natural," as a notion presenting no special difficulties or raising further questions if accepted, to which the mind offered no resistance, as a feature of body barely separated from the directly perceptible.

(38) *L'Histoire des principes de la Dynamique avant Newton* in *Revue de Metaphysique et de Morale.* Année 28, 1921, p. 688. The particular "vue aussi théorique," referred to, is Newton's assumption that "Les propriétés du mouvement sont conformes au moule mathématique que nous fournit la Théorie des Fonctions."

(39) Perhaps the most striking example, because of its long and still continued importance, forms the theme of F.A. Lange's *History of Materialism*, which, emphasizing throughout the methodological validity of "materialism," insists equally strongly on its complete metaphysical invalidity.

(40) The "problem" is avoided in the realm of symbolic logics. Here are admitted to a parity an indefinite number of independent, sometimes mutually contradictory, tautologous systems, arising from premisses which are not in question, since they are acknowledged as arbitrary (tough not

consequently random), and which can also serve as regulative fictions — rules of syntax — setting up a standard of coherence, which alone can be relevant here. Such systems are empty of "content," have no reference beyond themselves, since the entire "meaning" of any sign employed is merely the totality of its relations to the other signs within the systems. Most steps in mathematical reasoning, e.g., (Tan II = Sin II/Cos II) show themselves formally as being only "a definitional transformation of an antecedent self identity" (A.V. Quine, *Truth by convention* in *Philosophical Essays for A.N. Whitehead*, London, 1936, pp. 90-125). But the view that mathematics might be only such another system, or set of systems, as this, became possible at only a very late historical stage, for the increasing correspondence between the structure of various branches of mathematics, the mutual harmony and apparent inevitability of their premisses, produced an impression of phoenix-like singleness which had first to be broken down by the emergence of non-Euclidean geometries, and Booleian algebras. Platonists insisted, of course, that mathematics rested on "hypotheses," but not in order to denigrate at, but to relate it to metaphysics, and so allow of intelligible explanation for the fact that mathematical results accorded so well with the intuitional picture of the world.

(41) Cohen: *Reason and Nature*, p. 16. The passage goes on to consider what an untrained observer could have gained, though "experiencing" everything, at some of "the most famous and epoch making experiments of modern times," such as those of Hertz or Michelson, in order to show that "Observations unillumined by theoretic reason is sterile." (One might add that the results of the Michelson-Morby experiment had to wait nearly thirty years to receive any fruitful interpretation. A novel context of theory in which this data had a logical place was necessary before this could acquire "meaning" and cease to be merely enigmatic).

(42) cp H. Jeffreys: "It is sometimes considered a paradox that the answer depends not only on the observations but on the question, it should be a platitude" etc. (*Theory of Probability* preface, Oxford, 1939.)

(43) Collingwood: *The Idea of Nature*, p. 42. An excellent detailed illustration, since it might superficially have been suspected to be an example of the reverse, is furnished by A.P. Usher's tabulation of the gradual recognition and solution (the first much the more troublesome) of successive related problems by Cardan, Porta, de Cause, Toricelli, Boyle, Guerick, Worcester, Savery, Papin, Huygens, leading "progressively towards an explicit concept of a steam engine, though no adequate synthesis was achieved," a process which culminated by clearly formulating this particular "problem," "and set the stage for Newcomen's synthesis" (*History of Mechanical Inventions*, p. 25 et seq).

(44) Poincaré: *La Valeur de la Science*, pp. 24-25.

(45) Illuminating are the shocked verdicts on Kepler's total work, passed by later scientists, recorded by Whewell: that he had "miraculous good fortune in seizing truth across the wildest and most absurd theories," that this success "may well inspire with dismay those who are accustomed to consider experiment and rigorous induction as the only means to interrogate nature with success." Laplace declared "Il est affligeant de voir ce grand homme même dans ses derniers ouvrages, se complaire avec délices dans ses chimériques speculations, et les regarder comme l'âme et la vie de l'astronomie." Whewell himself, allowing that Kepler's mysticism apparently did not impede his successful "prosecution of research," sharply separates the two, saying, in his fertile mind "weeds and grain throve and flourished side by side almost undistinguished, and he gave a peculiar appearance to his harvest by gathering and preserving the one class of plants with as much care and diligence as the other" (*History of Inductive Sciences*, vol. I, pp. 317-320).

(46) See particularly, Burtt: *Metaphysical Foundations of Modern Physical Science*, p. 65 et seq. Galileo's "confident belief in the mathematical structure of the world emancipated him from the necessity of close dependence upon experiment."

(47) Some typical minor instances are: Columbus' theories, drawn from the Aristotelian physic, of the proportionate distribution of earth and water on the earth's surface; C.M. Hall's invention of achromatic lenses (of different refracting media) which obviated a supposedly irremediable defect of refracting telescopes — resulting from his incorrect views on the structure of the eye and the functions of the humours it contains; Balmer's search for mystic numerical harmonies, which drew him to "discover" along with much nonsense, the regularity exhibited by the wave lengths of the hydrogen spectrum; Hamilton's devising of quaternions — by his own account, from what now appears only a misleading metaphorical syggestion in a fallacious remark of Kant's on mathematics; Carnot's principle — established, as he believed, by a theory of the nature of heat, which soon after refuted, brought the principle into temporary disrepute — until Clausius' vindication of it. Of the relation between the status of the hypothesis and the predictions made from it, "a spectacular instance is the prediction of wireless waves from the electromagnetic theory of light, another the prediction of what is called conical refraction in optics, from the older wave theory of light, another the prediction of the wavelike character (in some respects) of electrons from the newer quantum theory" (E.T. Bell, *The Search for Truth*, N.Y., 1935, p. 80). An earlier example is the way in which the phlogiston theory had been taken as "proved" by the verification through direct experiment, of various predictions made from it, as for instance that the union of phlogiston (of which carbon ws supposed to consist almost entirely) and of "dephlogisticated metal" should restore the original metal itself (carbon heated with lead calx did, of course, yield lead).

But the striking success in practice of deductions made from premisses or suggested by representations, later abandoned as false, is a notable feature of all past science, indeed if its total history is considered, a very large portion of all discoveries must have originated in this fashion. An illuminating discussion of the relations between "théories abstractes et représentations concrètes dans la physique moderne," and of the logical defects, and distortions imparted by these latter, which nevertheless "ont joué un rôle des plus utiles dans le dévelopement des théories physiques, sans elles le progrès de ces théories aurait été dans beaucoup de cas considérablement valenti, si ce n'est définitivement entravé," is to be found in de Broglie *Continue et Discontinu en Physique Moderne*, Paris, 1941, p. 91 et seq. On analogies underlying past scientific, especially chemical, theories and the predictional successes of these, see Metzger, *Les Concepts Scientifiques*, e.g., p. 43 et seq. on the "success" — in terms of the discoveries it produced — of a fantastic eighteenth-century theory of combustion, which took the refractive power of substances as indices to their "combustibility."

(48) See Nunn: *The Aim and Achievements of Scientific Method*, p. 71.

(49) Lovejoy: *The Great Chain of Being*, p. 333.

(50) J. Ekehorn, *Sherrington's "Endeavour of Jean Fernel" and "Man on his Nature," Comments by*.... Pt. I, p. 36, Stockholm, 1947. (Acta Medica Scandinavia, Vol. 127, Suppl. 187.)

(51) Prost. *Les Sciences et les Arts Occultes au XVI^e^ — Siecle* vol. I, Introduction, p. iii.

(52) Their positive contribution is discussed by E.W. Gudger, *The five great Naturalists of the Sixteenth Century* (Isis XXIII 1934/1935, p. 21 et seq.).

(53) Olschki. *Bildung und Wissenschaft im Zeitalter der Renaissance*, p. 37. Apart from this consideration, Daremberg's verdict may well stand (*Histoire des Sciences Medicales*: Paris 1870 vol. 1, p. 355 — quoted Zilbourg, *The Medical Man and the Witch during the Renaissance*, p. 88) that the history of medicine in the sixteenth century is much less significant and theoretically less interesting than that of the preceding one; may in fact "be reduced to the following three points: the humanists busy discussing texts; anatomists scrutinizing nature; and Paracelsus dreaming at high noon and raving delirious whil in full possession of his senses."

Harvey however refers to the heart as "a piece of machinery in which through one wheel give motion to another, yet all the wheels seem to move simultaneously" (Butterfield: *Origins of Modern Science*, p. 44). The development of this approach to physiology later in the century may be seen in the achievements of Stensen and Borelli whose work *On the Motion of Animals* has been called "a supreme example of the application of the science of mechanics to the study of living organisms" (Ibid p. 100 et seq.). For a considerable period thereafter it is noticeable how in this sphere "mechanical explanations," because of their more perspicuous intelligibility and analogical coherence with other more advanced or supposedly better founded sciences, are sought in preference to chemical ones even when these would seem the most natural. (Huygens typically opens his *Traité de la lumière* by defining "la vraye Philosophie" as that "dans laquelle on conçoct la cause de tous les effets par des raisons de mechanique" see Lenoble: *Mersenne* p. 364.) An illuminating example in the early eighteenth century is Derhem's treatment of respiration: he notices the difficulties travellers experience in breathing when crossing the Alps or Andes and continues, "Thus it appears, that an air too subtile, rare and light, is unfit for respiration: but the cause is not the subtility, or too great delicacy, as Mr. Boyle thinks, but the too great lightness thereof, which renders it unable to be a counter balance, or an antagonist to the heart, and all the muscles ministring to respiration, and the diastole of the heart." Later, returning to this topic, he sets out various chemical reasons that have been suggested as the purpose of this process, as that "it conveyeth a nuro-aerial ferment to the blood, to which the animal spirits are owing, and all muscular motion" — only to dismiss these and affirm "the principal uses to be, to move, or pass the blood from the right to the left ventricle of the heart. Upon which account persons hanged or drowned, or strangled by catarrhs, so suddenly die, namely, because the circulation of their blood is stopped." "For the same reason also is it, that animals die so soon in the air pump." And he appends a formidable list of experiments, performed by himself and others, relating largely to the resuscitation of animals by artificial respiration and blowing air into the lungs, as undeniable proof of this theory. (*Physico — Theology* I, 1, p. 41; IV, 7, pp. 181-185.)

(54) E. Ekehorn, op. cit. (supra n. 50) p. 30; such problems, it is thereupon remarked, and their successful resolution, may be seen as products of some quite specific period, for "there must be the means for reply, and enough collateral knowledge to make the answer worth while."

(55) Given the *amount* of blood driven forward at each pulse beat, and the *rate* of beat, and the total *volume* of blood contained in the body, the heart can be shown to deal with such a volume every few minutes, and to throw out a weight of blood, exceeding that of a man, in less time than this quantity could be reasonably supposed to be freshly created! (In addition to such reasoning and mechanical considerations regarding the functions of the valves in the veins, Harvey also appears to have been influenced by preliminary considerations of the widespread importance of "circularity" and "circular processes" in the Universe, vide Walter Pagel: *Wm. Harvey and the Purpose of Circulation.* Isis, vol XLI, 1950.

(56) An attitude reflected in an interesting article of J.R. Partington's (in *Annals of Science*, Vol. IV, No. 3, July, 1939) on the *Origins of the Atomic Theory*, in the Renaissance: no influence or relevance is allowed to "the overrated Nicholas of Cusa," and "the speculations of Giordano Bruno" (on the three species of minima: punctus, atomus, monad) are dismissed as "metaphysical and of no physical importance. Bruno was a philosopher and not a scientist." (pp. 200-201) (A more satisfactory picture, exhibiting the constant interaction and close parallelism of metaphysical and physical speculation on this subject, and their continuous progress towards Dalton's conceptions, to which they equally form the necessary historical background, is given by G.B. Stoner in *Atomic Views of Matter in the 15th, 16th and 17th Centuries* [Isis X, 2, 1927, 445 et seq.].)

(57) For example, see the many surprising, historically indefensible tributes to the system of Epicurus (the ethical foundations of which rather inhibited contemporary interest in the natural sciences, and which adopted a thoroughly reactionary and hostile attitude towards astronomical studies, one of the most advanced and fertile departments of Greek science) quoted by More

(*Hellenistic Philosophies*, p. 51), such as, that it formed "the creed of men of science," represents "the most scientific elements of Greek antiquity" (Trezza) and its advocates "with respect to the laws and principles of Science come nearest of all the ancients to the science of our own time." (Walzer.) Boutroux discusses with examples such false comparisons, e.g., supposed anticipations of Cartesian geometry in the work of Apollonius, Oresme or Ghetaldi, commenting that such resemblance "sont souvent de pure forme, c'est à dire ne portent que sur les manifestations de la pensee scientifique (énoncés de faits, formules, ou théorèmes) et non point sur les tendances et l'action creatrice de cette pensée," he concludes that what is truly of consequence is not the observation that some particular fact is to be met with in a particular epoch, but to arrive at an understanding of how it had then entered a system, what current of speculation led to its being regarded as important, and what processes of thought it then served to originate (*L'Idéal Scientifique*, p. 11, et seq.).

(58) H. Miller: *Philosophy of Science and History of Science*, p. 63, Isis XXX, 1939.

(59) See R. Berthelot: *La Pensée de L'Asie et l'Astrobiologie*, Paris, 1938. On the interpretation of animism and astral-determinism, he writes: "D'un côté tout serait vivant, même le ciel et les astres; de l'autre, tout serait soumis a des lois numériques, lois périodiques, qui seraient à la fois des lois de nécessité et des lois d'harmonie et de stabilité." (p. 8)

(60) E.g., the seemingly well-attested phenomena connected with sorcery and magic were accepted indiscriminately and a view of natural causation that would explain them all was then sought for. (Typical of "facts" thus admitted, is Postel's defence of the literal truth of Apuleius accounts of witches and his own transformation into an ass in his novel, nothing Postel argues can be urged against their *possible* truth, and even if in this case some or all is invented, nevertheless, "certè similia sunt in experimentis. Nam quamvis sunt partim a poetis excogitate & fama locupletatae, tamen omnino falsae esse non possunt: quia impossibile est famosum esse omnino falsam, ut ait Philosophus, sunt enim famosa secundum partem necessaria" (*De Orbes Terrae Concordia*, I, 8, p. 62).

(61) On previous paragraph see discussions on "Naturalism" in Lenoble's *Mersenne*, esp. p. 6, et seq. — on its differentiation from later Cartesian mechanist systems, p. 112, et seq., on Pomponazzi's *de Incantationibus* and this movement X. p. 141, on the magnet's importance in such doctrines, etc.

(62) Mandonnet: *Siger de Brabant et l'Averroisme Latin*, pp. 43, 55, 56.

(63) A.N. Whitehead: *Adventures of Ideas* (Penguin ed., 1942), p. 139.

(64) P. Duhem: *Roger Bacon et l'horreur du Vide* (in *Bacon — Commemoration Essays* ed. Little), p. 268.

(65) Emmet: *The Nature of Metaphysical Thinking*, p. 216.

(66) *Metaphysics* II, 995A.

(67) *On the Heavens* II, 294A, p. 223-225.

(68) Rey: *L'Apogée de la Science technique Grecque*. Pt. 2, Chap. VI. "La notion du simple et le développement historique des sciences," "l'homme a commencé....par des notions toutes proches de ses actes habituels, des événements, auxquels il avait accoutumée d'assister et qui lui importarent le plus pratiquement." But in the end, what is arrived at is "le plus simple, c'est....à peu pres ce par quoi on a commence ces recharches et ce en quoi on a réussi en premier lieu à satisfaire plus au moins complètement les tendances profondes...de l'esprit, de l'intelligence et de la raison." (pp. 232-233)

(69) See Lenoble on the revelation of the defects of this scheme by criticism based on epistemological examinations such as that in Mersenne's *La Vérité des Sciences*: "en prêtant une valeur ontologique aux intuitions du sens commun sur l'espace, le grave, le léger, les éléments et tout le materiels des catégories il (Aristotle) croyant être assuré de la possession de principes incontestables. La simple critique des données sensibles...suffit à faire apparaître l'équivoque." (*Mersenne*, p. 348.)

(70) Aristotle, *Metaphysics*, 1063A.

(71) *Ibid*, 1029B.

(72) *Ibid*, 1043B.

(73) *Ibid*, 1010B.

(74) *Ibid*, 1010A.

(75) *Ibid*, 1063A.

(76) *Ibid*, 1006B.

(77) *Ibid*, 1038A.

(78) *Ibid*, 1025A.

(79) *Ibid*, 1007A.

(80) See Brunschvicg: *L'Expérience Humaine*, pp. 149-153. This feature at once encouraged the "Naturalist" doctrine previously discussed, and prevented Aristotelians from making any fundamentally damaging criticisms of them. Despite the bitter hostility to Naturalism these sometimes displayed, yet seventeenth century scientists were justified in looking on them as similar in their powerlessness to give any satisfactory account of phenomena considered as causes or effects, e.g., see Lenoble's account of the anti-Paracelsian writings of the physician and botanist, Thomas Evaste (1824-1883), who strongly resisted their indiscriminate importation of the miraculous into nature, trying to present it as an orderly regular system on Aristotelian principles, but who, although he criticised with sceptical common sense all supposed operations of occult forms and causes, was himself unable to suggest the substitution of any essentially different type of causality (*Mersenne*, p. 211, et seq. Lenoble comments, p. 216: "Toute cette critique des arguments naturalistes est marquée au coin du bon sens. Mais que propose-t-il à la place? Rien du tout. Il ne connaît lui-même d'outre action causale que celle des qualités.")

(81) 1556. Avj^{v}-Bj^{r}.

(82) *Metaphysics*, 1005B.

(83) Discussed Claggett: *Giovanni Marliani and Late Mediæval Physics*, p. 59 et seq.

(84) Testimonies as to how satisfactory this could appear are not infrequent. In 1591 Cattan's translator declares that the sciences have been almost perfected and exhaustively explored by man's equiring spirit, for man has in knowledge of nature "entred so farre, that he hath discovered the essence, constitution, and mixture of the most parte of things made, the proportions conveiances and differences of them, and the being and progresse of the faculties thereof, to what effects they do come, bringing forth the causes and reasons so manifest, that they cannot be disproved." (The *Geomancie of....Cattan*, Epistle Dedicatory, A2^{v}.)

(85) Dingle: *Science and Human Experience*, p. 14.

(86) Dingle: *Through Science to Philosophy*, p. 28.

(87) See Claggett: *Giovanni Morliani*, p. 33.

(88) *A Dialogue Philosophicall*, p. 4.

(89) An excellent example of its defects in this respect is offered by Porta's *Natural Magick*. He sets out to explore nature and to do this experimentally not merely to understand but to discover, predict and apply knowledge to practical ends; "I never wanted also at my House an Academy of curious Men, who for the trying of these experiments cheerfully disbursed their Moneys, and employed their utmost Endeavours in compiling and testing the matter of this book. The unit of Cause in nature he lays down explicitly, on commencing, is the essential form of things (their virtues he can only explain by giving them a divine beginning, and referring their operations to divine will). But he can then only discover as a principle on which these act, and which is to some extent susceptible of observation, the relations of sympathy and antipathy which they produce between things "whereof there can be rendered no probable reason: neither will any wise man seek after any other course hereof but only this, That it is the pleasure of nature to see it should be so." This is then his instrument for the investigation of nature, he expresses his observations in terms of it, he draws deductions from it as combined with certain facts that allow him to proceed to other facts and frequently by predictionof this sort claims the hypothesis vindicated. A sample of his scientific reasoning in this manner is — and these are "discoveries" etc. which he has been led to by it, and claims to have then proved by practical testing: "The Ape of all other things cannot abide a Snail: now the Ape is a drunken Beast, for they are wont to take an Ape by making him drunk; and (therefore) a Snail well washed is a remedy against drunkenness...The Wolf is afraid of the Urchin; thence if we wash our mouth and throat with Urchin blood, it will make our voice shrill, though before it were hoarse and dull like a Wolves voice," or again, the "love" between the Moorhen and the Hart, or the Goat and the Partridge is a sign that either of the members of such pairs may be used indifferently for the same remedies in medicine, etc. (*Naturall Magick...Wherein are set forth all the Riches and Delights of the Natural Sciences*." Preface; I.5, p. 6, I, 7, pp. 8-10.)

(90) Both quoted Dampier: *History of Science*, pp. 181, 184.

(91) *De Docta Ignorantia*, I. 11.

(92) Quoted Strong: *Procedure and Metaphysics*, p. 76, 89, from *Opus Novum de Proportionibus Numerorum*.

(93) See Duhem op. cit. (in Note 64), p. 278.

(94) "Adhuc autem gravius est quod post modum dicit: per rationem concludo de necessitate, quod intellectus est unus numero; firmiter tamen teneo oppositum per fidem...Ergo sentit quod fides sit de aliquibus quorum contraria de necessitate concludi possunt. Cum autem de necessitate concludi non possit nisi verum, necessarium, cujus oppositum est falsum et impossibile, sequitur secumbum ejus dictum, quod fides sit de falsa et impossibile, quod etiam Deus facere non potest." quoted Mandonnet *Siger de Brabant*, p. 152 from *De unitate intellecti*.

(95) Anagnine, "Pic de la Mirandole" (In *Rev. d'Hist de la Philosophie*, 2e Année 1934), p. 114.

(96) Mandonnet *Siger de Brabant*, p. 144-145.

(97) *De Dignitate et Augmentis Scientiarum* lib. 1, cap. 1. "Quare, sicut legi divinae obedire tenemur, licet reluctetur voluntas; ita et verbi Dei fidem habere, licet reluctetur ration. Etenim, si ea duntaxat credamus, quae sunt rationi nostrae consentanea, rebus assentimur, non auctori; quod etiam suspectae fidei testibus praestare solemus. At fides illa, quae Abrahamo "imputabatur ad justitiam, de hujusmodi re extitit, quam irrisui habebat Sarah: quae in hac parte imago quaedam erat rationis naturalis. Quanto igitur mysterium aliquod divinum fuerit magis absonum et incredible; tanto plus in credendo exhibetur honoris Deo, et fit victoria fidei nobilior." (*Works*, Vol. II, p. 427.)

(98) *Principles of Human Knowledge.* Introd. 3 (London, 1945, p. 6). Aristotle of course uses this same principle, that capacity will be concordant with appetite, but by restricting all cognition in man to the sensible, and founding thought on, and denying that it could be free from, images — and by denying the operation of the intellect if shown not to involve these, to be properly a part of man *qua* man, he implicitly excludes the desire for ultimate truth, as he explicitly does that for "eternity," from the class of those natural appetites that are proportioned to a future actuality. Vide infra Ch. 4.

(99) *Metaphysics*, 995A.

(100) *Metaphysics*, 1077B.

(101) See J.H. Randall, Jr. *Development of Scientific Method in the School of Padua*, p. 198 (J.H.I. I 1940, 177 ff).

(102) *De Crepusculis*, 1542, p. 1. "Porro hec mea demonstrandi methodus alia est fateor aliquando, ab ea qua prisci illi authoris *Menelaus, Ptolemaeus*, et *Geber* viri doctisimi usi sunt: sed ab *Euclide* et *Theodio* haud quaquam aliena."

(103) *On the Heavens*, II. 10.

(104) *De Rerum Varietate*, 1557 lib. IX "de Moribus."

(105) *De Subtiltate*, 1554, p. 9.

(106) E.g., the mathematician Tartaglia published a work on the subject *La Nova Scientia* which, although "Euclidean" in form of exposition and strictly mathematical in procedure, is vitiated by Aristotelian assumptions on physical questions — as on the rate of fall of bodies, or its apparent acceptance of the belief that a compound of artificial and natural motions was impossible, which results in the representation of the track of a canon ball as a straight line which suddenly terminates when artificial acquired motion is exhausted, and is replaced by a vertical line, representing the natural motion of tendency to the centre that then supervenes. (But Tartaglia is apparently himself uneasy about this last patently artificial Aristotelian dogma, and attempts to camouflage the improbable discontinuity it suggests by inserting a short curved path at the transitional point, thus allowing stages of violent, mixed and natural motions to the missile.) Dee, in the *Preface* insisting that in a common medium two bodies of the same form "aequall in quantitie or unaequall will move by aequall space in aequall tyme," comments "Hereupon, in the feate of Gunnyng, certain good discourses (otherwise) may receive great amendment, and forderance." The letters N.T. are set in the margin — a clear reference to Tartaglia's work and its Aristotelian defects.

(107) *A Discourse Apologeticall*, p. 120, and pt. II (new pagination), p. 200.

(108) See R. McKeon, *Aquinas' doctrine of knowledge and its historical Setting*, Speculum III, 1928, p. 426 ff.

(109) By Herlinus and Dasypodus, 1566, Strasbourg (*Analyseis geometrica sex librorum Euclides*).

(110) John Smith: *Discourses*, 1673, Disc. IV, chap. 8, p. 101.

(111) *Life* X and XIII (Rosan: *Proclus*, pp. 18, 20).

(112) Thus More: *Hellenistic Philosophies*, p. 78 et seq., and Armstrong, *The Architecture of the Intelligible Universe in the Philosophy of Plotinus*.

(113) E.g., *De. Civ. Dei* IX, 10, "Plotinus certae nostrae memoriae vicinis temporibas Platonem ceteris excellentius intellexisse laudatur" etc.

(114) E.g., in his translation of the *Hymns of Orpheus*, 1792 with dissertation on them (Taylor believed they revealed a true mystical theology) — he states for example (p. 13): "I shall everywhere deduce my information from the writings of the latter Platonists as the only sources of genuine knowledge on this sublime and obsolete enquiry." Of Plotinus and Proclus he writes, the philosophy of Plato was indebted "to the former for its restoration and to the latter for the complete development of all its sublimities and mysteries...(they) being allotted a nature similar to their master were the true interpreters of his sublime and mystic speculations" (Introd. to trans. of Plotinus, pp. XII-XIII).

(115) *Life*, ch. 38 (Rosan, *Proclus*, p. 35)

(116A)E.g., *Metaphysics*, 987B-958A.

(117A) *On the Heavens*, 303A-304B.

(118A) *Metaphysics*, 985B.

(119A) *Ibid*, 987B.

(116B) *Noctes Atticae*, lib. 111, cap XVII.

(117B)Henrici Ranzouii: *Catalogus imperatorum, regum, ac virorum illustrium, qui artem astrologicam amarunt, ornarunt et exercuerunt*, Lipsiae, 1584, p. 28.

(118B)Cherniss: *The Riddle of the Early Academy*, p. 83.
(119B)131A.

(120) The argument is little affected by whether the original basis of a word's signification be purely sensible or not, for as its meaning expands within a context, and its functions as a nexus of relationships are elaborated, then the sensible element of the experience it may have once indicated alone, can be viewed, in the Cambridge Platonists' phrase, as merely "the extrinsical occasion of thought." It is interesting that even Hume once admitted that although in a very restricted fashion (which is nevertheless significant here) reflection on past experience might give rise to new experiential conceptions, which could not be described merely as a mechanical juxtaposition of previously known elements, since it was possible, he held, to *imagine a colour* if, although never actually sensed, it be thought of as being intermediate between two known colours. (*Enquiry concerning Human Understanding*, II, 16 — it is true he dismisses it as an instance "so singular that it is scarcely worth our observing," but admits it as a "proof that the simple ideas are not always, in every instance, derived from the correspondent impressions").

(121) *Laws*, Bk. X, 892A-B.

(122) Fouillée: *La Philosophie de Platon,* Vol. I, p. 5.

(123) *Beyond Good and Evil,* quoted Urban: *The Intelligible World,* p. 24.

(124) *Opere latine conscripts* II, 2 Florence, 1890, p. 7.

(125) *Didascalon,* lib 2, cap. 17. See M. Claggett: *Some general aspects of Physics in the Middle Ages,* p. 30 (Isis XXXIX, 1948).

(126) B. Kieszowski: *Récherches sur la Philosophie de Jean Pic de la Mirendole,* p. 47 (Comptes Rendus des Séances de la Societé des Sciences et de Lettres de Varsovie XXIII 1930).

(127) *de Docta Ignorantia,* lib. III, cap. II.

(128) *Metaphysics* 1002A.

(129) Urban: *The Intelligible World,* p. 76.

(130) E.g., *Strom,* II, 4, 13; VI. 7, 57.

(131) *Life,* ch. XXII (Rosan: *Proclus*, p. 25).

(132) Quoted J.R. Halcomb: Synesius (in Smith and Wace *Dict. Christ. Biog.* vol. IV, London, 1887, pp. 756-780). (This confusion with the alchemist continued at least until the eighteenth century, e.g., du Fresnoy's account in *Hist. de la Phil. Hermétique,* Vol. I, pp. 40-56.) Similarly, in the renaissance, Elyot insists that man resembles God only in understanding; the statement that he was made in God's image can refer only to his intellect; he adds that the text could not mean in any way man's shape or bodily constitution for "certes thanne the ymage of godde were not onely divers but also horrible/monstruouse, and in some part ridiculouse" (*Of the Knowledge which maketh a Wise Man*, ed. Howard, 30^{r-v}=87-8). The whole theme of this dialogue, one of the most noble and attractive of renaissance productions in this genre, is the identity of virtue with knowledge, that he who knows, in the full sense, what is right, will always act in accordance with it, and that knowledge constitutes an approach to and imitationof God, beatitude and the soul's eternal bliss having to do only with the understanding — a thoroughly "intellectualised" interpretation typical of neo-Platonism. The statement is placed in Plato's mouth with a marginal reference to *Alcibiades I*, that "my profession hath ever been, that no man is happy except he be wise and also good [that this is a tautology has not at this stage been established] & that felicitie is in wisdome and goodnes / and contrariewise / that they which be ignoraunt and yll / be vnhappy / and that ignoraunce and synne is infelicitie and misery." (Ibid, p. 15^{r}=45). Now this ignorance which is the sole cause of sin can only result from body, partially obscuring the soul's understanding, but this it cannot do unless permitted by a diseased will, for of itself it clearly cannot "lette the soule, that is of a divine substaunce, to shew the effectes and disposition of her nature, *whiche is onely knowledge*" (Ibid p. 20^{v}=55).

(133) *Commentaires sur le premier livre d'Éléments d'Euclide,* trans. P. ver Eecke, p. 6.

(134) "C'est un fait capital pour l'intelligence de l'augustinisme, que la sagesse objet de la philosophie se doit toujours confondre pour lui avec la béatitude." (E. Gilson: *Introduction à l'étude, Saint Augustin,* Paris 1929, p. 1.)

(135) E.g., Du Mornay, *Treatise on Christian Religion,* trans. Sydney, chap. 2 (Sydney Works III, p. 279).

(136) See W.R. Sorley: *A History of English Philosophy,* Cambridge, 1937, p. 81.

(137) *Discourses* IV, 6, I. 1.

(138) E.g., *De Philosophiae Consolationis* V. 5, pp. 389-391. There are four grades: Sense, Imagination, Reason, and Understanding, under which a thing may be diversely considered. Each superior form of comprehension embraces the lowwer but does not depend on or employ them, thus, "Reason when it considereth any universitality, comprehendeth both imagination and sensible things without the use of either imagination or senses."

(139) See especially on Avicenna's epistemology as reproduced here, Goichon: *La Philosophie d'Avicenne et son influence en Europe Médiévale*, p. 31 et seq.

(140) Goichon: *Avicenne*, p. 104.

(141) R. McKeon: *Aquinas' Doctrine of Knowledge and its Historical setting*, Speculum 111, 1938, p. 426.

(142) *De Idiota* Dialogue 1.

(143) *Galileo's Platonism* in *Studies and Essays in the History of Science and Learning*, offered to George Sarton 1944, New York, 1947, p. 286, et seq.

(144) See Lenoble on Mersenne's relations to the Augustinian tradition, and adoption of Anselm's ontological proof "et cela annonce en somme, les *Méditations* de Descartes et son argumentation à partir d'une prise de conscience des données, de l'esprit" (*Mersenne*, p. 252), also on history of thesis "Intellectus quodammodo fit omnia" and its final connections with seventeenth century intellectualism and mechanism (Ibid p. 344).

(145) *A Treatise Concerning Eternal and Immutable Morality* (appended to TIS. 1845, ed. Vol. III) III, 3, 4 (p. 566); IV, 2, 4 (p. 580); IV, 5, 2 (p. 635). III, 3, 4 continues "so the mind or intellect may well be called (though in another sense than Protagoras meant it) the measure of all things." This phrase is popular among Renaissance Platonists, who in an earlier age are not always so careful as Cudworth to distinguish the intentions of the originator from their own applications — Pletho indeed takes Protagoras as a type of noble certitude — the converse of Pyrrhus, and ch. XXXVII of Cusa's *de Beryllo* (*Oeuvres Choisis* p. 489) is a vindication of Protagoras on similar lines.

(146) *De Fide Catholica*: After denying the emanation of the world from God's own substance, "nor did he form it after any model lest it should be thought that anything had already come into being which helped his will by the existence of an independent nature." (*Theological Tractates*, p. 57.)

(147) *Phil. Consol.* III, 9 (Loeb, p. 265). It is true this is from a poem, and which moreover is professedly based on the last part of the *Timaeus*, but no doubts are expressed in the surrounding text as to its truth.

(148) *Against Eutyches and Nestorius* III (*Theological Tractates*, pp. 87-89).

(149) *De Trinitate* II (Ibid p. 13).

(150) Mandonnet: *Siger de Brabant*, Vol. I, p. 118.

(151) Despite this resistance to direct definition, knowledge of it could be taken as nonetheless certain, since it formed the ultimate value terminating a series adequated to immediately experienced desires, which could thus serve to indicate degrees of approach to it, and the "direction," as it

were, in which it must be. For, "the Good differs from everything else in a certain respect....a creature that possesses it permanently completely and absolutely has never any need of anything else; its satisfaction is complete." (*Philebus*, 60B-C.)

(152) Foullée: *La Philosophie de Platon*, Vol I, p. X.

(153) Adamson: *The Development of Greek Philosophy*, Edinburgh, 1908, p. 106.

(154) Similarly Philo, after describing creation as modelled on Ideas (for God saw "that no object of perception would be faultless which was not made in the likeness of an original discerned only by the intellect") goes on to equate the place of the Ideas and the Divine Reason (Logos), "which was the author of this ordered frame (*De Opificio Mundi* IV, [16] and V [20]; *Works* I, pp. 15, 17). On the transformation of the Ideas, after Plato, until both their totality and "their place" are simply identified with the Divine Mind, see Rosan: *Proclus*, p. 100, et seq.

(155) *De Trinitate* XV, 13 (trans. Dods. Edinburgh, 1873, pp. 407-411).

(156) Saliba: *Étude sur la Métaphysique d'Avicenne*, p. 128.

(157) On Smith see de Boer, *Theory of Knowledge*, p. 41. On More, W.R. Sorley, *History of English Philosophy*, Cambridge, 1937, pp. 81-82, who quotes these phrases from *An Antidote against Atheism* I, 6; Appendix 2, 5.

(158) *The Boke named the Governor*, 1531, III, 23 (Everyman reprint, p. 273). Similarly in his dialogue *Of the knowledge whiche maketh a Wise Man*, Elyot places an argument in the mouth of Plato, based on the instincts, special aptitudes and responses to symbols of brutes, to establish that even they have knowledge that is not drawn from the senses (though this at the same time is distinguished from the full participation in Ideas, for the beasts have not that understanding that would allow them to engage on "nombrynge" unaccompanied by imagination, p. 29^{V}=74).

(159) This constitutes in fact Galileo's answer to the charge which he does not in any explicit phrase accept. He replies merely "What I think of the opinion of Plato you may gather from my words and actions," and then that he will allow this deduction of new and positive knowledge from a priori principles into which he leads the other two speakers, to stand as an example of "what my opinion is touching the attainment of knowledge" (Salusbury trans. Vol I, p. 169 et seq. cp. p. 138: "You must know that if a person apprehends not a thing of himself, it is impossible that others should make him understand it").

(160) Epistle VII, G.R. Morrow trans. (*Studies in the Platonic Epistles*, p. 207).

(161) *De Docta Ignorantia*, I. 14.

(162) Ibid I, 12.

(163) Ibid I, 4.

(164) *A Sytem of Logic*, I, 8.7 (London, 1892, ed. p. 105).

(165) *Die Grandlagen der Arithmetik*, II, 26, 28. Breslau, 1884, pp. 36, 38.

(166) C. Ritter: *Kerngedanken der Platonischen Philosophie*, pp. 77, 82. Quoted Lovejoy: *The Great Chain of Being*, p. 36.

(167) *Theaetetus*, 1848.

(168) *Against the Gnostics*, i.e., *Enn*, II, 9.16.

(169) *Ennead*, III, 6, 2.

(170) *Antidote against Atheism* (*Philosophical Writings*, ed. F.J. McKinnon, N.V., 1925, pp. 14-15).

(171) *De Docta Ignorantia*, I. II. The "source" of the form of the expression in Romans I. 20, "For the invisible things of Him from the creation of the world are clearly seen, being seen by the things that are made."

(172) Abel Rey: Introduction to *De docta Ignorantia*, trans. Moulinier, p. 20.

(173) *Idiota*, dial. I.

(174) Saliba: *Avicenne*, p. 145.

(175) It had a superficial attractiveness, and has perhaps been useful in contenting the minds of investigators with a general theory, so allowing them to proceed, psychologically unhampered, in work on which, in fact, such a theory has no practical bearing. Thus Cornford quotes from Lemery's *Cours de Chymie* of 1675, "The hidden nature of a thing cannot be better explained than by attributing to its parts, shapes corresponding to all the effects it produces. No one will deny that the acidity of a liquid cosists in pointed particles. All experience confirms this" (*Before and After Socrates*, Cambridge, 1932, p. 26).

(176) Bruschvicg, *L'Expérience Humaine*, p. 125, expresses the difference very precisely: "Le type d'intelligibilité, suivant Platon comme suivant Democrite c'est l'analyse. Mais, suivant l'heureuse terminologie de Leibniz, l'analyse démocritéenne est la division en parties, l'analyse platonicienne c'est la résolution en notions. Le Première laisse échapper le tout en tant que tout pour ne retenir que les elements constitutifs; la seconde au contraire, s'attache au tout lui-meme afin de comprendre ce que le détermine dans sa totalité. Tandis que Démocrate n'emprunte guère à la géometrie que l'image encore externe de la juxtaposition, Platon vise a l'intelligence des relations internes. Des lors, ce qui va devenir l'objet principal du mathématisme Platonicien, c'est que l'atomisme laissait inexpliqué: l'ordre, la proportion, auxquels l'objet est redevable de son forme esthétique, de son harmonie."

(177) *Ennead* IV, iii, 4.

(178) *Meno*, 81C.

(179) *Lives* IV, 2 (Vol. I, pp. 375-377).

(180) *De Architectura* 1, 1, 16, Vol. I, p. 26.

(181) de Boer: *Theory of Knowledge of the Cambridge Platonists*, p. 67.

(182) See P. Valéry: *Introduction to the method of Leonardo da Vinci* (trans. T. McGreery, London, 1939, p. 13). "For a student of organisms such as he, the bodyis not a piece of rubbish to be utterly despised. It has too many properties, it solves too many problems. It possesses too many functions, is capable of too many resources, not to correspond to some transcendental necessity that is sufficiently powerful to construct it, but not sufficiently powerful to be able to dispense with its complexities."

(183) *The Trueness of the Christian Religion*, Sydney trans. (Sydney Works, III, p. 234).

(184) de Boer, *Theory of Knowledge,* p. 148.

(185) The positions touched on in this section are dealth with fully, with some historical reference, in Wick's *Metaphysics and the New Logic*. On this particular question Wick develops (p. 52 et seq) arguments of C.S. Pierce (*On Some consequences of four incapacities*) viz. from the initial denial that we have an intuitive power of distinguishing an intuition from a cognition inferentially determined by others, the result may be reached that the conception of anything not discursively cognizable is a contradiction and cannot be presumed, while all cognitive activity is, in turn, reducible to the type of mediate discursive inference, every cognition being determined by some logically prior cognition. Hence a prime goal of knowledge becomes the gradual extraction of the informing principles of whole discursive systems.

(186) Emmet: *The Nature of Metaphysical Thinking,* p. 26.

(187) Hence Culverwell's assertion that we can never have complete intellectual knowledge of anything — "we can never exhaust the whole intelligibility of any entity"; meanwhile he justifies partial knowledge on cherence grounds and by asserting "the experience of certainty is imprinted on our souls by God along with other images." Its ultimate foundation is experience, far above sense, when the soul achieves a level where it can forget "its wrangling syllogisms" entering an intuitional unity with its supreme object, see de Boer: *Theory of Knowledge,* p. 61 et seq.

(188) Wick: *Metaphysics and the New Logic,* pp. 143-143.

(189) *Ennead* 1, 3, 5.

(190) See Robin: *La Théorie Platonicienne des Idées et des Nombres d'après Aristote,* p. 501, et seq.

(191) *Republic* VI, 509B.

(192) Jabobi Mazzini: *In Universam Platonis et Aristotelis Philosophiam Praeludia*....Venetiis 1597, p. 187, quoted Koyre, *Galileo and Plato,* p. 400 et seq J.H. I. IV, No. 4, 1943.

(193) *Dialogues Two Principal Systems,* Saldsbury trans. vol I, p. 181.

(194) *Sigilli Sigillorum*, Secunda Pars, Cap IV (Opere Lat. Conscripte, Florence, 1890, Vol. II, pt. II, p. 196-197).

(195) *Phaedrus* 247C.

(196) *Philebus* 59C.

(197) Ibid 57C.

(198) Ibid 56A-56B.

(199) Ibid 55.

(200) W.F.R. Hardie: *A Study in Plato,* Oxford, 1936, p. 35.

(201) *Statesman,* 283 and 260B.

(202) *Protagoras,* 356A.

(203) *Philebus,* 25-26B.

(204) *Protagoras*, 357C.

(205) *Philebus*, 51C-D.

(206) *Metaphysics*, 1090A.

(207) In Holland trans. of *Philosophy Commonly called the Moral*, 1657 ed., p. 834-835.

(208) *Metaphysics*, 1090A.

(209) *Commentary on Euclid.* Introd. Pt. 1, ed. cit. p. 9.

(210) *De lib. arbit.*, II 8, 21, discussed Gilson, *Introduction à l'étude de Saint Augustin*, p. 19 et seq.

(211) *L'Encyclie des secrets de l'Eternité*, 1571, cited Schmidt, *La Poesie Scientifique*, p. 187.

(212) *Discourse* IV, chap. 5.

(213) *Treatise concerning Eternal and Immutable morality* IV, 4, 5 (Appended *T.I.S.* 1845 ed., vol. III, p. 625).

(214) *Meditationes de Prima Philsophia*, Amsterdam, 1678, Med. V. "De essentia rerum materialem, et iterum de Deo quod existat," p. 31. The conclusion reached by this is "Atque ita planè video omnis scientiae certitudinem et veritatem ab una veri Dei cognitione pendere."

(215) C.p. G.H. Hardy, *A Mathematicians Apology*, Cambridge, 1940, p. 63-64. "I believe that mathematical reality lies outside us, that our function is to discover it or observe it, and that the theorems which we prove and which we designate grandiloquently as our creations are simply our notes of our observations," and Russell's declaration of his former belief "in the Platonic reality of Numbers, which in my imagination peopled the timeless realm of Being." (New Pref. to 2nd ed., *Principles of Mathematics*, 1937, p. X.)

(216) *Opus Majus* IV, I, 3, Vol. 1, p. 121-127.

(217) *Epistle* 79 (*Oeuvres*, trans. Druon, p. 508).

(218) *Opus Majus*, ed. Jebb, London, 1733, p. 64.

(219) *Opus Majus* (Burke trans.), Vol. I, pp. 121-127.

(220) *Op. Maj.*, Pt. V, Vol. II., p. 499 et seq.

(221) Bib. Nat. M.S. 16089 Printed R. Steele Isis XX, 1933, *Roger Bacon as Professor, A student's notes*, p. 83 et seq. (The arguments are very similar in style to those in *Op. Maj.* Pt. IV, Dist. I, Cap. II.)

(222) *De Beryllo*, Cap. XXXVIII (Opera 1450, p. 177 — unnumbered).

(223) *Dial 3. (Oeuvres Choises*, p. 251).

(224) A sidelight is the establishment of the compass as the invariable, often the sole, accompaniment of the emblem of Reason (usually a female figure). A multitude of engraved title pages from the sixteenth century onwards bear the two figures, a woman holding a compass (Reason), and another bearing a Bible (Revelation). Again, De Mornay is full of mathematical

"illustrations" of reason. The "Preface to the Reader" states that Religion myst be established, and will thus receive universal assent from Common Principles, developed in Euclidean fashion, "after the same manner, by this principle: He that from equall things taketh equall things, leaveth the remainder equall (Euclid lib. 1, prop. 45); and by a few other propositions which children learne in playing; the Mathematician leadeth us gentlie (and ere we be aware of anie mounting) unto this so greatlie renounced proposition and experiment of Pythagoras that a Triangle, the side that beareth up the right Angle, yeeldeth a sqaure quall to the other twayne which at first sight seemeth impossible, and yet degrees is found to be so of necessitie. Thus shall the Jew by common principles and conclusions verifie...(etc.)" Truth can be found and God known by combining statements of Aristotle and other pagan philosophers "Certesse in the manner as by Arithmetike, out of two and sixe we draw out one continuall proportionable line, hidden after a sort in either of them and yet greater than both of them together which is Eighteene" (trans. Sydney: *Works* III, pp. 251-254).

(225) *The Idea of Nature,* p. 94.

(226) A.E. Taylor: *Platonism and its Influence,* p. 12.

(227) Gilson: *Introduction de l'Étude de Saint Augustin,* p. 116.

(228) Collingwood: *The Idea of Nature,* p. 95. Elsewhere Collingwood returns to this theme to emphasise the importance of a Christian theology combining with a Platonic mathematician to produce this novel evaluation of the particular. For an emphasis on an omnipotent creator implied that nature could not merely be an imperfect approximation to an ideal realm, if the natural line was not exactly straight then it was exactly something else as God intended it, and it was the business of scientists, confident of the rationality of God, to discover why; hence, in some respects, Collingwood affirms "The Platonism of Renaissance natural scientists is not fundamentally Platonic, it is fundamentally Christian," and in this lay its power. (*An Essay on Metaphysics,* Oxford, 1940, p. 254).

(229) 68E-69. Trans. Cornford, p. 279.

(230) *De Cons. Phil* IV, 4.

(231) *De Doct. Ign.* II, 9.

(232) Charbonnel: *La Pensée Italienne au XVI^e siècle,* p. 444.

(233) *Le Progrès de la Conscience,* p. 39.

(234) *Two Principal Systems,* Salusbury trans. Vol. II, p. 137. The distinction he insists on between "logic" and "demonstrations" is not unimportant in this context. Earlier it is said (Ibid p. 23) that just as the composition of poetry can only be properly learned from the reading of poetry itself "Demonstration is learned from the reading of Books full of demonstrations, which are the Mathematical not the Logical" — in which once more a Platonic view of the limitations and method of education in relation to the prior potentialities of the mind seems to be assumed.

(235) See Lenoble, *Mersenne,* p. 235.

(236) The general thesis of *Formal Logic,* London, 1912.

(237) *Système du Monde,* 1799, V, 5, quoted Boutroux, *L'idéal Scientifique,* p. 132.

(238) *Euthyphro* 7 b-c.

(239) *Récherche de la Vérité* discussed Brunschwicg: *L'Expérience Humaine,* p. 5 et seq.

(240) Abel Rey (*Théorie physique chez le physicien contemporary*, 1905), quoted and discussed, Metzger, *Les Concepts Scientifiques* p. 156 et seq.

(241) "In the seed of a plant to the eye of God and to the understanding of man, there exists though in an invisible way the perfect leaves flowers and fruit thereof; for things that are *in posse* to the sense, are actually existent to the understanding" (*Religion Medici*, I, 50. *Works*, II, p. 74). It was in the field of biology that the assumption of "Legions of Seminal Ideas" that had yet to put on "the coats of their forms" seemed most requisite to supplement lack of demonstrable knowledge.

(242) *Metaphysics*, 1092C.

(243) Blanché: *La Science Physique et la Realité*, p. 3 & 33.

(244) *New Pathways in Science*, Cambridge, 1947 ed., p. 256, cp. p. 262, "what physics ultimately finds in the atom or indeed in any other entity studied by physical methods is the structure of a set of operations."

(245) Salusbury trans. Vol. I, pp. 86-87. Human knowledge comprehends little "extensively," but some things absolutely intensively; such are propositions in Geometry and Arithmetic, "in which Divine Wisdom knows infinite more propositions, because it knows them all; but I believe that the knowledge of those few comprehended by human understanding equalleth the divine as to the certainty objective, for that it arriveth to comprehend the necessity thereof than which these can be no greater certainty," for though a difference may be said to be that God knows them without a discursus, at least of a temporal kind "as to the truth of which Mathematical demonstrations give us the knowledge, it is the same which Divine Wisdom knoweth." The position rapidly becomes commonplace, and is met with frequently in allusions, thus Osborne, in passing, refers to "Mathematicks, the Queen of Truth" as "this Angelicall Knowledge," and after referring to the certainty of the demonstrations, declares it "the only knowledge we can on Earth gain, likely to attend us to Heaven." (*Advice to a son*, 1656, ed. Parry, London, 1896, pp. 13-14.)

(246) *Il Saggiatore (Opere* VI, 1933, p. 232).

(247) See Koyre, *Galileo and Plato*, J.H.I. IV, no. 4, Oct. 1943. "It is obvious that for the disciples of Galileo, just as for his contemporaries and elders, mathematicism meant Platonism" p. 424.

(248) P.P. Wiener, *The Tradition behind Galileo's Methodology* (*Osiris* I, 1936), p. 743.

(249) *La Loi de la Chute des Corps Descartes et Galilée. (Revue Philosophique*, Année 162, 1937, p. 153, separate publication as *Études Galiléennes*, III, 1939.)

(250) The legend has been examined, and ascertainable facts brought to light by Lane Cooper: *Galileo and the tower of Pisa* (N.Y., Cornell University Press, 1935) and A. Koyré, *Galileo et l'expérience de Pisa* (Annales de l'Université de Paris 12, 1937).

(251) *Principes* 11, 82, see Brunschvicg: *L'Experience Humaine*, p. 185.

(252) See on Mach's criticism of Archimedes Emil Borel: *L'Evolution de la Méchanique*, Paris, 1943, p. 24 et seq. Arnold Raymond's view that "the path followed by Archimedes in mechanics, though an admirable method of demonstration, is not a method of investigation," (*History of Science in Greco-Roman Antiquity*, London, 1927, p. 295) may be admitted without impugning the position that such formal expression is nevertheless the commonly desired end in the

presentation of results previously determined by no matter what psychologically helpful method of "discovery."

(253) Borel, *L'Espace et le Temps,* p. 28.

(254) *De Caelo,* 303B-304B.

(255) Eva Sachs: *Die fünf Platonischen Körper,* Berlin, 1917, p. 206.

(256) *Ennead* 111, 6, 13 et seq.

(257) Saliba: *Avicenne,* p. 64.

(258) *Crescas' Critique of Aristotle,* p. 307, Prop. XXXII.

(259) Francesco Patrizzi: *On Physical Space* (trans. B. Brinkmann from *Nova de Universis Philosophia 1593,* J.H.I. 4, 1943 p. 221 et seq).

(260) Crescas: *Critique of Aristotle,* p. 195.

(261) *Commentary on Euclid,* p. 4.

(262) *Vorrede* to *Metaphysische Anfangsgrunde der Naturwissenschaft* (1780) *Werke,* ed. Cassirer, Vol. IV, 1922, p. 372. Particular sciences rely on the apodeictical certainty of reason, which rests on a priori elements in thought. Science must *construct* its concepts to correspond with the given and "Nun ist die Vernunfterkentniss durch Konstruktion der Begriffe mathematisch"; philosophy is taken as less fundamental, by a distinction which reappears in the *Introduction to the Logic* of 1800, for it is "Rational Knowledge from mere Concepts," while mathematics is "Rational Knowledge from the Construction of concepts."

(263) *Ignatius his Conclave* (*Nonesuch Donne,* London, 1929, p. 363).

(264) *The Nature of Truth,* 1640, p. 104, he continues with a criticism of the senses: "When the nimble jugglers play their pranks you see and heare yet neither see nor heare," etc.

(265) Burtt: *Metaphysical Foundations,* p. 229.

(266) *La Monde,* ed. D.R. Paris, 1664, Chap. 1.

(267) *True Intellectual System,* Pref. to Reader, Vol. I, p. XXXII.

(268) De Boer, *Theory of Knowledge,* p. 162.

(269) *Our Knowledge of the External World,* London, 1914, p. 110.

(270) *The Mysterious Universe,* Cambridge, 1930, pp. 140-141.

(271) Borel: *L'Espace et la Temps,* pp. 151, 154.

(272) *A Mathematician's Apology,* Cambridge, 1940, p. 68. Cp Martin Johnson: *Science and the Meanings of Truth,* London, 1946, p. 11: "Nearly every recent writer on the philosophy of science has endeavoured to captivte or to scandalize his readers by pointing out that a lump of material is hard, cold, motionless, unpenetrable in the nonscientific account but....(in the scientific account)...reduces to points of singular intensity of electric field in empty space, its constituents totally inaccessible to the sight, touch, smell, hearing of our individual explorations of the world."

(273) Cp, however, Mersenne on the same topic in *Questions Théologiques*, "il semble que la capacité des hommes est bornée par l'ecorce, et par la surface des choses corporelles, et qu'ills ne peuvent penetrer plus avant que la quantité, avec une entière satisfaction. C'est pourquoy les anciens n'ont pen donner aucune demonstration de ce qui appartient aux qualités" (See Lennoble, *Mersenne*, p. 353).

(274) Thus Dee dwelt sometimes on the immense possibilities of mechanical development guided by mathematics. But perhaps the most complex machine actually in use in England in the 16th century was William Lee's stocking frame. Cardan's works dealing with machines still tend to treat tham as isolated "mirabilia," they amaze or amuse, rather than assist useful work; the designs of Beason might stimulate the imagination by grandiose claims,but would only have brought discredit on the new scientists' prophecies had an attempt been made to realise them. (They most assume, neglecting the weight of the structure, an increase in power directly proportional to size; they are purely ideal in their indefinite multiplications of pulleys and cogged wheels and screws.)
(275) It is hardly necessary to labour this point. Many examples are given by E.T. Bell: *The Development of Mathematics*, N.Y., 1940. Thus, pp. 21-22: over a century and a half "before anyone had dreamed of an electric dynamo the necessary mathematics of dynamo design was available." The Pythagoreans investigated polygonal numbers which only recently became of practical importance (in insurance and statistics); "the Conic sections were substantially exhausted by the Greeks about seventeen centuries before their applications to ballistics and astronomy, and through the latter to navigation, were suspected." "The fact is," wrote W.K. Clifford of mathematical research (*Lectures and Essays*, London, 1886, p. 70), "that the most useful parts of science have been investigated for the sake of truth and not for their usefulness," and adds a similar and pointed contemporary mathematical example.

(276) G.H. Hardy: *Some Famous Problems of the Theory of Numbers*, Oxford, 1920, p. 4.

(277) *Through Science to Philosophy*, p. 159. He has just quoted Eddington's phrase: "a thing may be said to be real if it is the goal of a type of enquiry to which I personally attach importance."

(278) *Metaphysical Foundations of Physical Science*, p. 300.

(279) *In Somn. Scip.*, I, 6, 19. "Esse autem dicimus intelligibilia videri, esse, corporalia omnia seu divinum corpus habeant sen caducum"; "Number," Macrobius declares, is "the first perfection of the incorporeal" (Ibid I, 5, 13; *Opera*, p. 15. See Whittaker, *Macrobius*, Cambridge, 1933, p. 59 et seq).

(280) E.g., Whewell (*History of Scientific Ideas*, p. 106 et seq) develops the thesis that mathematics is not merely a matter of definitions and assumptions logically organised, but is founded firmly on certain necessary truths corresponding to Ideas or Intuitions, natural to the mind, which exclude all alternative systems, thus on the Euclidean concept of parallels he observes, it is "a geometrical doctrine of which we see the truth with the most perfect insight of its necessity" (p.111).

(281) *Continu et Discontinu en Physique moderne*, Paris, 1941, pp. 87-88.

(282) "May not the Harmony and Discord of colours arise from the proportions of the vibrations propagated through the fibres of the Optick Nerves into the Brain" exactly as the harmonies and discords of sounds have a numerical basis? queries Newton (*Optics*, 1704, pt. 2, p. 136, Query 14). It was of course only with the appearance of his work that "the science of colours became as truly mathematical as any other part of Optics" (Burtt, *Metaphysical Foundations*, p. 206).
(283) *De Anima* II, 1. He argues elsewhere (*On the Sense*, ch. 4) that qualities cannot be so reduced as they are often contraries (as hot or cold) which figures and numbers cannot be.

(284) Showing this kind of sensation experienced depends not on the mode of stimulation of the nerves, but on the nature of the sense organ: light, pressure, mechanical irritation, acting on optic nerve or retina all producing luminous sensations (see Dampier, *History of Science*, p. 275).

(285) Karl Pearson's *The Grammar of Science* is one of the earliest of the very many modern presentations of this view, in support of which Varhinger's analyses of the self contradiction inherent in many of the most useful scientific concepts were also made.

(286) An example of H. Jeffries (*Theory of Probability*, Oxford, 1939, p. 343). "There are three main quantum theories, but all make the same predictions...The theories themselves are not the same and indeed each contains references *to things that have no meaning on another*. The treatment of them as equivalent refers on ly to the observable results and not to their actual content." Poincaré observes (*Science et Hypothèse*, p. 167) that an infinite number of "mechanical explanations" may be given for any finite set of phenomena, as long as no limit is set on the degree of theoretical complexity involved. Sir Edmund Whittaker similarly remarked in the Tarner lectures of 1947 (*From Euclid to Eddington*, p. 30) that space can be equally well mapped on either Euclidean or non-Euclidean principles "provided we make the requisite changes in our physical laws. It is purely a question of convenience whether we prefer to have an easily intelligible geometry with complicated physical laws, or a less intelligible geometry with simply physical laws."

(287) C.I. Lewis, *Mind and the World Order*, London (printed USA), 1929, p. 204.

(288) *Harmonices Mundi* (1619). The square of the periodic time of a planet is proportional to the cube of its mean distance from the sun (i.e., if these quantities are both taken as 1 in the case of the earth, to provide a standard, then for each of the other planets, both quantities will be represented by the same number). It is clear that while simple lengths of time, or distance, or even multiples of them, may figure in equations and still convey an intuitive impression of representing or describing what may be conceived of as effective "things," existing in nature, whatever the reference may be of the quantity obtained by squaring or cubing them, it provides no support at all to such an attitude, Kepler sought esoteric significance in the mathematical harmonies themselves to account for so perfect and complex a relationship. Additional psychological support was the realisation that every quantitative relation among phenomena can be put into a form which asserts the constancy of some quantity which can be calculated from the phenomena, but that this constant, this unchanging "quantity" is not in any of the individual phenomena taken singly, they are in continual change, only they vary proportionally and in accordance with, as though themselves governed by, this purely abstract quantity. (cp Burtt, *Metaphysical Foundations*, p. 53. Kepler "thinks of the underlying mathematical harmony discoverable in the observed facts as the cause of the latter, the reason he usually puts it why they are as they are.")

(289) *Republic*, Bk. VII, 529-530.

(290) One of the major themes of the *Preface*, where the familiar doctrine of the three worlds is given an epistemological interpretation. The lower world is that known by sense experience and imagination supplied by the senses, the upper is that in which the soul attains adequate intuitions of spiritual entities, knowledge in both involves a relationship between the mind and an external perceived reality. The mediant region is that of mathematics in which the mind may draw its whole matter for discourse from what it already possesses, and without any reference beyond itself may discover in this region the laws and patterns that will allow it to comprehend phenomena in both upper and lower worlds. The doctrine is given an apt emblem by Cornelius Gemma in *De Arte Cyclognomica*, which is set on the title page (and also reproduced and discussed at times in the text). From a winged heart rises a pillar surmounted by a circle (eternity) over which is set a pyramid (God) giving forth living fire. About the pillar of man's central nature coil two winged dragons as round a caduceus, forming three circles increasing in proportions from lowest to highest. The mouths of the dragons feed on the fire from the pyramind. The top and bottom

circles, however, are not complete but open — the upper open toward the pyramid, the lower open towards the inferior heart, but the middle where their bodies twice cross, is complete in itself. The three are labelled "Virtus Imaginatrix," "Ratio" and "Intellectus" (see pt. I, p. 11 for some verbal interpretation — where Man is described as planted by God in the earth, rooted inthe lower regions with his upper parts — "comam vero atque perpetuo frondente verticem...supra caeli extremam circumferentiam ad nunquam interituros ambitus religauit" etc.).

(291) *Ennead* I, 5, 8, states that an individual should live an amphibious life — — between the spiritual and sensible worlds.

(292) *Communsa Mathematica* II, 3, 3 (*Opera hact med.*, Fasc. XVI, ed. Steele, 1940, p. 117), cp also I, 1, 7, pp. 16-17, on the utility of mathematics and the general object of all philosophy.

(293) *Christ's Tears over Jerusalem* (*Works* II, p. 125).

(294) Cornelius Gemma gives an elaborately drawn emblem to illustrate the process of the way in which by "illumination" true "Ideas" are to be gathered through the medium of even the least of natural things (which also illustrates the manner in which "mathematical" propositions were applied analogically to reveal metaphysical truths). A round temple represents the human mind. It is blocked from the sun by a large outer wall with a small circular window. The rays of the sun enter through this (as in a pinhole camera) to cast an image much larger than the orifice through which they passed onto the temple (reflected light from this also renders visible the outer wall — or sensible things — from the temple). Gemma commnts "Ita & idearum influxus a superna vita in inferiorem derivati ex augustissimus maximè in angustiam particularem rediguntur, donec a materie atque corporibus reflexi iterum in humanos animos, ex singularibus facti universales, amplitudine pristina potiantur" (*De Arte Cyclognomica*, Pt. II, pp. 89-90). The source of this proposition seems to be the Pseudo Euclid *De Speculis*, prop. 9. "Ex hoc quoque ostendam, quod, cum sol intrat per fenestram, illud luminis eius, quod ingreditur et super terram cadit, magis est amplium quantitate fenestrae" (*Alkindi Tideus und Pseudo Euklid. Drei optische Werke*, ed. Bjornbo and Vogl, Berlin, 1912, p. 102, see also p. 112, for the same theorum used by Witelo, *Optics*, and by Baconin *Opus Majus* II). The same symbol makes an interesting appearance in Chapman's *Sir Giles Goosecap* II, 1, the narrowness of the circle here representing the low worldly estate of Eugenia's suitor that Lord Momford is arguing should, rightly regarded, prove no impediment: "The bigness of this circle held too near our eye keeps it from the whole sphere of the sun; but could be sustain it indifferently betwixt us and it, it would then without check of one beam appear in his fulness" etc.

(295) *Lives* III, 63 (Vol. I, p. 33).

(296) *Dialogue with Trypho*, 2, *Works*, p. 73.

(297) *The Practise of Chymicall and Hermeticall Physicke*, A.4^{r}.

(298) *Confessions*, VII, 9; de *Civ. Dei* X, 29 (Vol. I, 303-305). But de *Civ. Dei* VIII 9 (Vol. I, p. 233-234) discussed Platonism and Pythagoreanism under the heading "Oft that philosophy that comes nearest to Christianity," while on the manner of the soul's restoration to a body after death he declares: "Plato and Porphyry held diverse opinions, which if they could have come to reconcile they might perhaps have proved Christians" (*Ibid*, XXII, 27, Vol. II, p. 397).

(299) *Protrepticus* VI (*Works* I, p. 69, et seq). Clement's own doctrine of God has been said to be based on an "essentially heathen conception." He has not asked what is Spirit, or what is the Idea of the Good, but "what is the simplest thing conceivable? And he assumes that this is, and that it is the cause of all that exists." (Bigg, *The Christian Platonists*, p. 95.) Such a doctrine it may be noted, is also the starting point of Dee's *Monas*.

(300) *Opus Majus* II, 16, Vol. I, p. 68.

(301) *Ibid,* VII, Vol. II, p. 644.

(302) Taylor: *Platonism and its Influence*, p. 14.

(303) Trans. Sydney (Sydney, *Works* III, p. 365).

(304) Diogenes Laertius, *Lives*, Bk. 1, 9 (Myson, 600 BC) (Vol. I, p. 113).

(305) "Nay Nature itself invites us to be geometricians: it presents us with Geometrical Figures, with Circles, and Squares, with Triangles, Polygons and Spheres, and proposes them as it were to our Consideration and Study, which abstracting from its usefulness is most delightful and ravishing." (Constantin Huygens, *The Celestial World Discovered*, 1698, p. 84).

(306) Thus Butler writes of "a Mathematician": "His Art is only instrumental and like others of the same kind, when it outgrows its use becomes a mere curiosity; and the more it is so the more impertinent it proves....His Forefathers passed among the Ancients for Conjurors, and carried the credit of all Inventions, because they had the Luck to stand by when they were found out, and cry'd *half's ours*." Geometry he says, is to inventions in mechanics only what grammar is to the original use of language: "Mathematicians are the same Things to Mechanics as Markers in Tennis Courts are to Gamesters," and any that say that inventions are due to mathematics "are as wise as those that say no man can play well that is not a good marker." (*Characters*, p. 79.)

(307) A typical sixteenth century statement is Postel's "Certissimum est, quum omnis compraehensibilia ad hoc creavit Deus, ut de illis agnoscatur, ametur, laudeturq in aeternum datur infinitus, opus fere, ut omnia creata clarissimi sint ad intellectus nostri adoequationem per uentara: Nam ahoqui frustra essent condita." (*Absconditorum Clavis* A3^{r}) cf. Boyle "I see no necessity that intelligibility to a human understanding should be necessary to the truth or existence of a thing" (*Works* IV, p. 450, quoted Burtt, *Metaphysical Foundations*, p. 179).

(308) "The capital fault of materialism lies not in its belief that the primary qualities — or some of them — are objective, but in its denial that the secondary qualities are so. It seeks to *replace* the presented facts of experience by other alleged facts of which the former are explained to be only appearance." Nunn: *The Aim and Achievements of Scientific Method*, p. 16.

(309) Klibansky: *Continuity of the Platonic Tradition*, p. 29.

(310) The same interests are frequently found united in later thinkers such as Descartes or Malebranche, who owe a debt to this tradition of thought. Even of Mersenne, Lenoble records "Il n'a jamais écrit que deux pages de véritable lyrisme, l'une pur chanter la vie religieuse, l'autre les automates" (*Mersenne*, p. 81).

(311) Klibansky, op cit., p. 29.