Leonardo’s Color and Chiaroscuro Reconsidered: The Visual Force of Painted Images

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In a classic study now nearly thirty years old, John Shearman concluded that Leonardo’s paintings manifest an increasingly complex tonal structure and progressively lighter palette. Since then, The Last Supper has been cleaned, Leonardo’s fragmentary literary remains have been ordered, and medieval optics has been shown to be an important basis for the artist’s definition of painting. Now it is finally feasible to study developmental aspects of the extensive manuscript evidence for Leonardo’s interest in reflected color. The following essay examines the relationship between the qualitative and the quantitative aspects of painting in Leonardo’s thought. The same evidence may provide new insight into the status of art as a form of knowledge in the late sixteenth and early seventeenth centuries.

Over the last couple of decades, writers on Leonardo da Vinci’s optics have opened up interesting new lines of investigation, particularly concerning the ways in which medieval science provided the basis for the artist’s studies of vision, perspective, and the enterprise of painting in general.1 These studies have also made us aware that, while Leonardo played a negligible role in the history of science, his definition of painting as a science had significant consequences for the history of art.2 There is evidence at least since the mid-sixteenth century that Leonardo had an interest in the science of light and color.3

The classic study to which all subsequent students of Leonardo’s color are indebted, and to which the title of this paper refers, is J. Shearman, “Leonardo’s Colour and Chiaroscuro,” Zeitschrift für Kunstgeschichte, xxiv, 1962, 13-47. A grant from the University of Colorado at Boulder enabled me to develop and complete this article. An early version was read at the Sixteenth Century Studies Conference in St. Louis, October 1988. The analysis of Leonardo’s manuscripts is based on research carried out for my dissertation, “Il Codice Atlantico di Leonardo da Vinci: A Critical Interpretation of the Parte Primadonna of the Codex Vaticanus Urbinate 1270,” University of Virginia, 1988. I am grateful above all to David Summers for guiding that project. The following persons read various drafts of this essay and offered many excellent suggestions, which I have tried to incorporate: Janis Bell, Erika Doss, John Hoag, Pamela Jones, David C. Lindberg, Mary Pardo, and Martin Kemp, who made several of his papers available to me in manuscript while I was completing my study and before his Science of Art appeared. Heartfelt thanks are also due to Nancy Mann for her valuable editorial comments. I would also like to note my appreciation to librarians who permitted me to study their Leonardo holdings, at the Biblioteca Ambrosiana, Milan; the Biblioteca Nacional, Madrid; L’Institut de France, Paris; the Vatican Library; the British Museum and the Victoria and Albert Museum, London; and the Royal Library at Windsor. I am especially grateful to Professor Augusto Mariotti and Dr. Paolo Calla for arranging access to the original manuscripts.

1 The consensus is that Leonardo knew the writings of Roger Bacon, John Peckham, Witelo, and possibly others, including an Italian translation of Alhazen’s De causis usus by Lorenzo Calvinetti (see n. 45). The extensive literature on Leonardo’s studies in perspective can only be summarized here. The first systematic attempt to document Leonardo’s sources is E. Solmi, “Le fonti manoscritti di Leonardo da Vinci,” Gazzetta storica della letteratura italiana (suppl. 10-11), Turin, 1908 and 1911, 297-357. Present-day students of Leonardo’s writings are greatly indebted to the recent ordering of his fragmentary literary remains by C. Pedretti, 1984 and 1987, and A.M. Brizio, ed., Scritti scelti di Leonardo da Vinci, Turin, 1952; idem, “Il Trattato della pittura di Leonardo da Vinci,” in Scritti di storia dell’arte in onore di Livio Lodi Venturi, Rome, 1956, 399-408. The most important specialized studies are cited in n. 2.

2 References to Leonardo’s manuscripts follow standard forms of abbreviation (C.A. = Codex Atlanticus). I follow the folio numbers and letters of the Codice Atlantico di Leonardo da Vinci nella Biblioteca Ambrosiana di Milano, Reale Accademia dei Lincei, transcribed by G. Pliniani, 35 vols., Milan, 1894-1904, in order to permit concordance with the existing anthologies and literature; the current critical edition is edited by A. Mariotti, Il Codice Atlantico della Biblioteca Ambrosiana di Milano, transcribed by A. Mariotti, 12 vols., Florence, 1975-1980; R1 = (Richter, passage number); Codex Urbinis, n. 1 = number of passages established by Ludwig.) All transcriptions are based on direct autopsy of the original manuscripts, and published transcriptions cited in the notes. It has not always been possible to consult the latest editions of the notebooks in the Institut de France (Manoscritti dell’Instituto di Francia, Edizioni nazionali dei manoscritti e de disegni di Leonardo da Vinci, transcribed by A. Mariotti, Florence, 1982-1987). References to the anatomical manuscripts include the numeration established by the most recent edition, K. Keene and C. Pedretti, eds., Corpus of the Anatomical Studies in the Collection of Her Majesty the Queen, London, 1979, 3 vols. All abbreviations have been expanded.

3 Recent specialized studies that have contributed to a clearer understanding of Leonardo’s optics include Lindberg, 154-158, who expresses the opinion that Leonardo was reasonably well read in the sciences, but his knowledge of the past optical tradition was very imperfect; he frequently demonstrated a “confused and garbled form of traditional theory,” which showed no understanding of the central issue of traditional optics, namely the problem of the multiplication of rays influencing all parts of the eye, and he tended to treat radiation in “an unsatisfactory hysteric manner” (p. 156). On the other hand, as Pedretti, 1964, 70, notes, Leonardo’s awareness of the action of light rays in refraction, based on his knowledge of optical theory, contributed significantly to distinctions he developed between the artificial perspective used by painters, on the one hand, and the conditions of natural perspective in direct vision, on the other. As early as 1490-92, Leonardo observed that the eye sees distant objects as larger than they
critical values that Leonardo associated with the optical effects of painting. Rather than pursuing a single aim, the discussion poses a series of interesting questions about the relationship between the qualitative and the quantitative, the empirical and the theoretical. The arguments preserved in the Codex Urbinas, painting founded on optical principles is superior to the science of simple perception and other mathematical sciences because it provides a logic of going from figures to objects, with what is beautiful in the works of nature and the creation of the world.3 The following essay examines  

result from a critical perspective on art, therefore, although its explanation for this phenomenon is dated, late eighteenth-century perspective does not account for the circumstances that would require the artist to convert the focus of the eye when viewing the scene in the distance. Other recent studies have attempted to rearticulate the meaning of Renaissance art and the theory of perspectival painting, in optical theory, that is less hack but less hacky. This approach is also advocated by Leonardo, who was interested in art but less interested in art. What did Leonardo say about the appearance and function of Renaissance paintings? How would later artists view this kind of theoretical writing? 

Only recently has Leonardo’s vast and fragmentary literary remains been ordered and his sources in formular critical theory investigated, making feasible a systematic study of the development of the aspects of Leonardo’s scientific and aesthetic thought. There is little evidence of critical writing on painting. I hope that the following examination of the manuscript evidence—however partial—will motivate the task of historical reconstruction. It will not succeed in reproducing the ideas of Leonardo’s optics at the expense of the Exposition of Foundation of his Ideas. I. Ellia, “Did Leonardo Develop a Theory of Perspective?” (Journal of the Warburg and Courtauld Institutes, 40, 1977) 520-528, notes that the Exposition of Foundation of Leonardo’s knowledge is a significant factor even in his last writings, for example, in his consideration of the elimination of deep perspective. If painting is an easy matter, however, to make these connections, which often take the form of technical discussions of scientific problems accessible to a general intellectual audience. For the first part of the essay guides the reader through related discussions on recurring topics as they are preserved in Leonardo’s notes. The purpose of this essay is to try to see, by describing the organization of these discussions in the manuscripts, it will demonstrate that hitherto uninformed arguments of ideas exist in Leonardo’s notebooks. Second, it will suggest that, over the thirty-year period of his literary activity, Leonardo attempted to formulate a unified theory of artificial pictorial composition in which color was a central consideration. 

3 We refer here to the elaboration of this aspect by the history of science, a word that the present study will try to recover. 

4 On the use of perspective by art, see Kemp, 1992. For a historical overview of the scientific literature, see Ludwig, 1963. For an overview of Leonardo’s late edition of Afrius and this work, see its publication in 1772. (Ed. Kemper, 1963.) For a discussion of Leonardo’s optical writing, with references to translations, translated into Italian” and English, this is available in the English edition of Afrius’s writings. 

5 For Leonardo’s possible contribution to the rise of new styles of art and music in the late sixteenth and early seventeenth centuries, see the important work by R. Jacques, “Leonardo’s Writings on Music and the Development of the Baroque Style,” in Artibus et Historiae, 12, 1971, suggesting that Leonardo’s writings on color played a significant role in the development of the Baroque style. 

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and early seventeenth centuries, exclusively the province of painters. However arbitrary it might have seemed to Leonardo, who lived in an era when the mathematical and physical sciences were in their infancy, the chain of cause and effect was too useful for the sake of the present-day analyst to distinguish between the investigative science of perspective and the descriptive mathematici artis. Leonardo's extensive studies of the effects of atmospheric perspective and distance on light, shade, and color involved different procedures and subject matter. However, the term "perspective" for Leonardo is often applied, for example, to the application to painting of knowledge gained from the physical science of perspective rather than directly from perspective theory. The use of stereoscopic techniques in scientific and artistic projection made possible, demonstrations of skilful foregrounding and artistic imaging and atmospheric illusion.

Leonardo was one of the first artists to describe painting as a natural science grounded in optics. And, indeed, there is no excuse for painting to be a science that does not have a scientific foundation. Evidence pointing to light now, though still far from complete, suggests that a number of sixteenth-century artists have provided an empirical foundation for perspective that drew upon the same sources:


Kemp has recently argued with convincing evidence, the development of painting in the sixteenth and early seventeenth centuries had become pronounced by 1600. Even if perspective theory became a deductive science only in the early seventeenth century, the trend was clear. Kemp suggests that it was much earlier. Renaissance mathematical treatises on perspective, and other, more practical writings on stereographic projection that provided explicit information on the construction of perspective figures, as well as on the use of perspective in architecture, were published in the early sixteenth century, but the practical application of perspective to painting was not yet widespread. Ciphered figures and illusionistic architecture did not furnish painters with the information they needed to compose on scientific principles what Leonardo called "realistic" perspectives. The technical demands of painting projected the need for a science of pictorial relief, and artists utilized these tools. But Leonardo's interests were not confined to perspective, and other writings that appeared the appearance of light, color, and atmosphere, would have met a need for the qualitative (rather than strictly quantitative) treatment of these—color not met by any other sources we know. Leonardo defined painting as a model of a scientia, a term, apparently originating with Thomas Aquinas, that was applied to Aristotelian science. From that "mixed" theoretical and practical knowledge.

Leonardo's definition of painting has been variously translated, as A.C. 583 of R. H. Bernhard's definition of optics in his paper, Leonardo's sources in perspective and his acquaintance with Cardano's works. However, there is a consensus that Leonardo's definition of perspective is "not a strict definition, but rather a broad statement of the use of perspective in painting." The statement is more a "definition of perspective" in terms of "the use of perspective in painting," than a "technical definition." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective." The statement refers to the "optical apparatus" of the painter, which is not necessarily a "technical device for creating perspective.

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Following these literary models, Leonardo defined painting as a physical, mathematical science founded on optical principles. The most mature version of his definition is preserved in the first chapter of the Codex Urbinas, which has dozens of different versions of the Codex, defined painting as a mathematical science that belongs to geometry, the investigation of continuous quantities. Several noted that the relationship between mathematical and physical entities, as he would later state in the Codex Urbinas and elsewhere concerning pictorial composition based on optical principles.

The manuscript evidence calls for revisions in the critical perspectives of the science of painting. According to which Leonardo defined color, an artist was principally interested in light, color, and shadow. As Leonardo defined color, the tradition that defined color as an investigative science ground in both mathematical principles and experimental methods. The Codex Urbinas, however, the model does not yet distinguish clearly between mathematical and physical entities, as he would later state.

Leonardo's De color and effect. After his death, his works were published and disseminated, with the aim of discussing the Codex Urbinas, in a paper entitled "Principles of the Science of Painting" (Fig. 1). Leonardo synthesized theoretical and scientific knowledge when he discussed the visual fields of painted images in terms of color and light. In many passages, he defends painting both as a science and as the most noble art because it provides a medium for the representation of the purest form of truth with the greatest amount of truth and light. Leonardo discussed how the artist manipulates these concepts to create images in actual appearance. He studied the relationship between color and form, and how these two elements are interrelated to create the illusion of depth and space.

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For Leonardo, the primary importance of the geometry that explains the physical action of light is the analogy between light and color and in three painted images. As he refined his definition of painting as a science capable of achieving mathematical certainty, Leonardo drew closer to the laws of logic and imagination (in terms of painted and mental images), grounded in the geometric analysis of light associated with Alhazen's theory of direct vision and medieval, neo-Aristotelian psychology of the internal senses. The meaning of light is clarified by the light rays striking surfaces, and the conception of the imagination as part of a complex of eternal forms with the capacity to receive external images (like a mirror), then to combine, analyze, and store them, are the foundation for Leonardo's continuous discussions of color and light in relation to the visual force of painted images.2 A clear schematic diagram of this geometry is preserved in the Codex Urbinas, in a paper entitled "Principle of the Science of Painting" (Fig. 1).

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Leonardo's Color and Chiaroscuro Representations

Leonardo's approach to color and light, particularly in his sfumato technique, reflects a deep understanding of the interplay between these elements. He believed that color and light are not independent but are manifestations of the same universal force. In his writings, he often discusses the way light and color work together to create the illusion of depth and volume.

Leonardo's color theory is rooted in the concept of sfumato, which he used to create a soft, gradual transition between colors rather than a sharp, defined line. This technique allowed him to create a sense of depth and atmosphere in his paintings.

Leonardo's color palette is characterized by a wide range of tones and shades, which he used to create a sense of naturalism in his works. He often used colors that were not traditionally associated with the subjects he was painting, such as using blue to represent flesh tones or green to represent grass and foliage. This approach allowed him to create a more realistic and vibrant representation of the world around him.

Leonardo's color theory is reflected in his paintings, such as the "Mona Lisa" and "The Last Supper," where he used his expertise in color to create a sense of depth and atmosphere. His understanding of color and light is a testament to his genius as an artist and a scientist, and it continues to influence artists and art historians to this day.

Leonardo's color and light theory is rooted in his understanding of the nature of light and color, and his approach to painting was characterized by a deep understanding of the interplay between these elements. His works are a testament to his ability to create a sense of naturalism and realism through the use of color and light, and his theories continue to influence artists and art historians to this day.
with painting. Comparisons of the arts, or of the senses, occur in the midst of these discussions. The passage sends us back to Alberti's prescriptions for figurative decorum in Book II of "Della Pittura" (1435-45). In this case, Leonardo was interested in painting on the order of Alberti's prescriptions for figurative decorum, so that pictorial decorum was described in increasingly formal terms. Leonardo noted that Alberti's words "little to Alberti's canon and his theory of pictorial order, although these passages preserve traces of the "trattato" sequence in both form and content. The earliest sequence on Alberti's Parole, L. 108-109, paraphrased passages. On the other hand, Leonardo's discussions of perspective and color were composed with a level of refinement that is not obvious in Alberti's writings. In fact, Leonardo was one of the first to use the term "perspective" which was derived from the Greek word "peirassomein" meaning "to measure out." Leonardo's interest in the science of perspective was evident in his treatises on perspective and color, and the way he understood the relationship between these two concepts was fundamentally different from Alberti's. Leonardo's approach to painting was more experimental, and his discussions of perspective and color were intimately connected to his own artistic practice. This is evident in his treatises "Trattato della Pittura" (1490), "Codex on the Science of Painting" (1500), and "On the Rocks" (1504). The passage describes how Leonardo understood the relationship between perspective and color, and how he related these concepts to his own artistic practice. His approach to painting was not just theoretical, but was based on his own experiences and observations. Leonardo's language makes sense if we understand the phenomenon of light on the principle that a small moving figure, like light, has a tendency to reflect, color, and be seen as a mirror or something of the same kind. Reflected color was a subject traditionally discussed in optical treatises, which, both Alberti and Leonardo, had entered into scientific discussions of painting. Aristotle, as well known, defined color as visible, and light that moves the imagination (De anima 2620b). Color resides in light, and the phenomenon of light on the principle that a small moving figure, like light, has a tendency to reflect, color, and be seen as a mirror or something of the same kind. Reflected color was a subject traditionally discussed in optical treatises, which, both Alberti and Leonardo, had entered into scientific discussions of painting. Aristotle, as well known, defined color as visible, and light that moves the imagination (De anima 2620b). Color resides in light, and the phenomenon of light on the principle that a small moving figure, like light, has a tendency to reflect, color, and be seen as a mirror or something of the same kind. Reflected color was a subject traditionally discussed in optical treatises, which, both Alberti and Leonardo, had entered into scientific discussions of painting. Aristotle, as well known, defined color as visible, and light that moves the imagination (De anima 2620b). Color resides in light, and the phenomenon of light on the principle that a small moving figure, like light, has a tendency to reflect, color, and be seen as a mirror or something of the same kind. Reflected color was a subject traditionally discussed in optical treatises, which, both Alberti and Leonardo, had entered into scientific discussions of painting. Aristotle, as well known, defined color as visible, and light that moves the imagination (De anima 2620b).

For the reference to Alberti, see the following note: Another important account confirming the acquaintance of artists with Aristotle's Discourse of color in the Medici libraries and collections at the time is the survey by Michael Zuckerman, "Leonardo da Vinci's Drawings of Color," in Leonardo da Vinci and the Medici: Art and Science, ed. by M. Zuckerman and T. Gubrium (New York, 1994), pp. 81-104.

In his discussion of the science of painting, Alberti, bk. 1, ch. 11, observed that "To reflect a color on the surface from which it is reflected, we see this when the light of the sun falls on the surface and is reflected by the mirror, so that the color is visible to the eye." He then commented that this phenomenon is observable in natural phenomena, such as the reflection of colors on the surface of water or on the surface of a polished metal plate. He also noted that the reflection of colors is an important aspect of the science of painting, as it allows the painter to create realistic images by accurately reproducing the colors of objects as they appear in nature.

In his third concordance, Leonardo da Vinci recorded a passage on the "second tone of natural color," demonstrating his interest in the science of painting and his ability to draw from a wide range of sources to develop his own theories. This passage is significant because it demonstrates Leonardo's interest in the science of painting and his ability to draw from a wide range of sources to develop his own theories. This passage is significant because it demonstrates Leonardo's interest in the science of painting and his ability to draw from a wide range of sources to develop his own theories.

Leonardo's interest in the science of painting is evident throughout his work, as he was one of the first artists to systematically study the science of color and light. His work on the science of painting is still considered one of the most important contributions to the field of art and science, and his theories continue to be studied and applied by artists and scientists alike.
the argument by ca. 1490 (in favor of introspection). Leonardo also familiarizes us with Pecham's discussion of the extrinsic light of the eye, which follows Aristotle even further by contending that the natural light emitted by the eye plays a role in vision by modulating extrinsically bright lights so that they do not overwhelm the power of sight.

Leonardo formulated the same problem concerning pupil tolerance that he had raised in the Madrid Codex more clearly than a few years later in SS E, which was composed after further investigations of pupil dilation and image formation (found in SS D and E, both dated ca. 1504). Related statements on pictorial reality, also subsequent to these investigations, probably occur first in MS A, ca. 1508-10, where the exact sequence of the passages, however, cannot be reconstructed. Leonardo defined the problem in a series of passages in SS E, ed. 17v, dated by Pedretti to 1513 or slightly later (Fig. 5). The conflict that concerned him is that darkness is the best condition for the eye to see and know, but brightness is the best condition for essential, or fully illuminated, color.

Painting, First. The pupil of the eye diminishes as much as the quantity of illumination increases and impresses itself.

Second. The pupil of the eye increases as much as the brightness of the day or other light that impresses itself on the pupil diminishes.

Third. The eye sees and knows the things that are so much more intensely as its pupils dilate and this is proved in nocturnal animals like cats and other, flying (animali) like the owl whose pupils make the greatest variation between large and small in darkness and illumination.

Leonardo was aware of Pecham's argument, which he excised ca. 1492 (see further discussion by Ackerman in p. 1245-53, 1550). But as late as ca. 1530 Leonardo referred to Pecham's examples of the nocturnal vision of animals, for example, in SS E, ed. 17v.

On the day of these manuscripts, the perspectival argument by Stroud, 1529.

Pedretti, 1984, 25. These passages in MS E are included in the "trattato sequence" cited in Appendix II. In the Trattato di Visione of 1517, translated into Latin by Stroud (1550), and proven to have been written by Leonardo before the last不留 in MS B, as it is rather large, Daddo's perspective on painting and perspective to combine and at the same time differentiate between optical and the perspective of the human eye. The manuscript of the human eye has been used for a treatise on painting, according to Stroud, who also notes that Leonardo's treatise on painting was a treatise on painting, The term "optical" does not denote in painting, while Daddo's perspective was written down in 1517, and in the Trattato di Visione of 1517.

Fourth. The eye placed in illuminated air sees darkness behind the illuminated windows of dwellings.

Fifth. All the colors placed in shadowed places appear to be of equal brightness to themselves.

Sixth. All the colors placed in illuminated places never vary from their essence.

As this sequence clearly shows, the problem Leonardo saw (taking sides with those scientists who defined categories of dark, unsaturated colors and bright, saturated ones) that colors are most essentially themselves in bright light, which the pupil cannot tolerate. He restated the last two propositions about color in terms of "natural holocentric," as in a passage on the root page, fol. 29v (Fig. 6, under the heading "pictura"). Colors placed in shadow participate more or less in their natural beauty as they will be more or less dark; the greatest beauty is in the luminous, great splendor.

Leonardo imagined a scenario in which an adversary argued that the variety of colors visible in shadow is equal to the variety visible in bright light, which Leonardo disagreed, maintaining that there is less variety in the darker surfaces (vestue) of painting. The solution to this problem of representing the plasmon and intensity of color in light and shadow is elaborated in Leonardo's Codice B in Book A, and in MS E and G (with respect to pictorial composition) has already been mentioned: the viewer cannot compare the intense colored light of a splendor when he looks directly into the path of that light, can see in his beauty when he sees it from an oblique angle. Thus, by selecting these conditions for his depiction (which substitute perception of the quality of intense light for its quantity), the painter can present the viewer with the beauty of fully illuminated color on Optical Principles. Here, then, Leonardo defined painted color in terms of natural light effects.

And consequently, he defined all color in terms of the following tenor: unity without light, all colors are perceived as being dark. In this way, Leonardo transformed the quantified aspects of color into qualitative aspects that had critical values attached to them. And in doing so, he transformed words like splendor, intensity, and essenzial from the descriptive vocabulary of optics to the critical language of art.

Principles of the Science of Painting: Treatment of Boundaries

We have now covered the main problem that Leonardo set out in the "trattato sequence," but there is another topic related to the question of color, which we now turn to: the treatment of boundaries. The treatment of boundaries is a topic related to the treatment of pictorial composition. Address: advice addressed to students in the form of precepts, and scientific discussions, in the form of treatises on painting, and in the form of treatises on painting, and in the form of treatises, as well as students in the form of treatises on painting. The original edition of the Codex Urbinas destroyed the original reference to the Codex Urbinas, but the notes contained in the original manuscripts are a good source of information. The original edition of the Codex Urbinas destroyed the original reference to the Codex Urbinas, but the notes contained in the original manuscripts are a good source of information.
according to subject matter. Their context must, therefore, be studied in the original manuscripts. In the "Trattato sequence" Leonardo recorded problems formulated with reference to optical principles tested against various kinds of experience, such as descriptions of direct observations and imagined situations, "thought experiments," geometric sketches and calculations, and practical demonstrations. In other passages, he reworded his conclusions to the rules of a preceptive "art" suitable, like Alberti's treatise, for training students. These are the passages, most familiar to modern readers from the Tetratet, commonly associated with Leonardo's pictorial procedures. Yet the pecuities are intimately connected with, and inseparable from, the specific scientific discussions they once accompanied.

We can fully understand how the subject of light figured into Leonardo's considerations of painting only by turning to his discussions of color, the second important pictorial problem (investigated through) the science of natural optics. Treating principles of pictorial composition in Madrid Codex II around 1500-05, Leonardo was concerned with the problem of representing the most beautiful (i.e., fully illuminated) color, given the limited tolerances of the pupil to let light into the internal sense of the image. In the later B and G, the focus of discussion gradually shifted from the relationship between light and the internal sense to an explanation of light in terms of observed phenomena. Companion of the late writings with Madrid Codex II and B and G, and related evidence in other notes, suggests that in the course of these investigations of optics, Leonardo synthesized two distinct problems of pictorial representation that he drew from his Albertian inheritance and qualified by his own studies of science. One problem is what drawn lines can correspond to in nature, given that mathematical lines are not visible. The other is how to represent color on optical principles, given that the pupil cannot tolerate splendor, beginning at his studies of Euclidean geometry around 1497, and during his subsequent investigations of light and shadow ca. 1502-1506 (and until his later writings), Leonardo developed the basis for a new definition of painting which made the distinction between mathematical and physical line an important consideration.

The core of a consistent program for the representation of optical light (the basis of Leonardo's late definitions of pictorial painting) is the understanding that the artist was primarily concerned with light reflected at the boundaries (brown) of colored, curved surfaces, to the variable extent that these boundaries are distinct. In B and G on fol. 23v (Fig. 7), Leonardo gave a clear definition of optical, or pictorial, perspective in these terms, corroborated by many other notes of the same period. Seen from the standpoint of his own considerations in B and G, Leonardo's investigations of light in B and Madrid Codex II make much more sense:

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The Fate of Leonardo’s Definition of Color

Although the theory of color developed in Leonardo’s later years was innovative and profoundly influential, his views on color and light were also subject to certain limitations. In his work, Leonardo focused on the relationship between color and light, proposing that color is a result of the interaction between light and the object it illuminates. This concept is reflected in his famous statement, "Color is the harmony of light and shadow." However, Leonardo’s understanding of color was not without its controversies and limitations.

Leonardo believed that color is perceived by the eye as a result of the light reflected from objects. This was a significant departure from the prevailing theories of color, which often emphasized the role of light as the primary cause of color perception. Leonardo’s approach laid the groundwork for later developments in the field of color theory, but it also highlighted the complexity of the subject and the need for further exploration.

Leonardo’s ideas on color have been influential in various fields, including art, science, and philosophy. His work continues to inspire researchers and artists alike, and his contributions to the understanding of color remain relevant today.

The State of the Issues

The qualitative treatment of light, shadow, and color in optical principles is an important element in the sixteenth- and seventeenth-century concept of color. Leonardo’s works, particularly his treatises on color and light, have been influential in the development of the field. However, his views on color and light were not without their limitations. Additionally, the influence of Leonardo’s ideas on the development of color theory has been significant, but further research is needed to fully understand the impact of his work on the field.

Leonardo’s conception that painting is a "universal language" because its imagery is constructed on the surface of the canvas has been a controversial topic. Some scholars argue that Leonardo’s ideas were influenced by the works of other artists, while others maintain that his ideas were unique and original. Further research is needed to fully understand the impact of Leonardo’s ideas on the development of painting and the arts.

The ethical implications of Leonardo’s definition of color have been widely debated. Some scholars argue that Leonardo’s ideas were influenced by the works of other artists, while others maintain that his ideas were unique and original. Further research is needed to fully understand the impact of Leonardo’s ideas on the development of painting and the arts.

Commentary

"Leonardo's depiction of color is a profound exploration of the subject, and his ideas continue to be an inspiration for artists and scientists alike. His work on color and light is a testament to the power of ideas to shape our understanding of the world around us."
Appendix I

Early References to Leonardo's Writings on Optics

The first comprehensive reference to Leonardo's writings on optics, specifically his knowledge of "the principles of distribution," dates back to the publication of Boccaccio's "Leonardo da Vinci's Speculum Magnifici," written around 1527. Leonardo's views definitively were disseminated widely when Baldassare Castiglione's "The Courtier," published in 1528, included a section on the "Art of Painting," among them passages otherwise lost to us in his "Trattato dell'arte della pittura." Not long thereafter, in his L'Opera di sculture, paintings, and architecture, he drew from Leonardo's treatise on perspective. In Castiglione's "Trattato dell'arte della pittura," Leonardo's treatment of mathematical perspective, and referred to autograph writings on movement paraphrased in the Codex Huygens. According to Costello, at least four manuscripts copied of the (hitherto) treatise on painting were in Florence around 1530. Significantly, a sixteenth-century copy of the treatise was in the library of the Florentine Academy in 1570 (Costello, 191). The Leonardo manuscript, Collini's own was sometimes mistakenly identified with the Codex Huygens, composed some of his most significant contributions to the field of art and the visual arts.

Evidence of attention to Leonardo's scientific writings is easier from the later period. For instance, Giovanni Boccaccio referred to the existence of unpublished writings by Leonardo in his De Rebus. In the same year, Gian Paolo Baconio published Leonardo's treatise on perspective, among them passages otherwise lost to us in his Trattato dell'arte della pittura. Not long thereafter, in his L'Opera di sculture, paintings, and architecture, he drew from Leonardo's treatise on perspective. In Castiglione's "Trattato dell'arte della pittura," Leonardo's treatment of mathematical perspective, and referred to autograph writings on movement paraphrased in the Codex Huygens. According to Costello, at least four manuscripts copied of the (hitherto) treatise on painting were in Florence around 1530. Significantly, a sixteenth-century copy of the treatise was in the library of the Florentine Academy in 1570 (Costello, 191). The Leonardo manuscript, Collini's own was sometimes mistakenly identified with the Codex Huygens, composed some of his most significant contributions to the field of art and the visual arts.

The sources and authorship of the Codex Huygens have puzzled generations of scholars. Later, it has been demonstrated that Carlo de' Ferrari, an artist who was also associated with Melzi's project of the Codices Urbinati, compiled the handbook, though he was not, strictly speaking, its author. This dossier on perspective, compiled by Melzi and transferred to Giuseppe Cesare, on which both Giuseppe Cesare and his son, Giuseppe Cesare, are known. Among these manuscripts were an early copy of Leonardo's "Trattato dell'arte della pittura," Collini's own was sometimes mistakenly identified with the Codex Huygens, composed some of his most significant contributions to the field of art and the visual arts.

When interest in Leonardo's writings on optics produced documentary evidence in other quarters, the focus upon Leonardo's writings on painting was transferred to his perspicuous and illuminating exemplars. In 1623 Gallo wrote a letter to his friend the Florentine painter Lodovico Cigoli in Rome concerning the relative merits of...
Appendix II

"Trattato Sequences" in Leonardo's Writings

Trattato sequences consisting of a definition, a problem and a demonstration are found in Leonardo's writings.

(A) as a, ca. 1492-93 (dated 10 July 1492 on fol. 114r)

related discussion: 81r on the movement of the eye and the impression impressed in the impression 82r-86r: problems of mechanisation interpreted with discussion of optics 86r: black and white and brightness in perspective confounds the painter (cf. 136r: A133 L16, the discussion of the subject matter, probably after Federico 86r: painting seen through a window from luminous places appears dark (cf. Madonna Codex Urb. n. 47r): Prospettiva on the physical and mental, the model for portraying figures in relation to the subject matter 86v on the painter's studio, and its illumination, and on the mentalisation of painting without too much detail 87r: contrast with good judgment and how modes of portraying figures in the issue with respect to the wall and placement of the eye

(A) as b, ca. 1492-93 (dated 10 July 1492 on fol. 114v)

related discussion: 82r on the movement of the eye and the impression impressed in the impression 83r: black and white and brightness in perspective confounds the painter (cf. 136r: A133 L16, the discussion of the subject matter, probably after Federico 83v: painting seen through a window from luminous places appears dark (cf. Madonna Codex Urb. n. 47r): Prospettiva on the physical and mental, the model for portraying figures in relation to the subject matter 82v on the painter's studio, and its illumination, and on the mentalisation of painting without too much detail 83v: contrast with good judgment and how modes of portraying figures in the issue with respect to the wall and placement of the eye

(B) as a, ca. 1492-93 (dated 10 July 1492 on fol. 114r)

related discussion: 84r on the subject matter, probably after Federico 84v: painting seen through a window from luminous places appears dark (cf. Madonna Codex Urb. n. 47r): Prospettiva on the physical and mental, the model for portraying figures in relation to the subject matter 84v: contrast with good judgment and how modes of portraying figures in the issue with respect to the wall and placement of the eye

(B) as b, ca. 1492-93 (dated 10 July 1492 on fol. 114v)

related discussion: 85r on the subject matter, probably after Federico 85v: painting seen through a window from luminous places appears dark (cf. Madonna Codex Urb. n. 47r): Prospettiva on the physical and mental, the model for portraying figures in relation to the subject matter 85v: contrast with good judgment and how modes of portraying figures in the issue with respect to the wall and placement of the eye

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(B) Madrid Codex II (n. 5939), ca. 1508-09 (dated November 30, 1504, on fol. 23v and 22v).

Scientific discussions of painting concerned with the relationship between the light that the pupil of the eye can tolerate and the amount of light that reaches the internal surface of the interior. The sections on painting in this manuscript refer often to Albertian precepts about figure composition. However, Leonardo never considers the disposition of figures in relation to natural composition as he had in an A, but in relation to the light which makes the pupil contract. In his discussion of lustre, Leonardo determines where the observer ought to stand so that his point of view will not coincide with the direct path of light from the point of lustre.

4. Fol. 28r and 29v.

Definitio: lustre (cf. nos. A, fol. 113v; D, E 17v fully illuminated color is the most beautiful, and then lustre takes on more color of the reflecting body, on the difference between lustre in opaque and transparent bodies. Related discussion: 21r judgment of brightness and darkness by the impression (with geometric diagrams). 24v discussion of lustre and the impression with geometric diagram: cf. A, fol. 113v; fol. 26r: light and dark judged by the eye. 25r-26v: greatest beauty of wholly illuminated light, in relation to pupil dilatation. 26r: absol. pupil dilatation and contraction, and the internal sense of the impression in nocturnal animals and humans (cf. Codex Urbains, nos. 14, 19, and 32). Dark objects against bright backgrounds. Comparison of the senses: fol. 28r: light and hearing, with reference to nocturnal animals. Precepts 26r: figures are the Nina will have more grace when placed in universal light rather than under many small lights, because the former emphasizes relief (cf. nos. A, 94v). 4r.

5. Fol. 28v-29v, 72v.

This sequence contains three successive drafts for a definition of perspective: A. A folio.

Perspective: there is a mathematical science. Comparison of the senses: objects of light and hearing (cf. visual lines and light).

A. Fol. 6v.

Definition: perspective is a mathematical science.

Comparison of the senses: objects of light and hearing (cf. visual lines and light).

Fol. 6v.

Definition: perspective is a mathematical science that concerns continuous quantities within rules to connect the object with the eye. Comparison of the senses: the objects of light, hearing, and taste.

Fol. 6v.

Definition: perspective is a mathematical science that mediates the senses by the first degree of certainty.

Comparison of the first special senses.

Related discussion: 26r-27v: problems of light and shadow. 27r: discussion of rational propositions in arithmetic, the study of discrete quantity, and geometry, concerned with continuous quantity. 30v-36r on reducing bodies to cubic forms. 20r-27r: dividing cubes. 28r-29r: pupil, and contraction in black light (cf. 23r: 27v-28v: light and dark on faces).

28v-29v: through occasional references until fol. 29v: discursions of stylistic customs (cf. nos. A 20v, 19v, and 11v). 27v: on the selection of places that give great relief to things on the harmonious disposition of lines (customary according to the position of light in the arrangement of figures) (cf. nos. A 90v; G, fol. 23v). 72r: preceptive definition of the perspective of colors. 23v, 28r: definition of the perspective of colors, their elimination with distance (cf. 27v: A 90v, 96v, 89v, 119v).

Fol. 127v.

Definition of the perspective in painting with reference to pupil dilatation, the beauty of reflected color. Precepts: 128v (recorded in a slightly more orange ink and not entirely legible) discussion of the decorative, on the careful placement of muscles and shadows (how to achieve beauty of color and avoid ugly ones).

(C) Libro A, ca. 1500-10, as reconstructed by Pedretti from passages contained in the Codex Urbains.

Pedretti (1941) reconstructed the order of 167 passages according to their sequence in the Codex Urbains, the order that has been followed here. The present arrangement of passages on each folio cannot be determined, and the content of forty of ninety-six folios is unknown. The pattern established in the two earlier manuscripts is not clear here, where fol. 12-34 all concern painting, but echoes of the "brattolet sequence" pattern are discernible. Discussion includes comparisons of the arts (of painting and sculpture). Consideration of the contrast of figure and ground, and the boundaries (formen) of objects is important throughout. Leonardo advises artists to construct architectural abstractions by maneuvering simple contrasts of value for the sake of pictorial harmony.


24v.

Cartes 24-38: a continuous discussion, which can be described as two subsequences joined by passages on the comparison of the arts.

Cartes 24-34.

Discussion of the three kinds of decorative shadows.

Relevant discussion: Cartes 24-32 advices the painter to study with rules (cf. nos. A, 94v, 112v, compiled in the Codex Urbains n. 47). Discussion of perspective is used in painting and Albertian precepts for figurative decorum are considered in the discussions, but the following passages include considerations of perspective: Cartes 24-28 on the field of figures, oppositions of light against dark. Cartes 27-28 on the boundaries of lights and shadows.


Comparison of brightness: Cartes 32-40: three comparisons of painting and sculpture (Codex Urbains, no. 41, the last paragraph of nos. 41, and 44).


Definition: on the nature of boundaries (formen) (cf. nos. G, fol. 25v).

Related discussion: Cartes 28-30: discourses of perspective and colors are confused, as is the sequence above. The following passages include considerations of perspective: Cartes 28-30 on composite colors. Cartes 30-32 on the figures from their fields (las porps). Cartes 32-40 on original generation and derivative shadows. Cartes 33-36: on simple and compound shadows.

Cartes 28-30.

Definition: on the nature of color in Brooke's I and II of Debita Trinita (fol. 31r-32v). Cartes 33-36: Albertian precepts on figurative decorum, versus the in the arts.


Definition: of two kinds of shadows.


Definition: painting is the composition of light and shade combined with color.


6. Fol. 58r.

Definition: the first part of painting shows the relief of figures, generated by means of three perspectives.

Related discussion: Cartes 60-70: on perspective that distinguishes opaque bodies: discussion of a very particular perspective in terms of boundaries (formen).

6. Est. Ca, n. 1510-15. The manuscript is dated January 9, 1510, on the verso of the front cover. Of all the intact manuscripts that contain discussions of painting, this one presents most clearly the "brattolet sequence" pattern developed in nos. A. These are still vestiges of the sequence, including seven formal definitions, and Albertian considerations of landscapes painting dominate the discussions.

1. Fol. 5v.

Precepts on the variety of figures.

2. Fol. 14v.

Definition: simple and composite (composita) perspective made by.

Related discussion: Cartes 11v on good figures in universal light. 12v-13v: precepts and descriptions on portraying the varied light on figures by comparison of lights.
3. Fols. 19r–30v can be described as a sequence composed of two subsequences:
   a. Fol. 19r
   
   Definition (confined with precepts): the judgment of the painter depends on three considerations: relief, light and shadows of the figures in the stora, and comparison of the figures according to the stora (cf. Ms E, fol. 80v).
   Related discussion: 19v–23r: light and shadow in landscape, city scenes, 26v: aspects of landscape including the position of the sun, shadows of trees.
   
   b. Fol. 23v
   Definition: on the principal parts of painting, fields and boundaries of figures.
   Related discussion: 24r-v, 25v, 27r–30v: considerations of color, light, arrangement of trees, in landscapes.
   
   *5. Fol. 32r
   Definition: on the angle of vision in perspective, and the boundaries of figures in painting.
   Related discussion: 32v–33r: on the ramification of plants.
   Precepts: 33r: on deriving rules for the position of plants and figures with respect to light and shadow (cf. 19r).

4. Fol. 37r
   Definition: on the boundaries of figures.
   Related discussion: on the color of illuminated boundaries. (See also, 44r: accommodation of pupils in nocturnal animals: cf. Madrid Codex II, 25r–27r.)

5. Fol. 53r
   Definition: discourse on painting: the three parts of perspective that concern painting.
   Related discussion: diminution of colors in the transparent medium.

(F) Other “Trattato sequences” and related discussions on individual sheets:

There are many passages related to the definitions of perspective recorded in Leonardo’s discussions of painting, such as outlines for treatises on perspective and treatises on motion, including optics (Codex Arundel, fols. 232, ca. 1490; Codex Arundel, fols. 130–133, c. 1503–05; Codex Atlanticus 68v–a, ca. 1498; C.A. 132 r–b, ca. 1508; C.A. 179v–c, ca. 1492; C.A. 203 v–a, ca. 1490–92; C.A. 203 v–a, ca. 1490–92; C.A. 270, ca. 1490; C.A. 318 v–a, dated June 2, 1496; C.A. 360 r–a, ca. 1504; C.A. 360 r–c, ca. 1508, plan for a treatise or index on painting, not in Leonardo’s handwriting [see Pedretti, 1964, 238–240, with English translation]). The most complete discussion of these passages is found in Pedretti, 1977, i, 119–226. In addition to the passages cited below are many others preserved only in the Trattato, which awaits a modern systematic study correlated to notes extant in Leonardo’s own handwriting. (My dissertation [as in n. 1] systematically compares the Parte prima of the Codex Urbinas with the manuscript evidence.)

1. Quaderni anatomici VI fol. 22r (Keele/Pedretti, n. 109R and 109B)
   Definition: paragraph 3: every opaque body participates in the color of its object.


2. Quaderni anatomici IV, fol. 15r (Keele/Pedretti, n. 117R)
   Precepts: paragraphs 1, 3, 4, 7, and 8: on varieties in the stora, faults of the painter, treatment of drapery.

3. Codex Atlanticus 277v–a, ca. 1513–14
   Comparison of painting and sculpture (see Pedretti, 1977, commentary to R. 111).

4. Codex Atlanticus 305r–a, ca. 1506–08
   Comparison of painting and sculpture (see Pedretti, 1964, 124, considering this passage as a draft for Libro A, Carta 29.48).

Frequently Cited Sources


———, 1977, Commentary, The Literary Works of Leonardo da Vinci. Compiled and Edited from the Original Manuscripts by Jean Paul Richter, Berkeley-Los Angeles, 2 vols. (wherever possible, references to Pedretti’s scholarship are made to these volumes, which cite his own earlier publications).


