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Leonardo da Vinci's Perspective and Optics. Elements of a Scientific World View

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This study began in February 1973 at the instigation of Dr. Kenneth Keele, who suggested that in order to understand Leonardo da Vinci's writings on linear perspective one would need take one or two key quantitative passages, follow the instructions, and determine whether they were based on actual experiments.

Throughout the spring and summer of 1973 Dr. Keele and the writer, under the auspices of the Wellcome Institute in London, reconstructed the procedure of several passages and concluded firmly that Leonardo's linear perspective was experimentally based. The results were recorded in the form of a paper originally intended for the *Annals of Science.*

Meanwhile it became apparent that the methods used in these experiments had served in turn as the basis for Leonardo's approach to colour perspective, diminution of form perspective, and indeed the whole of his »science«, including the physics of light, heat, motion. Soon the paper pointed towards a monograph.

A joint grant from the Wellcome Foundation to both Dr. Keele and the writer made it possible, once the latter had completed a dissertation on the history of perspective at the Warburg Institute, to begin on the project full time as of July 1975. But meanwhile Dr. Keele had been beckoned to help with a new edition of the anatomical manuscripts in her Majesty's collection at Windsor.

These new commitments restricted Dr. Keele's direct involvement in the project to weekly or fortnightly sessions. Nonetheless, work continued and by the summer of 1976 it had become clear that Leonardo's related studies of optics would require a second volume and not just a further chapter.

An extension of the grant from the Wellcome Foundation for a second year made it possible to search thoroughly all Leonardo's writings on linear perspective and optics and produce a preliminary plan for the chapters.

In August 1977 a further grant from the Volkswagen Stiftung made it possible for the writer to come to Wolfenbüttel and begin volume one. After a year volume one exists in draft. A brief outline of the chapters and the principal themes of the book follows. Due to limitations of space details are often omitted.

A survey of scholarship on Leonardo's perspective stUdies confirms that relatively little had been settled concerning this topic. To be sure a considerable amount of material was brought to light by Richter in his famous translation of 1883. But this work has two chief limitations.

First, the limited number of line drawings that it contains, *pace* Lord Clark's claim that the drawings »were reproduced so well that it is hard to remember how long ago the book appeared«, are not reliable. For example the figure accompanying CA 42 rc (Richter 101) omits a crucial letter without which the passage remains indecipherable.

Regrettably this problem of unreliable drawings continues in Pedretti's (1977) recent commentary on Richter. For example in relation to the so-called curvilinear perspective passage on *Madrid II*: 15 (vol. I page 148) only four of the five diagrams given by Leonardo are reproduced and of these four the one on the far right omits the line joining *st* in the figure.

Richter's second shortcoming was his concentration on the written texts which led him to omit many diagrams both with and without short descriptions. Here Pedretti's commentary has done a great service in at least alluding to a great number of these »visual statements« in Leonardo's writings, although, to take a further example concerning the curvilinear perspective debate,

Pedretti's recent commentary does not discuss an important passage on CA 353rbc (dated elsewhere by him 1485-1487) which contains the most specific reference in Leonardo's notes to a curved projection plane.

If one turns to the scholarship of the past decades one finds a growing tendency to concentrate on aspects peripheral to the key issues of linear perspective, e.g. anamorphosis Bassoli (1938), Pedretti (1953, 1956, 1957) or curvilinear methods White (1949, 1957), Sanpaolesi (1960), Maltese (1962) and Pedretti (1963).

Meanwhile those who have entered upon the central questions have at best offered only isolated examples, e.g. Castelfranco (1952), Francastel (1593), Wittgens (1954) and Maltese (1962). It is moreover striking that, with the exception of Agostini (1954) which contained no diagrams and offered no analysis and Pedretti (1977) who concentrated on chronology, there has been no recent attempt to approach Leonardo's perspective in its entirety. Indeed Mesnil's (1922) stimulating short survey was the last attempt to approach these studies in some systematic fashion. The present study is an attempt to redress the balance.

Following an introduction that surveys the literature chapter one returns to Antiquity and develops Panofsky's important insight that the visual angles precept of Euclid's *Optics* fundamentally contradicts the principles underlying linear perspective. This leads to a re-evalutation of the usual claim that linear perspective followed necessarily and naturally from Euclidean optics. The play and interplay of five disciplines is briefly presented as crucial for explaining the evolution of Renaissance perspective. A summary of contributions made by fifteenth century theorists such as Alberti and Piero della Francesca is given and Leonardo's position relative to them is established.

There follows a systematic discussion of Leonardo's perspective writings using the Ms A (149Z) as an introduction to his procedure both in experiments and in recording information. A discussion of how Leonardo defined the role of perspective in relation to other sciences follows.

The next chapter examines the surveying origins of Leonardo's perspectival approach and proceeds to examine his various experimental demonstrations. Details of the reconstructions carried out by Dr. Keele and the writer are given in appendices.

Chapter four turns to note first a series of theoretical diagrams without text, then diagrams of perspectival aids and in turn various practical applications of perspective including *mazzocchi* figures, regular bodies, spheres, and conic sections, which brings to light interesting connections with Dürer, as well as a number of technical drawings. The chapter ends with Leonardo's treatment of the horizon question particularly interesting because one can trace how his interests in this question began with surveying experiments in the 1480's with distances of 100 braccia which he then extended and from which he subsequently extrapolated, unfortunately misleading, rules which led him ultimately to a purely fictitious theoretical estimate of the distance to the horizon, which he nonetheless used in turn to modify earlier perspective ideas. In this shift from everyday concrete experience to an abstract rule we have a case study for the problems of trying to link practice and theory.

This leads to colour perspective at once a generic and a specific term. In general it refers to all alterations of colour due to the medium, the original colour of the objects or physiological effects in the eye (an adaptation it will be noted of the three basic variables in linear perspective: plane, object and eye). As a general category colour perspective subsumes aerial perspective - his »azure« law concerning distant objects and perspective of shadows, both of which are experimentally tested by Leonardo albeit the former has, in addition, a long tradition going back to Aristotle with which Leonardo was probably familiar.

As a specific category, colour perspective involves experimental demonstrations using the glass pane of linear perspective as well as a simple law, later qualified, that dark objects become lighter and light objects become darker with distance which law, incidentally, leads Leonardo to challenge an adversary, probably Alberti, who held a contrary view. 27

That distant objects gradually disappear is an everyday experience that was discussed widely already in Antiquity. Leonardo's approach goes a crucial step further in attempting to quantify the problem. He experiments with the diminution of a man at distances up to 600 feet. He studies the diminution of trees and identifies 5 stages in the process (cf. his practice in painting *Ginevra de Benci)*. He even attempts to find formulae for modifying factors such as thickness of the air. There follows a consideration of the further applications of Leonardo's perspective methods to the whole of his science.

The development of his »pyramidal law« is discussed. It is shown that there are striking parallels between aspects of this pyramidal law and a debate in the commentary tradition of Aristotle's *Posterior Analytics* in turn further evidence to suggest that when Leonardo said he was an *omo sanza lettere* he may well have been as ironical as Cicero when he said that he was an *homo sine ingenio sine litteris.*

This chapter ends with a detailed analysis of the long perspective passage beginning on BM Arundel 279 which reveals that Leonardo had effectively demonstrated, albeit not clearly appreciated, the inverse square law (it is always said he never got beyond the inverse law) with respect to his powers of nature. This throws new light on a nexus of problems that link him with Galileo and Mersenne as well as revealing that he had implicitly solved the photometry law two centuries before Bouguer's codification thereof.

Next comes a systematic re-examination of those passages presumed to relate to curvilinear perspective, involving a close scrutiny of Leonardo's definitions of "prospettiva naturale« and »prospettiva accidentale« which reveals a) that Richter mistranslated these terms as »natural« and »artificial« perspective which led b) via, von Schlosser and Panofsky, to the assumption that »naturale« was curvilinear perspective and »accidentale« was linear perspective and since Leonardo preferred »naturale« this led c) to the belief that Leonardo preferred curvilinear perspective. Correctly translated »prospettiva naturale« is linear perspective and »prospettiva accidentale« is also linear perspective but under special circumstances. In other words Leonardo's qualms concerning the use of »naturale« vs. »accidentale« have effectively nothing to do with curvilinear perspective as in generally assumed.

Leonardo was the first of the fifteenth century thinkers to see beyond the rhetoric that Euclidean optics and linear perspective (both were called *perspectiva* and the terms were much more confused than Panofsky would have us believe), must be identical in their laws. Leonardo demonstrated that there exist tensions between the subjective visual experiences recorded in Euclidean optics and the objective laws of linear perspective.

It is significant that he did not go one step further and attempt to adjust the traditional theory of optics with the new perspective practice. Contrary to what Panofsky would have predicted Leonardo was content that there should exist a tension between a subjective theory of vision and objective principles of linear representation. The belief that vision and representation ought to coincide is a nineteenth century notion that has tempted many since to read back into the past a unity it never knew.

The conclusion will attempt to answer the paradox that although perspective plays no conspicuous role in most of Leonardo's paintings, its laws underly not only his art but in fact his entire »scientific« world view.

Appendices will explain some technical aspects of linear perspective, offer an outline of fifteenth century methods, provide translations of related texts in Piero della Francesca, Luca Pacioli and Caesariano as well as details of the experiments reconstructed at the Wellcome Institute.

The draft for volume one is complete. The complementary volume on Leonardo's optical studies is to be written in 1978-1979.