1980HisSc..18..233C

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SCIENCE AND THE ARTS IN THE RENAISSANCE: THE SEARCH FOR TRUTH AND CERTAINTY, OLD AND NEW

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"Man is to render praise to God"—so wrote Leon Battista Alberti in the mid-fifteenth century—"to satisfy him with good works for those gifts of excelling *virtù* that God gave to the soul of man, greatest and pre-eminent above all other earthly animals".[1] Works could satisfy their creator with those qualities of *virtù* in any kind of activity ranging from the conduct of family life to painting and architecture. All when they did so shared the common characteristic indicated by Alberti when he explained by the method of perspective for "the painter how he can represent with his hand what he has conceived with his mind".[2]

The term *virtù* in Renaissance Italian indicated a style of intellectual and consequently practical behaviour. A man of *virtù*, acting rationally in the image of his Creator, was a man with intellectual power (*virtù*) to command any situation, to act as he intended, like an architect producing a building according to his design, not at the mercy of fortuitous circumstances or *fortuna*. Whether in mind or matter, in the natural sciences or the constructive arts, in private or political life, a man of *virtù* aimed always to be in rational control of himself as a moral being and in relation to his fellow men and to nature, in control of what he did and what he made. He was the rational artist in all things.

The conception of the *virtuoso*, the rational artist aiming at reasoned and examined control alike of his own thoughts, intentions, and actions, and of his surroundings, seems to me to be of the essence of the European morality, meaning both habits and ethics, out of which the European scientific movement was generated and engineered. In this context the rational artist and the rational experimental scientist appear as exemplary products of the same intellectual culture. The rational perspective artist formed in his mind a conception of what he would represent by an antecedent analysis of visual clues organized optically by geometrical perspective; the rational experimental scientist proceeded likewise by an antecedent mathematical and conceptual analysis of his subject-matter. They shared an intellectual commitment to the cultivation of *virtù*. This common commitment offers an invitation, then, to relate the styles of scientific thinking in any period to contemporary styles of thinking in the

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1980HisSc..18..233C

arts, in philosophy and theology, and in practical affairs. It offers likewise an invitation to analyze the various elements that make up an intellectual style in the study and treatment of nature: conceptions of nature and of science, of scientific inquiry and scientific explanation, of the identity of natural science within an intellectual culture, and the intellectual commitments and expectations that affect attitudes to innovation and change. These questions again, asked comparatively of different cultures, offer a culturally integrated view of the historical problem of the unique origins of modern science in the society of Western Europe.

The scientific movement has been concerned with man's relations with nature as perceiver, as knower and as agent. If we can characterize the commitment to the ideal of deciding by argument and evidence all questions about what exists and about what should be done, we can see in the origins of modern science a series of Western responses to the recovery of ancient thought made by a new society with some different mental and moral commitments and expectations. Medieval and early modern Europe had a different view of nature and of man and his destiny, a different theology, a different economy, and a different view of technology. We may distinguish three broad stages of intellectual response and orientation, each developing a characteristic style of formulating and solving its problems.

With the first intellectual impetus given by the recovery of ancient texts from the twelfth century came a primary intellectual achievement. This was the grasp and critical elaboration by the philosophical community of the medieval schools and universities, of the construction of a demonstrative explanatory system on the models of Euclid's geometry and Aristotle's natural philosophy. Together with this came a critical elaboration of logical precision, from methods formalized by Aristotle, for the control of argument and evidence to decide a question, including decision by calculation, observation, and experiment. Secondly came a matching of this logical control of argument and calculation with a likewise theoretically designed and measured control of a variety of different materials and practical activities. Programmes towards this end already expressed from the twelfth century that urge towards rational analysis and ingenious contrivance for the material mastery of nature,[3] which was to be achieved in action by the practitioners of a diversity of arts. This group, working essentially outside the universities but not without university contacts, came to succeed by making rational and, where possible, quantitative analysis precede material construction or action. Thus they achieved control of the measured representation of visual space by perspective painting and sculpture, and of time by the mechanical clock, of music by measured temporal patterns of pitch and interval, of spatial location and transport by trigonometric surveying and

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1980HisSc..18..233C

cartographic coordinates, of building and machines by a search for rational mechanics, of commerce and administration by systematic book-keeping and numerical recording. The goals of the arts, whether technological or aesthetic, should not be confused with those of philosophy and the sciences, but it does not seem difficult to recognize in them all a common intellectual style in which each reinforced the others, and all came to contribute to the third stage of the origins of modern science. That was the confident establishment of the "new sort of philosophizing"[4] in the "physico-mathematical experimental learning"[5] of the seventeenth century. The intellectual approaches leading in this way to a conception both of scientific inquiry and of artistic composition as cognate arts of the soluble began with the recognition that theoretical analysis and rational design must precede material analysis and construction. They concluded with an experimental science that combined, with effective logical precision, a theoretical search for common forms of explanation with a practical demand for accurately reproducible results.

Some of the characteristics of this intellectual culture which produced the rational European movement of both science and the arts can be exemplified from that enterprize of the search for truth and certainty which became explicit in the middle stage of this intellectual orientation, during the fifteenth and sixteenth centuries. European intellectual life received a considerable stimulus in the late fifteenth and early sixteenth centuries from the recovery, publication and active use of a body of Greek philosophical and scientific writings hitherto either unknown or with little influence in the Latin West. These writings fell into two main groups, with some overlap, each producing a corresponding response, centred at the beginning in Italy.[6]

The first group of writings comprized philosophical texts, notably the extant works of Plato translated into Latin by the Florentine philosopher Marsilio Ficino together with then-associated Hermetic documents, and detailed reports of Greek atomism and scepticism provided especially by Lucretius, and by Sextus Empiricus and Diogenes Laertius. These were taken up by philosophers dissatisfied with established academic Aristotelianism, who saw them primarily as a means of finding other, more acceptable, rational criteria for knowledge in general and for religious knowledge in particular, and of bringing about moral improvement and educational reform. At the same time they introduced a complex intellectual and moral crisis: from Plato and the Hermetics as ambiguous alternatives to the Christian theology of creation with its integral moral doctrine of providence; from the atomists by the elimination of Providence altogether; and most pervasively from the sceptics whose arguments, launched into the republic of letters by Montaigne, produced a continuing intellectual insecurity to become, in the discriminating treatment of such as Marin

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1980HisSc..18..233C

Mersenne and Descartes and Pascal, an integral part of European thinking. The second group of writings comprized texts on the mathematical sciences and arts and their applications. Of these some came to exert a powerful general influence upon intellectual history, while others of greater specialization, about optics and mechanics and music and so on, supplied the theory used and developed by practical mathematicians and artists.

The intellectual commitments of the two groups of persons primarily interested in these writings can best be compared by looking at their conceptions of a common subject: the place of mathematics in intellectual culture. Such a comparison shows that they shared a very general outlook as members of the same integrated world, but that the uses they saw for mathematics and their conceptions of rational choice were poles apart. The debates and practical experience over all these questions promoted in their specialized range a growth of the technical content of the sciences and arts, but more generally and more subtly they promoted shifts of intellectual style, most profoundly perhaps in the commitments and expectations of disagreement as well as agreement. The comparison illustrates again the need for us to understand the whole context of thought about true knowledge and its value, if we are to see how art and science as problem-solving activities fitted into the contemporary scheme of knowledge and existence.

The most striking characteristic shared by this intellectual inheritance was its mathematical rationalism, dominating the conception of a whole range of knowledge and practice from physics and the visual and musical arts to ethics and theology. The ultimate literary source of this rationalism was Plato, with behind Plato the Pythagoreans, notably Archytas of Tarentum. Platonic or Pythagorean rationalism had a long history in medieval thought, through Plato's *Timaeus,* through St Augustine, and also through Aristotle himself. It received a new life in the fifteenth century from Ficino's Latin versions and commentaries, and also from other contemporary scholarship, of which much the most important for the mathematical sciences and arts was that included in Giorgio Valla's great work *De expetendis et fugiendis rebus opus* (1501: On things to be sought and to be shunned). In this Valla presented a compendium of all the sciences and arts, aimed at both intellectual enlightenment and moral education from a point of view which he shared both with the moral philosopher Ficino and with their contemporaries Leonardo da Vinci and Albrecht Dürer and other practical artists.

The point of view which they shared had been established in Platonic thought as a specific theory of nature and of man's relation to nature as perceiver, knower and agent. Nature had been designed by divine art on the analogy of human art with mathematical order and proportion perceptible by sight and hearing, but properly graspable only by the

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1980HisSc..18..233C

intellect. Conversely, Valla cited Archytas to the effect that man had first to conceive in his mind both what he wanted to explain, and what he wanted to make or do. Science was knowledge of stable universal principles such as mathematicians knew. The artist, before making something, by reason "fashions and forms it inwardly, and accordingly makes an image for himself of everything that is to be portrayed".[7] Valla saw both the experimental science of nature and the constructive arts (mechanical, plastic, visual, musical) as the imposition of reason by antecedent analysis, above all through mathematics.

In this view Valla was guided also by two other ancient authors whose works were to exert a powerful influence upon the intellectual history of the sixteenth century. The Roman architect Vitruvius insisted on the precedence of theory in any rational action, and in particular of mathematical theory in a constructive art. The authors of the first Italian edition of *De architectura* (1521), begun by Cesare Cesariano and continued by Benedetto Giovio and Bono Mauro, developed this in a fascinating exegesis of the words 'machinatio' and 'machina' (which have in Greek and Latin the same range of meaning from mechanical contriving to political machination as they do in English and other modern European languages) into a view of inquiry into the operation of things as cunning intellectual contriving. Again they cited Archytas as a mechanic, famous for constructing a wooden dove which flew, to illustrate that intellectual contrivance must first find out by reasoning both what men wanted to explain and what they wanted to "put into practice through a burning desire to produce in sensible works with their own hands that which they have thought out with the mind".[8]

Valla's other general guide was the Hellenistic Greek philosopher Proclus. In his commentary on Euclid's *Elements of geometry,* Proclus set out a Platonic and Pythagorean scheme which was to offer probably the most influential programme for the mathematical sciences and arts in the sixteenth century. He saw mathematics as an intermediate science, generated by the mind but both stimulated by and projected upon the world of the senses. In one direction its reasoning replicated the complex material world with a world of ideas, and led the mind from the observable uncertainties of matter to the rational certainties of the highest abstractions. In the other direction, by descending into matter it delivered out of itself the principles both for scientific understanding of the material construction of the world and for the materially constructive mathematical arts. These sciences and arts included those to which in both theory and practice Renaissance Italy above all, but also the Netherlands and other European centres, made their major contributions to the intellectual history of the European scientific movement, by the development of rational mechanics, of cosmography and cartography, of optics applied to perspective

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1980HisSc..18..233C

painting and sculpture, and of measured music. All involved a rational inquisition, representation, and finally imitative manipulation of nature. The perspective artists made the geometrical optics they learnt from Euclid and his ancient and medieval successors yield a practical method of showing precisely what would be seen under specified conditions of angle of vision, distance, reflection and refraction, shadow and so on and of transfering this three-dimensional information to a two-dimensional surface. Albrecht Dürer's assertion, that "a good painter is inwardly full of figures", which pour forth "from the inner ideas of which Plato writes",[9] was made by an artist with technical experience in the practical mathematics of design, and should be so understood. Likewise, a precise technical bearing should be understood in the mathematical rationalism of Leonardo da Vinci's repeated assertions that all art must begin in the mind before it can issue through the hands, and that nature has necessary laws which art must follow but which, unlike nature, the artist is free to manipulate acording to his own design. Thus the rational artist was the exemplary man of *virtù*, always in control of what he made within the rationally examined limits of the possible. For "whatever exists in the universe through essence, presence or imagination he has first in the mind and then in the hands".[10] The inquisition of nature, for this master both of design and of the intellectual play of thought-experiments, was then a pursuit of intellectual contrivance and machination: "O speculator on things, I do not praise you for knowing the things that nature through her order naturally brings about ordinarily by herself; but I say rejoice in knowing the end of those things that are designed by your own mind."[11]

The philosopher Ficino shared this view which made man through his rational imitation and manipulation of God's designs nature's rival and master, alone among animals capable of inventive progress. But Ficino's attention was focussed on another aspect of Platonism. His was a rational artist's vision of man's moral principles of action. In imposing mathematical order and proportion on matter the Platonic God in both classical and Christian thought gave the world a morally as well as intellectually normative harmony. This harmony came to have various meanings such as simplicity, economy and fitness, which supplied a conception of sufficient explanation with profound influence in the history of science. Harmony was also the bond linking Renaissance science, the visual and musical arts, medicine, and ethics. For such a philosopher as Ficino, mainly interested in moral enlightenment, virtue, like painting, must likewise be designed first in the mind before it could issue in action. In this he reinforced with the new Platonism the essentially Aristotelian style conceived for the mastery of human nature, and the cultivation of the habit of virtue true to that nature, by practice guided by right

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1980HisSc..18..233C

reason. Beyond that he saw with Plato in mathematical ideas an efficacious means of leading the mind from the material world and its concerns upwards to theology and the contemplation of the divine creator. Within this Platonic scheme Ficino elaborated a complex system of correspondence between the macrocosm of the world and the microcosm of the human body and soul, and of the harmonious influence transmitted through the primary media of light and sound. From this he developed a practical moral psychology for encouraging virtue by means of visual designs and music, which would draw down corresponding influence from the heavens.[12]

The contrast between the moral philosophers and the practical mathematicians and artists lay in their conception of rational choice, This is yet another illustration of the complexity of the intellectual landscape through which we must follow the scientific movement. It was for the role of mathematical ideas in moral and theological education that mathematics was encouraged by many philosophers of Platonic leanings during the sixteenth century. It is significant that in Italy there was a link between efforts to promote both Platonism and mathematics in universities, including Jesuit universities, persisting into the negotiations for appointments to chairs in each subject of Galileo's older contemporaries and of Galileo himself. Within this context the moral philosophers saw mathematics essentially as a stage in moral and theological education. Its certainty was for the religious an antidote to scepticism. Its use was to help to induce a general state of mind leading to virtuous action. The philosophers who saw mathematics thus rather as a means to moral and theological education, than to solving scientific or practical problems, were often notable too for their eclectic tolerance of apparently opposing systems. This was an ancient and widespread mental attitude, based on the optimistic belief that all great thinkers when correctly interpreted must be found to harmonize in truth. Hence the tradition that the proper work then for philosophers was to look for concordance between apparently opposing authorities, so that Plato and Aristotle and even the atomists, although probably not the sceptics, would be found to agree in essentials with each other and all with true theology.[13]

In sharp contrast was the brutal insistence of the practical mathematicians and artists that accurate thinking and precisely controlled action alike required the exact identification of specific problems, and that the solution of specific problems required an uncompromising choice. The sciences of nature and the contructive arts were at their cutting edge alike the products not of a general state of mind but of clear limited decisions. The practical mathematicians and artists found their problems in contemporary practices, illuminated by the newly edited and translated Greek works on the mathematical sciences. These were both general, like those of

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1980HisSc..18..233C

Proclus and Pappus, and specialized, like those of Euclid and Ptolemy on optics and on music, of Aristoxenus on music, and of Archimedes and the Aristotelian *Mechanica* on that subject. These subjects in Greek thought comprised *techne*, or art, as distinct from *episteme* or true science. But by the turn of the sixteenth century, the success of the mathematical and technical arts in solving limited problems had put them into a position for the claim to be made that they alone could discover the only true science of nature there was.[14]

The intellectual approaches leading through sixteenth century thought to this conception of science as an art of the soluble may be broadly summarized as follows. Recognition that theoretical analysis and rational design must precede material analysis and construction led to the conception of rational sciences of mechanics and optics and music and so on, all within the limits of the possible. "I have seene all enginiers deceiv'd", wrote Galileo in 1593, "while they apply their engines to works of their owne nature impossible; in the success of which both they themselves have bene deceiv'd, and others also defrauded of the hopes they had conceiv'd upon their promeses". For effects could be obtained only "according to the necessary constitution of nature . . . . And . . . all wonder ceases in us of that effect, which goes not a poynt out of the bounds of natures constitution".[15] Art could not cheat nature, but by discovering, obeying and manipulating natural laws, with an increasing emphasis on quantification and measurement, art was seen to deprive nature of its mysteries and to achieve a mastery exemplified by rational prediction. This rational mastery was illustrated also by the growing popularity of the modelling and extension of the natural by artificial constructions, ranging from clockwork devices to perspective representations as imitative models of the natural clues for perception. In science the model was seen as a means of investigating and explaining the natural. So nature, envisaged in Platonic thought at the beginning of the century as an expression of divine geometry, had been given by the mathematical arts an extended image at the end. For Plato, wrote a French regius professor of these arts who was also a physician, in answering the question what God did, should not have stopped at "he always geometrizes" but should have added "and always mechanizes. For this world is a machine, and indeed the greatest, most efficacious, firmest and most shapely of machines".[16]

Such words must be understood in their intellectual context and that context was certainly not yet that of Descartes. Yet without imposing a completely mechanistic conception of nature, the mathematical sciences and arts combined by the end of the sixteenth century to create within European intellectual culture an effective context for solving problems. I shall conclude with one example. The solution by Johannes Kepler in

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1980HisSc..18..233C

1603/4 of the fundamental physiological problem of vision, that of how the eye formed an image on the retina, was the first major modern physiological discovery. With this demonstration, Kepler introduced a new conception of how to investigate the relation of perceiver to perceived in all the senses. It became as important as William Harvey's later demonstration of the circulation of the blood in opening new prospects for physiology in general. Before Kepler, developments in perspective painting and in the instrumentation of surveying and astronomy had created both a geometrical theory of visual space and a technique for demonstrating what would be seen under specified optical conditions and for representing this upon a plane surface. Two notable contributions prepared the ground for Kepler's solution. The first was Alberti's conception of a picture as a section of the pyramidal figure formed by the lines of vision connecting the object seen with the eye, and his demonstration of how to make the section correctly by viewing the object or scene through a checkered screen. The second was Leonardo da Vinci's use of another device, a camera obscura for throwing an inverted picture of the scene through a pinhole on to a screen. Leonardo compared the eye to a camera obscura with a lens in it, but assiduous attempts by both anatomists and mathematicians throughout the sixteenth century to explain how the eye effected vision all foundered on the same difficulty: the inverted image. The problem as inherited from Greek and medieval optics had been formulated to include questions of perception and causation which prevented a purely geometrical analysis of the formation of the image. Kepler succeeded by first isolating the geometrical optics of the eye as an answerable question to be treated apart from all other aspects of vision. He answered it by treating the living eye on the model of a camera obscura with a lens in it, and by reforming the optical geometry of how this device focussed the picture on to the retinal screen. This demonstration provided contemporaries both with a model of scientific method, and with a scientific basis for reintroducing the investigation of the complexities of the perceptual process: for example, how to understand the retinal image as accurately symbolic rather than literally representative of the scene perceived. It provided at the same time a clear scientific basis from which to correct and extend the natural performance and range of the senses by means of artificial instruments.[17] Later in the century, from a similar background in the development of measured and instrumented music, the resonating strings of a lute were to be proposed as a model for the analysis of pitch by the ear.[18]

We may see then in the mathematical sciences and arts of early modern Europe one fecund cultural source of that conception of man's relation to nature as perceiver and knower and agent which came to characterize

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1980HisSc..18..233C

the European scientific movement and with it more generally European culture. In this context we may ask ourselves a question. The successes of the mathematical and technical arts in solving limited and clearly defined problems threw a critical light upon all claims to access to the true science of the nature of things. This intellectual experience was paralleled elsewhere in the scientific movement, for example in the search in biology and medicine for taxonomic criteria that would provide at once a practical classification of living organisms and their diseases and the true natural and causal system. We may ask then what is the comparative value, for scientific as for artistic creation and discovery, of precision with its limitation of risk risking a limitation of vision, as against a general state of mind? What is its value as against such intellectual commitments and expectations as likened reasoning towards mechancal design with that towards aesthetic and moral design, and against the suggestive sources of the imagination which may yet yield only verbiage?

Galileo enjoyed the habit of "speculative minds" in reading "the book of nature, always open to those who enjoyed reading and studying it with the eyes of the intellect. He said that the letters in which it was written were the propositions, figures and conclusions of geometry, by means of which alone was it possible to penetrate any of the infinite mysteries of nature".[19] About this "book of nature, where things are written in only one way" he "could not dispute any problem *ad utranque partem*"[20] as in a scholastic exercise; for the book of nature was "the true and real world which, made by God with his own hands, stands always open in front of us for the purpose of our learning".[21] Galileo aimed to define for his contemporaries the rational identity both of nature, and of natural science in specific distinction from other diverse forms of thinking within contemporary intellectual culture. He reminded theologians sacred or profane of "the difference that there is between opinable and demonstrative doctrines; so that . . . they might the better ascertain themselves that it is not in the power of professors of demonstrative sciences to change opinions at their wish . . .; and that there is a great difference between commanding a mathematician or a philosopher and directing a merchant or a lawyer, and that the demonstrated conclusions about the things of nature and of the heavens cannot be changed with the same ease as opinions about what is lawful or not in a contract, rent or exchange".[22] Again he wrote of a certain philosopher: "Possibly he thinks that philosophy is a book and a fiction by some man, like the *Iliad* or *Orlando furioso,* books in which the least important thing is whether what is written in them is true. Well . . . things are not like that."[23] It was scandalous "to allow people utterly ignorant of a science or an art to become judges over intelligent men and to have power to

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1980HisSc..18..233C

turn them round at their will by virtue of the authority granted to them—these are the novelties with power to ruin republics and overthrow states".[24]

Galileo's public controversies dramatized a subtle shift in the commitments and expectations of disagreement as well as agreement in the intellectual style of the early modern heirs at once of Aristotle and of Moses. His account of scientific objectivity is for us a brisk antidote to the naïver sociological relativism promoted (for whatever motives) by people evidently ignorant of the distinction between the history of science and the history of ideology. His arguments communicate the specific identity of the scientific movement, an identity requiring in its adequate historians, as in those of music or painting, a specific technical mastery of its content. He lays out for us an intellectual enterprize integrated by its explicit historic criteria for choosing between theories and investigations at different levels of the true, the probable, the possible, the fruitful, the sterile, the impossible and the false. By means of these criteria natural scientists have exercized a kind of natural selection of theories and investigations, which has directed scientific thinking as the history of solving problems while at the same time embodying them in ever more general explanations. Thus it is the history of objective progress in knowledge.

Galileo with his learned love of literature, music, and the visual and plastic arts, his eloquent baroque Italian and his matching skills as lutanist and as draftsman, his sense of scientific elegance and of cosmological design, his insistence on being both a philosopher and a mathematician, his desire to win an argument as well as to win the truth—Galileo belongs as recognizably as any of his literary or artistic or philosophical contemporaries to the Tuscan intellectual culture into which he was born. With his aggressive creative energy he too, as he described the musical interval of the fifth, "tempering the sweetness by a drop of tartness, seems at the same time to kiss and to bite".[25] He was an exemplary man of *virtù*, the rational experimenter, in all these sciences and arts of the Renaissance. In that we shall surely find no contradiction. In that context we seem most likely to see how the defining capacity of both art and science to solve specific problems drew in operation upon the suggestive sources alike of the analytical and the constructive imagination.

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1980HisSc..18..233C

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1980HisSc..18..233C

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17. *Cf.* Crombie, "Kepler: de modo visionis", in *Mélanges Alexandre Koyré,* introd. de I. B. Cohen et R. Taton, i (Paris, 1964), 135–72; *idem,* "The mechanistic hypothesis and the scientific study of vision", *Proceedings of the Royal Microscopical Society,* ii (1967), 32–47; *Styles* (ref. 1), ch. 4.ii; M. Baxandall, *Painting and experience in fifteenth century Italy* (Oxford, 1972); S. Y. Edgerton, Jr, *The Renaissance rediscovery of linear perspective* (New York, 1975); and Alberti, above, ref. 2.

18. *Cf.* Crombie, "The study of the senses in Renaissance science", *Actes du Xe Congrès international d'histoire des sciences: Ithaca N.Y. 1962* (Paris, 1964), 93–114; *idem,* "Mathematics, music and medical science", *Actes du XIIe Congrès international d'histoire des sciences: Paris 1968,* iB (Paris, 1971), 295–310; *idem,* "Marin Mersenne (1588–1648) and the seventeenth-century problem of scientific acceptability", *Physis,* xvii (1975), 186–204; *idem, Galileo and Mersenne* (ref. 1), ch. 9; also C. V. Palisca, "Scientific empiricism in musical thought", in *Sevententh century science and the arts,* ed. H. H. Rhys (Princeton, 1961), 91–137; D. P. Walker, "Some aspects of the musical theory of Vincenzo Galilei and Galileo Galilei", *Proceedings of the Royal Musical Association,* c (1973–74), 33–47; *idem, Studies in musical science in the late Renaissance* (London and Leiden, 1978).

19. Vincenzo Viviani, "Racconto istorico della vita di Galileo" (1654; *Le opere,* xix, 625); *cf.* R. Mondolfo, *Figure e idee della filosofia della Rinascimento* (Firenze, 1963), 117–59, 291–373; Crombie, "The primary properties and secondary qualities in Galileo Galilei's natural philosophy", in *Saggi su Galileo Galilei* (Firenze, preprint, 1969); *idem,* "Sources of Galileo's early natural philosophy", in *Reason, experiment and mysticism in the scientific revolution,* ed. by M. L. Righini Bonelli and W. R. Shea (New York, 1975), 157–75; *idem,* "Philosophical presuppositions . . ." (ref. 1).

20. Galileo, note of 1612, *Le opere,* iv, 248n.

21. Galileo, "Prima Lettera circa le Macchie Solari" (1612; *Le opere,* v, 96n.).

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