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## INTRODUCTION

This collection of essays assembles current research on the role of optics in Leonardo da Vinci's thought and art. This project originated at a conference on Leonardo's optical theory held at the Kunsthistorisches Institut in Florenz in May 2010, and the initial roster of papers was soon expanded to include additional essays on recent restorations and technical analysis of Leonardo's paintings. Combining essays that focus on Leonardo's theoretical writings with others that center on his pictorial practice, this book aims to facilitate an integrated approach to Leonardo's optics that addresses systematically the relations between theory and pictorial practice—literally how Leonardo translated one into the other.

The reason for revisiting Leonardo's optics—one of the most venerable topics of Leonardo's studies—lies in the rich scholarship of the past few decades on Renaissance scientific culture, theories of vision and Leonardo's painting practices. Renaissance scientific culture and the richness of its activities and protagonists has emerged as part and parcel of mainstream humanism, and thus it is now possible to evaluate the place of Leonardo within the practices and networks of artists, scholars, humanists, doctors and polymaths who participated in the rediscovery of ancient scientific literature, in the invention of new instruments and in conducting scientific experiments<sup>1</sup>.

<sup>1</sup> Significant studies on Renaissance scientific culture include: A. Grafton, *Defenders of the text. The traditions of scholarship in an age of science, 1450-1800*, Cambridge/MA 1991; G. Olmi, *L'inventario del mondo. Catalogazione della natura e luoghi del sapere nella prima età moderna*, Bologna 1992; T. DaCosta Kaufmann, *The mastery of nature. Aspects of art, science and humanism in the Renaissance*, Princeton 1993; P. Galluzzi, *Gli ingegneri del Rinascimento*, Firenze 2006; I. Rowland, *The culture of the High Renaissance*, Cambridge/New York

Moreover, recent scholarship on medieval and Renaissance optics has clarified the significance of this middle science (*scientia media*), which, situated between philosophy and mathematics, was devoted to the study of vision rather than the study of light<sup>2</sup>. Grounded in Ibn Al-Haytham's *De aspectibus*, the eleventh-century Arab text on vision that was translated into Latin in the early thirteenth century and into Italian about a century later, optics was the experimental science *par excellence* in medieval and Renaissance Europe. The discipline was uniquely positioned to address the

1998; P. Findlen, *Possessing nature. Museums, collecting and scientific culture in early modern Italy*, Berkeley 1994; P. Smith, *The body of the artisan. Art and experience in the scientific revolution*, Chicago 2004; D. Freedberg, *The eye of the lynx. Galileo, his friends, and the beginning of modern natural history*, Chicago 2002; B. W. Ogilvie, *The science of describing. Natural history in Renaissance Europe*, Chicago 2006; *Making knowledge in early modern Europe. Practices, objects, and texts, 1400-1800*, ed., by P.H. Smith, B. Schmidt, Chicago 2007; P.H. Long, *Artisan/practitioners and the rise of the new sciences, 1400-1600*, Corvallis/OR 2011; A. Marr, *Between Raphael and Galileo. Mutio Oddi and the mathematical culture of the Renaissance*, Chicago 2011; S. Kusukava, *Picturing the book of nature. Image, text, and argument in sixteenth-century human anatomy and medical botany*, Chicago 2012.

<sup>2</sup> Significant studies on medieval and renaissance optics include: G. Federici Vesconini, *Studi sulla prospettiva medievale*, Torino 1965; D. Lindberg, *Theories of vision from Al-Kindi to Kepler*, Chicago 1976; S.Y. Edgerton, *The Renaissance rediscovery of linear perspective*, New York 1975; D. Summers, *The judgment of sense. Renaissance naturalism and the rise of aesthetics*, Cambridge/New York 1987; A.A. Crombie, *Science, optics, and music in medieval and early modern thought*, London 1990; W.G. L. Randles, *The unmaking of the medieval Christian cosmos, 1500-1760. From solid heavens to boundless aether*, Aldershot/UK 1999; R. Nelson, *Visuality before and beyond the Renaissance. Seeing as others saw*, Chicago 2000; U. Szulakowska, *The alchemy of light. Geometry and optics in late Renaissance alchemical illustration*, Boston, 2000; S. Dupré, *Renaissance optics. Instruments, practical knowledge and the appropriation of theory*, Berlin 2003; A.M. Smith, «What is the history of medieval optics really about?», in: *Proceedings of the American Philosophical Society*, CXLVIII, 2004, pp. 180-194; D.G. Denery, *Seeing and being seen in the later medieval world. Optics, theology, and religious life*, Cambridge/New York, 2005; J.M. Mancha, *Studies in medieval astronomy and optics*, Aldershot/UK 2006; *The mind's eye. Art and theological argument in the middle ages*, ed. by J.H. Hamburger, A.M. Bouché, Princeton/NJ 2006; H. Bredekamp, *Galilei der Künstler: der Mond, die Sonne, die Hand*, Berlin 2007; V. Ilardi, *Renaissance vision from spectacles to telescopes*, Philadelphia 2007; D. Summers, *Vision, reflection and desire in western painting*, Chapel Hill/NC 2007; *Lottica di Leonardo tra Alhazen e Keplero: catalogo della sala di ottica del Museo Leonardiano di Vinci*, ed. by L. Luperini, Milano 2008; *Renaissance theories of vision*, ed. by J.S. Hendrix, C.H. Carman, Farnham/UK 2010; H. Belting, *Florence and Baghdad: Renaissance art and Arab science*, Cambridge/MA 2011 (German: Munich 2008).



relations between cognition and the senses, and to bridge the high culture of university learning with the practices of workshop training<sup>3</sup>. Leonardo's optical writings and practices are thus contextualized more precisely within the medieval tradition of optics, and it is now possible to follow the development of his thoughts over the years, to detect his uncertainties and internal debates on specific issues, and to understand the role of optics not only in relation to painting but also in relation to natural phenomena at large<sup>4</sup>.

<sup>3</sup> The first English edition of Ibn Al-Haytham's *De aspectibus* by A. I. Sabra (*The optics of Ibn Al-Haytham: Books 1-III: On direct vision*, ed. by A.I. Sabra, London 1989) is now complemented with the recent one by A.M. Smith: *Alhacen's theory of visual perception. A critical edition with English translation and commentary of the first three books of Alhacen's De aspectibus*, ed. by A.M. Smith, 2 vols., Philadelphia 2001; *Alhacen's on the principles of reflection. A critical edition with English translation and commentary of Books 4 and 5 of Alhacen's De aspectibus*, ed. by A.M. Smith, 2 vols., Philadelphia 2006; *Alhacen on image-formation and distortion in mirrors. A critical edition with English translation and commentary of Book 6 of Alhacen's De aspectibus*, ed. by A.M. Smith, 2 vols., Philadelphia 2008; *Alhacen on refraction. A critical edition with English translation and commentary of Book 7 of Alhacen's De aspectibus*, ed. by A.M. Smith, 2 vols., Philadelphia 2010. On Alhazen's influence on Renaissance optics see: G. Federici Vescovini, «Contributo per la storia della fortuna di Alhazen in Italia: il volgarizzamento del *MS Vat. 4595* e il *Commentario terzo del Ghiberti*», in: *Rinascimento*, v, 1965, pp. 17-49; D. Lindber, «Alhazen's theory of vision and its reception in the west», in: *Isis*, LVIII, 1967, pp. 321-341; Edgerton, 1976 (as in n. 2); Summers, 1987 (as in n. 2); Belting, 2011 (as in n. 2).

<sup>4</sup> Significant studies on Leonardo's optics include: C. Pedretti, *Leonardo da Vinci on painting. A lost book (Libro A)*, Berkeley/CA 1964; V.P. Zubov, *Leonardo da Vinci*, 1968, Cambridge/MA; J. Shearman, «Leonardo's color and *chiaroscuro*», in: *Zeitschrift für Kunstgeschichte*, xxv, 1972, pp. 13-47; C. Pedretti, *Commentary to: The Literary Works of Leonardo da Vinci by J. P. Richter*, 2 vols, Berkeley/Los Angeles 1977; M. Kemp, «Il concetto dell'anima in Leonardo's early skull studies», in: *Journal of the Warburg and Courtauld Institutes*, xxiv, 1971, pp. 115-134; Id., «Dissection and divinity in Leonardo's late anatomies», in *Journal of the Warburg and Courtauld Institutes*, xxxv, 1972, pp. 200-225; Id., «Leonardo and the visual pyramid», in: *Journal of the Warburg and Courtauld Institutes*, xl, 1977, pp. 128-49; J. Ackerman, «Leonardo's eye», in: *Journal of the Warburg and Courtauld Institutes*, xli, 1978, pp. 108-146; D. S. Strong, *Leonardo on the eye. An English translation and critical commentary of Ms. D in the Bibliothèque nationale, Paris, with studies on Leonardo's methodology and theories on optics*, New York/London 1979; M. Kemp, *Leonardo da Vinci. The marvelous works of nature and man*, Cambridge 1981; K. Keele, *Leonardo da Vinci's elements of the science of man*, New York 1983; C. Maltese, «Gli studi di Leonardo sulle ombre tra la pittura e la scienza», in: *Arte Lombarda*, lxi, 1983, pp. 95-101; C. Maltese, «Leonardo e la teoria dei colori» in: *Römisches Jahrbuch für Kunstgeschichte*, xx, 1983, pp. 209-219; K. Veltman, K.D. Keele, *Studies on Leonardo da Vinci. 1. Linear perspective and the visual*

Finally, as numerous works by Leonardo have been restored or analyzed in recent years, immense new knowledge of his painting practices is emerging from restoration and conservation laboratories around the world<sup>5</sup>. Al-

*dimension of science and art*, Munich 1986; J. Bell, «Color perspective, c. 1492», in: *Achademia Leonardi Vinci*, v, 1992, pp. 64-77; Id., «Aristotle as a source of Leonardo's theory of color perspective after 1500», in: *Journal of the Warburg and Courtauld Institutes*, lvi, 1993, pp. 100-1188; C. Farago, «Leonardo's color and *chiaroscuro* reconsidered», in: *Art Bulletin*, lxxiii, 1993, pp. 63-88; A. Nagel, «Leonardo and *sfumato*», in: *Res*, xxiv, 1993, pp. 7-20; F. Fehrenbach, *Licht und Wasser. Zur Dynamik naturalphilosophischer Leitbilder im Werk Leonardo da Vincis*, Tübingen 1997; F. Frosini, «Pittura come filosofia: Note su *spirito e spirituale* in Leonardo», in: *Achademia Leonardi Vinci*, x, 1997, pp. 35-59; Id., «Leonardo da Vinci e il nulla: stratificazioni semantiche e complessità concettuale», in: *Il volgare come lingua di cultura dal Trecento al Cinquecento*, ed. by A. Calzona, F.P. Fiore, A. Tenenti, C. Vasoli, pp. 209-232; F. Fehrenbach, «Veli sopra veli. Leonardo und die Schleier», in: *Ikonomie des Zwischenraums. Der Schleier als Medium und Metapher*, ed. by J. Endres, B. Wittmann, G. Wolf, Munich, 2005, pp. 121-147; F. Fiorani, «The colors of Leonardo's shadows», in: *Leonardo. The International Society of the Arts, Sciences and Technologies*, xli, 2008, pp. 271-278; J. Bell, «*Sfumato* and acuity perspective», in: *Leonardo da Vinci and the ethics of style*, ed. by C. Farago, Manchester 2008, pp. 161-188; A. Nova, «Il vortice del fenomeno atmosferico e il grido metaforico: le *Tempeste* di Leonardo e il *Piramo e Tisba* del Poussin» in: *Wind und Wetter. Die Ikonomie der Atmosphäre*, Venezia 2009, pp. 53-66.

<sup>5</sup> Leonardo's *Annunciation* and the *Baptism of Christ* were restored in the early 1990s; the *Madonna of the Carnation* in Munich in 2006, the *Virgin of the Rocks* from the National Gallery in London in 2009-2010, the *Virgin and Child with St. Anne* from the Musée du Louvre in Paris in 2010-2011 and the *Adoration of the Magi* from the Uffizi is under restoration at the time of writing. In addition, others works have been analyzed in great detail: the portrait of *Ginevra de' Benci*, the *Mona Lisa* and the Uffizi drawing for the *Adoration of the Magi*. The recent bibliography on Leonardo's painting technique includes: U. Baldini, *Un Leonardo inedito*, Firenze 1992; A. Del Serra, «L'incanto dell'Annuncio. Rendiconto di restauro», in: *L'Annunciazione di Leonardo. La montagna sul mare*, ed. by A. Natali, Milano 2000, pp. 95-111; M. Seracini, «Indagini diagnostiche sulla *Adorazione dei Magi* di Leonardo da Vinci», in: *La mente di Leonardo. Nel laboratorio del genio universale*, ed. by P. Galluzzi, exhibition catalogue (Florence, Galleria degli Uffizi, 28 March 2006-7 January 2007), Firenze 2006, pp. 94-101; A. Del Serra, «Il restauro», in: *Lo sguardo degli angeli: Verrocchio, Leonardo e il Battesimo di Cristo*, ed. by A. Natali, Milano 1998, pp. 95-118; L. Syson, R. Billinge, «Leonardo da Vinci's use of undrawing in the *Virgin of the Rocks* at the National Gallery and *St. Jerome* in the Vatican», in: *Burlington Magazine*, cxlvii, 2005, pp. 450-463; *Mona Lisa. Inside the painting*, ed. by J. P. Mohen, M. Menu, B. Mottin, New York, 2006; L. Keith, «In pursuit of perfection. Leonardo's painting technique», in: *Leonardo da Vinci. Painter at the court of Milan*, ed. by L. Syson, L. Keith, exhibition catalogue (London, National Gallery, 9 November 2011-5 February 2012), London 2011, pp. 54-77; L. Keith, A. Roy, R. Morrison, P. Schade, «Leonardo da Vinci's *Virgin of the Rocks*:



though Leonardo's procedures vary from painting to painting, and often from one area to another in the same painting, new evidence is consistent in suggesting that he constructed the painted image simultaneously from a pictorial and optical point of view. To capture the precise movements of his figures and their background, Leonardo did not rigidly separate the different phases of underdrawing, undermodelling, underpainting and the application of final paint layers; rather, he mixed one with the other freely. This mass of new materials on Leonardo's painting technique calls for a fresh examination of how exactly Leonardo translated his optical knowledge into visual form or, vice versa, if and how his painting practice inspired further optical research. It therefore seems particularly urgent to evaluate his optical theory side by side with his painting practice, especially since these two important branches of Leonardo's studies are more often than not kept apart, even though, for Leonardo, they were constituents of the same thought process. Nevertheless, because it goes against the long history of the reception of Leonardo's optical writings, the process of unifying Leonardo's optics and his painting practice is easier to imagine than to execute.

The historiographical separation of the theory and practice of Leonardo's optics can be traced to the unavailability of his original optical writings, which remained unpublished until the nineteenth century —a state of affairs common to his notes in other fields of knowledge. But in the case of optics, the aggravating factor was that the little that was known contributed to a highly misleading view of Leonardo's optics. Among the most consequential misinterpretations was that Leonardo's optics was not understood as part of his broad philosophical inquiry on cognition and the senses, which in turn was rooted in the medieval optical tradition, but rather as pertaining exclusively to painting. It was however correctly understood that for Leonardo optics was foundational to the representation of light and colors in his art. Further complicating the reception of Leonardo's

Treatment, technique and display», in: *National Gallery Technical Bulletin*, xxxii, 2011, pp. 32-56; *La Sainte Anne. L'ultime chef-d'œuvre de Léonard de Vinci*, ed. by V. Delieuvin, exhibition catalogue (Paris, Musée du Louvre, 29 March-25 June 2012), Paris/Milan 2012. An extensive examination of Leonardo's drawing technique is in *Leonardo da Vinci. Studio per l'Adorazione dei Magi*, ed. by F. Camerota, A. Natali & M. Seracini, Firenze 2006. See also the essays by E. Walmsley, R. Bellucci, C. Pasquali and C. Frosinini in this volume.

optics was the fact that its correct understanding as pertaining to light and colors was soon replaced by an erroneous interpretation that associated it with darkness. Study of Leonardo's optics continued to follow that misleading path for centuries, and it was only from the late nineteenth century onward, when the systematic publication of Leonardo's manuscripts in critical editions and facsimile form was undertaken, that his optics emerged as part of his broader philosophical inquiry on nature, cognition and the senses. Paradoxically, however, as Leonardo's writings came to the fore, his paintings and drawings receded into the background, and the study of Leonardo's optics became essentially a matter of textual analysis that, by and large, excluded the consideration of his painting and drawing practices.

It is worth retelling in greater detail the early reception history of Leonardo's optics because it had major bearing on Leonardo's studies for centuries and also because it is this discrepancy of approaches that this volume seeks to address.

#### THE EARLY RECEPTION HISTORY: OPTICS AND PAINTING

The earliest account of Leonardo's optics relates it to painting, and comes from an author who was well placed to comment on it since he knew Leonardo and optics, and was also a discerning connoisseur of art. Better known as a historian, Paolo Giovio had learned optics as a student of medicine at the university of Pavia and, like any Renaissance doctor, he resorted to it in his practice when he had to figure out the alignment of stars and planets to diagnose maladies, prescribe cures and select herbs for medicines. Giovio met Leonardo, perhaps in Milan around 1510, certainly in Rome between 1513 and 1515, when they both lodged in the Vatican palace. Leonardo himself may have explained to Giovio his views on optics and painting, perhaps showing him his writings and painting. Equipped with theories of optics and direct familiarity with Leonardo, Giovio commented perceptively on the artist's view of painting as a science based on optics, that is, an art devoted to the creation of the illusion of relief on a flat surface through the depiction of light, shadows and colors according to the rules of optics. He wrote:

[Leonardo] placed rendering through modeling, as a means to represent images on a flat surface, before other forms of rendering with the brush. And noth-



ing was more important to him than the rules of optics, which he followed to study the principles of light and shadow exactly and minutely<sup>6</sup>.

Giovio's note was part of a short biography on the artist he drafted in 1528 and reworked later, probably around 1540, but that he never printed. His perceptive, albeit brief, assessment of Leonardo's optics never reached the large public.

Nor did the other primary conduit of Leonardo's optics, that is, the extensive selection of optical precepts that Leonardo's faithful pupil Francesco Melzi prepared for publication around 1540 make it to the public at large. Wishing to fulfill his master's desire to publish a book on the science of painting and following what must have been Leonardo's own method for compiling topical manuscripts, Melzi went through his master's original manuscripts, selected notes and drawings pertaining to painting and optics, copied them on leaf pages, and ultimately rearranged them in a new manuscript which he titled *Libro di pittura*. In this process Melzi rearranged the ordering of Leonardo's original notes. Nonetheless, the *Libro di pittura* preserved and transmitted Leonardo's innovative approach to the creation of relief in painting through a quantitative and qualitative approach that integrated natural philosophy and optics. Indeed, the largest section of Melzi's *Libro di pittura* was titled «De ombra e lume» and was entirely dedicated to optics, its novelty residing in the geometrical and quantitative treatment of the blurred edges of shadows, colors and reflexes, which Leonardo uniquely analyzed in detailed diagrams. Melzi never published the *Libro di pittura*, which remained unknown for centuries, even though it was kept in famous libraries, first in the library of the duke of Urbino and later in the Vatican library<sup>7</sup>.

<sup>6</sup> Paolo Giovio's biography is in C. Vecce, *Leonardo*, Roma 1998, pp. 349-357; quotation on p. 355. Optics was not mentioned among Leonardo's accomplishments in other early biographical sketches, such as Antonio Billi's, written between 1516 and 1525; the Anonimo Gaddiano briefly mentions that Leonardo «assai valse in mathematica, et in prospettiva non meno» (Vecce [as in this n.], p. 360).

<sup>7</sup> On the *Libro di pittura*, see: *Libro di pittura*. Codice urbinat. lat. 1270 nella Biblioteca Apostolica Vaticana, ed. by C. Pedretti, C. Vecce, Firenze 1995; and *Treatise on Painting*. Codex urbinas latinus 1270, 2 vols., ed. by A.P. McMahon, Princeton 1956, for an English translation. See also: Pedretti, 1977 (as in n. 4); C. Farago, *A critical interpretation of Leonardo da Vinci's Paragone, with a new edition of the text in the Codex Urbinas*, Leiden 1992.

This means that from the mid sixteenth century onward, with Leonardo's original manuscripts out of reach, Giovio's comments left unpublished and Melzi's *Libro di pittura* buried in private libraries, Leonardo's innovative instructions to painters to create relief through optics were lost. What instead circulated widely was the misleading account of Leonardo's optics contained in Giorgio Vasari's life of the artist and in the drastically abridged copies of Melzi's *Libro di pittura*.

At face value, Vasari praised Leonardo as the initiator of the «third manner» of painting, but a closer reading of his flattering prose reveals that his assessment of Leonardo's optics in relation to painting was far from positive. Explaining how Leonardo adjusted lights and shadows in his works, Vasari wrote:

It is an extraordinary thing how that genius, in his desire to give the highest relief to works he made went so far with dark shadows, in order to find the darkest possible grounds, that he sought for blacks which might make deeper shadows and be darker than other blacks, that by their means he might make his lights the brighter<sup>8</sup>.

He added that Leonardo's method «turned out so dark that, no lights remaining there, his pictures had rather the character of things made to represent an effect of night, than the clear quality of daylight». Unequivocally unsympathetic was his concluding remark that «in the art of painting, he added to the manner of coloring in oils a certain obscurity (*oscurità*)», although Vasari did grant that this *oscurità* inspired modern artists to give «great force and relief to their figures». Even more misleading were Vasari's remarks on Leonardo's painting technique: «he tried the strangest methods of seeking out oils for painting, and varnishes for preserving works when painted». To further illustrate this point, he recounted an anecdote

<sup>8</sup> G. Vasari, *The lives of the painters, sculptors and architects*, translated by G. du C. de Vere, 2 vols., New York 1996, vol. 1, p. 630. Classic studies on Vasari's life of Leonardo, which however did not comment on Vasari's assessment of Leonardo's optics, are: P. Rubin, «What men saw: Vasari's life of Leonardo da Vinci and the image of the Renaissance artist», in: *Art History*, XIII, 1990, pp. 34-46; P. Barolsky, «Vasari and the historical imagination», in: *Word and Image*, xv, 1990, pp. 286-291; A. R. Turner, *Inventing Leonardo*, Berkeley/Los Angeles, 1994, pp. 55-67.



on Leonardo and Pope Leo x that has since made its way into Leonardo's legend:

It is related that, having a work being allotted to him by the pope, he straightway began to distil oils and herbs, in order to make the varnishes; at which Pope Leo said; 'Alas! This man will never do anything, for he begins by thinking of the end of the work, before the beginning'.

As an accomplished painter in any medium and as the author of the technical introduction to his *Lives*, Vasari unquestionably knew well the value of experimenting with oil and was undoubtedly familiar with the use of varnishes not only to «preserve works when painted» but also to build a painting from the ground up via the application of glazes of varying thickness. Indeed, what made Leonardo's painting technique exceptional was not his use of unusual pigments or techniques but his mastery of the application of thin layers of glazes, which he achieved through experimentation with oils.

It is often remarked that Vasari had limited knowledge of Leonardo's paintings and an even more selective one of his writings. Indeed, his account of Leonardo's method to adjust lights and shadows «to give the highest relief» seems to describe one of the few paintings he knew, the unfinished *Adoration of the Magi*, which he must have seen in the Florentine house of Amerigo Benci and which is uniquely revealing of Leonardo's early stages of painting—that is, underdrawing and undermodeling—but obviously misleading on the final outcome of his works. In the unfinished *Adoration*, Leonardo never arrived at the gradual build up of diluted colors and thin varnishes over the undermodeling which, in its unfinished status, seems indeed more suitable to represent what Vasari called «an effect of night» than the «clear quality of daylight». As misleading as Vasari's characterization of Leonardo's optics was, it was also extremely successful in circulating widely Leonardo's *oscurità*.

At a more fundamental level Vasari must have understood that Leonardo's painting based on optics was intrinsically incompatible with *disegno*, the unifying principle of the arts in which artists were trained at the Ac-

<sup>9</sup> Vasari, 1996 (as in n. 8), p. 638.

cademia del Disegno. Funded in 1563 with Vasari's contribution and under the auspices of the Medici duke, whose artistic and propagandistic needs it served, the Accademia fostered a curriculum that was fundamentally at odds with Leonardo's optics. His blurred edges required extensive study, prolonged observation of nature and slow execution, all elements that were too distant from the abstraction of *disegno* and which were ultimately unsuitable to the speedy execution of multiple ducal commissions.

Interestingly, Vasari's dismissive view of Leonardo's optics matches the one that emerges from the other major conduit for the dissemination of Leonardo's optics. This was the drastically abridged version of Melzi's *Libro di pittura*, which circulated widely in manuscript copies and was published as *Trattato della pittura di Lionardo da Vinci* in 1651<sup>10</sup>. These abridged texts excluded completely Leonardo's quantitative analysis of aerial perspective, reflected colors and lights and shadows that Melzi had gathered in the large section on «De ombre e lume» of his *Libro di pittura*, at the same time that it privileged Leonardo's qualitative precepts dedicated to colors and the

<sup>10</sup> On the abridgment of Melzi's *Libro di pittura* and its first publication as Leonardo's *Trattato della pittura* see: K.T. Steinitz, *Leonardo da Vinci's Trattato della Pittura. A bibliography*, Copenhagen 1959; Pedretti, 1964 (as in n. 4), pp. 95-174; Pedretti, 1977 (as in n. 4), vol. 1, pp. 12-86; E. Gombrich, «The *Trattato della Pittura*: Some questions and desiderata», in: *Leonardo e l'età della ragione*, ed. by E. Bellori, P. Rossi, Milano 1982, pp. 141-158; M. Kemp, «A chaos of intelligence: Leonardo's *Traité* and the perspective wars in the Académie Royale», in: *Il se rendit en Italie. Études offertes à André Chastel*, Rome/ Paris 1987, pp. 415-426; F. Fiorani, «Abraham Bosse e le prime critiche al *Trattato della Pittura* di Leonardo», in: *Accademia Leonardi Vinci*, v, 1992, pp. 78-95; J. Barone, «Illustrations of figures by Nicholas Poussin and Stefano della Bella in Leonardo's *Trattato*», in: *Gazette des Beaux-Arts*, CXLIII, 2001, pp. 1-14; Id., «Seventeenth-century illustrations for the chapters on motion in Leonardo's *Trattato*», in: *The rise of the image*, ed. by T. Frangenberg, R. Palmer, Burlington 2003, pp. 23-49; D. Spati, «Cassiano dal Pozzo, Poussin and the making and publication of Leonardo's *Trattato*», in: *Journal of the Warburg and Courtauld Institutes*, LXVI, 2003, pp. 143-188; F. Fiorani, «The shadows of Leonardo's *Annunciation* and their lost legacy», in: *Imitation, representation and printing in the Italian Renaissance*, ed. by R. Eriksen; M. Malmanger, Pisa/Roma 2009, pp. 119-156; *Re-reading Leonardo. The Treatise on Painting across Europe*, ed. by C. Farago, Farnham/UK, 2009; T. Frangenberg, «Abraham Bosse in context: French responses to Leonardo's *Treatise on Painting* in the seventeenth century», in: *Journal of the Warburg and Courtauld Institutes*, LXXV, 2012, pp. 223-260. The abridged copies of Melzi's *Libro di pittura* are now available at: [www.treatiseonpainting.org](http://www.treatiseonpainting.org). See also the essays by J. Bell and R. Nanni in this volume.



atmosphere, and to the movement of the body. Although the importance of this qualitative discussion of aerial perspective, reflected colors and the movement of the body in the abridged copies should not be overlooked, since it filled a void in the artistic theory of the time, the omission of the geometry of reflection and light destroyed the unity of Leonardo's thoughts on optics. Still under debate is what exactly later writers, such as Giovanni Paolo Lomazzo, Giovanni Battista Armenini, Daniele Barbaro or Pietro Accolti knew of Leonardo integrated approach to optics. In the practice of painting, Leonardo's optics appears only in the works of a few artists who had access to Leonardo's qualitative and quantitative analysis through his original manuscripts, such as Nicolas Poussin and possibly Federico Barocci<sup>11</sup>.

In spite of Giovio's correct assessment of Leonardo's optics in relation to painting and Melzi's attempt to publish Leonardo's original notes and diagrams on optics, knowledge of Leonardo's optics was based on Vasari's misleading comments and on the equally misleading abridged copies of Melzi's *Libro di pittura* for centuries. Only in 1817, when the erudite Guglielmo Manzi published the entire *Libro di pittura*, which he had recently rediscovered in the Vatican library, did the study of Leonardo's optics moved to a new track<sup>12</sup>.

#### FACSIMILES AND CRITICAL EDITIONS: OPTICS AND KNOWLEDGE

The comprehensive understanding of Leonardo's optics, that is, the fact that for Leonardo optics pertained not only to painting but also to a broad

<sup>11</sup> On Nicolas Poussin's knowledge of Leonardo's optics see: E. Cropper, «Poussin and Leonardo: Evidence from the Zaccolini MSS», in: *Art Bulletin*, LXII, 1980, pp. 570-583; J. Bell, «Cassiano dal Pozzo's copy of the Zaccolini manuscripts», in: *Journal of the Warburg and Courtauld Institutes*, LI, 1988, pp. 103-125; F. Fiorani, «The theory of shadow projection and aerial perspective. Leonardo, Desargues and Bosse», in: *Desargues en son temps*, ed. by J. Dhombres, J. Sakarovich, Paris 1994, pp. 267-282 (republ. in: *Leonardo da Vinci. Selected scholarship in English*, ed. by C. Farago, 5 vols., New York 1999, vol. 4, pp. 215-230). ; P. Robison, «Leonardo's *Trattato della pittura*, Nicolas Poussin, and the pursuit of eloquence in seventeenth-century France», in: *Leonardo da Vinci and the ethics of style* (as in n. 4), pp. 189-236; *Re-reading Leonardo*, 2009 (as in n. 10).

<sup>12</sup> *Trattato della pittura di Leonardo da Vinci, tratto da un codice della Biblioteca Vaticana*, ed. by G. Manzi, Roma 1817.

theory of knowledge based on the senses, started to emerge only with the systematic publication of Leonardo's writings in critical editions and in facsimile form from the late nineteenth century onward. Fundamental was the publication of the manuscripts at the Bibliothèque de l'Institut de France in Paris edited by Ravaisson-Mollien between 1881 and 1891, which included some of Leonardo's manuscripts more heavily focused on optics: *Manuscript A*, *Manuscript C*, *Manuscript F* and *Manuscript G*. Following Ravaisson-Mollien's example, between 1894 and 1904, Giovanni Piumati published the *Codex Atlanticus*, which included numerous sheets, notes and diagrams on optics that spanned Leonardo's entire life. As he was working on the *Codex Atlanticus*, Piumati published also the anatomical books from the Royal Library at Windsor Castle, which included fundamental sheets on optics, the anatomy of the eye and, above all, the faculty of the mind that were meant to elaborate on the data collected by the senses (Book A appeared in 1898 and Book B in 1901). In 1909 Giulio Calvi published the *Codex Leicester*, in which Leonardo had copied some of his latest thoughts on optics, the sun and the moon<sup>13</sup>.

<sup>13</sup> *Les manuscrits de Leonard de Vinci*, ed. by C. Ravaisson-Mollien, 6 vols., Paris 1881-1891; *Il codice atlantico di Leonardo da Vinci della Biblioteca Ambrosiana di Milano*, ed. by G. Piumati, Milano 1894-1904; *Dell'anatomia. Fogli A*, ed. by G. Piumati, T. Sabachnikoff, Paris 1898; *Dell'anatomia. Fogli B*, ed. by G. Piumati, T. Sabachnikoff, Torino 1901; *Il codice di Leonardo nella biblioteca di Lord Leicester in Holkham Hall*, ed. by G. Calvi, Milano 1909. Modern facsimile and critical editions followed these early ones; the most significant for optics are: *Manuscripts de l'Institut de France* (Manuscript A, B, C, D, F) ed. by A. Corbeau, N. De Toni, Grenoble 1964; *I manoscritti dell'Institut de France*, ed. by A. Marinoni, 12 vols, Firenze 1986-1990; *Il codice atlantico della Biblioteca Ambrosiana di Milano*, ed. by A. Marinoni, 24 vols., Firenze 1975-1980; *The Codex Hammer of Leonardo da Vinci*, ed. by C. Pedretti, Florence 1987; *A catalogue of the drawings of Leonardo da Vinci in the collection of His Majesty the King at Windsor*, ed. by K. Clark, Cambridge/UK 1935 (2<sup>nd</sup> ed.: London, 1968-1969, with C. Pedretti). From the late 19<sup>th</sup> century onward, Leonardo's optical writings are available also in anthologies such as: *The literary works of Leonardo da Vinci compiled and edited from the original manuscripts*, ed. by J.P. Richter, London 1883; 2<sup>nd</sup> ed.: Oxford, 1939 (London 1970); E. MacCurdy, *The notebooks of Leonardo da Vinci*, 2 vols, London 1938; A. Agostini, *Le prospettive e le ombre nelle opere di Leonardo da Vinci*, Pisa 1954; and *Leonardo on painting*, ed. by M. Kemp, New Haven/ London 1989. These popular anthologies, while providing a useful and easy entry into Leonardo's notes, should be used with caution as they assemble Leonardo's precepts topically and thus disrupt the integrity of his original pages as well as the chronological development of his thought.



From this firsthand analysis of Leonardo's manuscripts, it emerged that Leonardo was an attentive reader of optics. Edmondo Solmi, in his study of Leonardo's sources, was able to identify specific references to earlier optical authors, including Aristotle, Euclid, Ptolemy, Roger Bacon, John Pecham, Witelo, Biagio Pelacani of Parma, although he did not detect the influence of Alhacen, as Leonardo had never mentioned the Arab philosopher in his writings<sup>14</sup>.

Above all, what emerged from the early facsimile publications of Leonardo's writings were the stunning optical diagrams of innumerable objects illuminated by different kind of light sources—the sun, candles, windows, the atmosphere—that rendered the optical effects Leonardo described in his optical precepts down to their minutest details. At times Leonardo planned with extreme care the page layout—words are few and limited to brief descriptions of the elements represented in the accompanying diagrams, which instead are many, large, highly finished and appropriately characterized by delicate optical effects. In other instances, words take over and the drawings are just quick sketches. Leonardo always, however, integrated word and image, a topic that eventually would become central to the study of his optics.

As the range of Leonardo's optics became clearer, interpretations varied on the artist's place in the history of modern optics, that is, the science devoted to the behavior of light. In 1905 Solmi, who was a careful reader of Leonardo's writings, did not resist the temptation to twist the artist's optical writings in order to present him as a forerunner of modern optics, while in 1939 Domenico Argentieri credited him with the invention of the telescope. In 1954 Vasco Ronchi also interpreted Leonardo's optics in relation to modern optics; unlike Solmi and Argentieri, however, he denied the artist any

<sup>14</sup> E. Solmi, *Scritti vinciani. Le fonti dei manoscritti di Leonardo da Vinci e altri studi*, Firenze 1976, which includes his essays on Leonardo's sources dated 1908 (pp. 1-344) and 1911 (pp. 345-406). The influence of Alhacen on Leonardo has been investigated more recently by B. S. Eastwood, «Alhazen, Leonardo, and late medieval speculation on the inversion of images in the eye», in: *Annals of Science*, XLIII, 1986, pp. 413-446; M. Kemp, «The Hammer lecture (1992). The beholder's eye: Leonardo and the 'errors of sight' in theory and practice» in: *Achademia Leonardi Vinci*, v, 1993, pp. 153-162; J. Bell, «Leonardo and Alhazen: The cloth on the mountain top», in: *Achademia Leonardi Vinci*, vi, 1993, pp. 108-111; D. Raynaud, «La perspective aérienne de Léonard de Vinci et ses origines dans l'optique d'Ibn Al-Haytham (*De aspectibus*, III, 7)» in: *Arabic Sciences and Philosophy*, IXX, 2009, pp. 225-246. See also the essays by D. Raynaud and F. Fiorani in this volume.

significance in the history of optics, a position that lingered for decades, and to which Eugenio Garin and David Lindberg also subscribed<sup>15</sup>.

It took a few decades to return to the issue of Leonardo's optics and to investigate it not in relation to modern optics but in relation to the notion of optics that Leonardo and his medieval contemporaries shared, that is, the study of vision. In 1963 Anna Maria Brizio followed Solmi's methodology and detected specific instances of Leonardo's debt to Witelo, but she was also among the first to urge the consideration of the «centro artistico» of Leonardo's optical investigations: his concerns as a painter and his focus on the transmission of knowledge in visual form. Brizio also brought to attention Leonardo's terminological inconsistency —the words *spezies*, *similitudini* and *simulacra* all appear in his writings— which she interpreted as a sort of «non finito linguistico analogo al suo non-finito pittorico»<sup>16</sup>. Carlo Pedretti provided indispensable tools to further the study of Leonardo's optics in his volume on the so called *Libro A*, a lost book on painting that included extensive passages on optics, and also in his *Commentary* on Jean Paul Richter's anthology, in which Pedretti attempted the first synthesis of Leonardo's optics<sup>17</sup>. In the 1960s Kenneth Keele looked at Leonardo's optics in relation to the artist's investigation of the physiology of the senses, but he did not detect Leonardo's debt to medieval optics on the matter. This was the task undertaken by Martin Kemp in a series of seminal essays of the 1970s, as well as in his 1981 monograph on the artist, which demonstrated the place of Leonardo's ideas and concepts in a long tradition of optical and philosophical studies<sup>18</sup>. Kemp redirected Leonardo's scholarship on optics

<sup>15</sup> E. Solmi, «Nuovi studi sulla filosofia naturale di Leonardo da Vinci: Il metodo sperimentale, l'astronomia, la teoria della visione», in: *Atti e memorie della Reale Accademia virgiliana di Mantova*, 1905, pp. 1-233; D. Argentieri, «L'ottica di Leonardo», in: *Annali dei lavori pubblici*, LXXVII, 1939, pp. 785-835; V. Ronchi, «Leonardo e l'ottica», in: *Leonardo da Vinci. Saggi e ricerche*, Roma 1954, pp. 158-185; E. Garin, «Sull'ottica di Leonardo», in: *Giornale critico della filosofia italiana*, xxxv, III, 1, 1956, pp. 280-282; but see also Id., «Il problema delle fonti del pensiero di Leonardo», in: Id., *La cultura filosofica del Rinascimento italiano*, Firenze 1961, pp. 388-401; Lindberg, 1976 (as in n. 2).

<sup>16</sup> A.M. Brizio, *Lettura Vinciana*, Vol. III, *Razzi incidenti e razzi riflessi*, Vinci 1963, p. 12.

<sup>17</sup> Pedretti, 1964 (as in n. 4); Pedretti, 1977 (as in n. 4).

<sup>18</sup> Kemp, 1971 (as in n. 4); Kemp, 1972 (as in n. 4); Kemp, 1977 (as in n. 4); Kemp 1981 (as in n. 4). M. Kemp delivered a paper on "Leonardo and experiment" at the conference in 2010, but it was not possible to include it in this volume.



and novel studies emerged from the work of Kim Veltman, Donald Strong and many of the authors included in this volume<sup>19</sup>. Today the analysis of Leonardo's optical writings is routinely conducted through an integrated approach based on paleography, literature, art history and the history of science, which makes it possible to contextualize these writings within both Leonardo's life and Renaissance culture.

#### LEONARDO'S OPTICS

It is thanks to the scholarship of the past decades that it is now possible to document Leonardo's lifelong observations of optical phenomena, which the artist recorded in geometrical diagrams, jotted notes, sketches, drawings and lengthy passages. Following the model of early authorities, he based his investigation on every possible aspect of medieval optics, from mirrors, shadows and proportions to the anatomy of the eye, the propagation of light and the geometry of reflection and refraction. He made or imagined experiments with colored light sources, projective screens and apertures, and investigated optical illusions and errors. He also recorded philosophical musings on the interaction between sensory data and the intellectual faculties of common sense, imagination and memory, following Arab and medieval philosophers in their attempt to explain the role of the senses in the acquisition of knowledge. It is also clear that Leonardo was relentless in trying to transfer his optical observations from one system of representation (geometrical and optical diagrams) to another (painting and drawing), and in attempting to ground his *chiaroscuro*, aerial perspective, reflected colors and theory of proportions in optics.

Leonardo not only intended to make optics the basis of artistic training, but he also planned an illustrated book on the topic, although he characteristically never brought it to fruition. In light of the careful study of his manuscripts, it is possible to establish that, at least twice, Leonardo went through the entire body of his manuscripts to select precepts on optics, which he first copied on loose sheets and then reassembled in separate manuscripts almost exclusively dedicated to the topic. The first

<sup>19</sup> See bibliography in n. 4.

instance took place around 1490, when Leonardo assembled *Manuscript A* and *Manuscript C* of the Bibliothèque de l'Institut de France in Paris, which contain extensive sections on optics and painting. The second instance occurred nearly twenty years later, around 1510, when he assembled the manuscript known as *Libro W*, which is now lost<sup>20</sup>. A couple of years earlier, around 1508, Leonardo compiled two more optical manuscripts, *Manuscript D* and *Manuscript F*, in which he gathered notes on the anatomy of the eye and other optical phenomena generated by the atmosphere, rain, the sun and moon. At the very end of his life, he assembled notes on astronomical optics in the *Codex Leicester*.

#### THE COLLECTION OF ESSAYS

The essays gathered in this volume, which were written by art historians, conservators, restorers, philosophers and historians of science, return to many aspects of Leonardo's optics. Some reexamine his use of earlier sources, others his practice of optics, and others still his painting techniques, terminology, theory and legacy. The essays build on earlier methodological approaches, mix disciplines and clarify matters of chronology and interpretation. Along the way, they all interrogate the intersection between optical theory and painting practice.

David Summers examines the long history of *chiaroscuro*, not only in relation to optics, but also in relation to rhetoric, and explains that for Leonardo *chiaroscuro* was a compositional device used to achieve emphasis by placing forms and outlines against specific backgrounds. Those same forms, outlines and backgrounds are the focus of Elizabeth Walmsley, who, through a comparative analysis of infrared reflectographies, x-rays images and the direct observation of the portrait of *Ginevra de' Benci*, shows the incremental adjustments of Leonardo's painting technique from underdrawing to underpaint to final layers.

Other authors investigate the relations between Leonardo's portraits and optics. Pietro Marani argues for the «generative and fecund» role of

<sup>20</sup> On the relation between *Manuscript C* and *Libro W*, see Pedretti, 1964 (as in n. 4), pp. 146-151.



Leonardo's painting activities for his optical research, and interprets the Milanese portraits as anticipations of Leonardo's art theoretical writings, especially his *Paragone* of the arts and his argument on the primacy of the eye. Romano Nanni looks at Leonardo's precepts on portraiture in the *Trattato della pittura* of 1651, detecting a discrepancy between the artist's portraits and the art theory that circulated under his name in Baroque Europe.

In other essays, the principles of the inverse proportionality of linear perspective, which Leonardo adopted as a model for the explanation of natural phenomena, come to the fore. Janis Bell shows that Leonardo applied inverse proportionality also to what he called *la prospettiva delle ombre*, a term the artist introduced after 1500 to indicate non-linear perspective. Bell not only relates the theory of the «prospettiva delle ombre» to Leonardo's own pictorial practice, but she also reveals its legacy in the pictorial practice of Fra Bartolomeo, Rosso Fiorentino and later Nicolas Poussin, as well as its ramifications in seventeenth-century French art theory. Fabio Frosini follows Leonardo's thought process step by step to explain how Leonardo applied the optical principle of the propagation of light to a variety of phenomena which were not caused by action by contact, as Aristotelian physics would dictate, but by action by distance or what Leonard called *potenze spirituali* and which he considered foundational to his natural philosophy. Frank Fehrenbach investigates Leonardo's late theory and practice in relation to the meaning of the point, which Leonardo defined both as the *ultimo principio* of painting and as the motor of transition between being and non-being. Leonardo's late pictorial practice is the focus of Cinzia Pasquali, who wonders if certain effects of the transparency of colors in the garments of the figures in the *Virgin and Child with St. Anne* should be related to Leonardo's optical studies, or instead due to the unfinished status of the painting.

Frank Zöllner analyzes the differences between sharp and blurred focus, detecting a change in Leonardo's works—the early works tend toward sharpness while the later ones toward blurriness—which he explains in light of Leonardo's movement away from the rigid rules of linear perspective. Roberto Bellucci reconstructs Leonardo's procedures for the drawing of the architectural background in his *Annunciation* through the use of infrared reflectographic images that do not distort the painted image. Not only was the architectural background—and consequently, the entire painting—based on the golden ratio, but the perspective drawing was

executed entirely on the surface of the panel rather than being transferred from a preparatory drawing. Cecilia Frosinini offers a first examination of Leonardo's technique for the underdrawing and the undermodeling of his *Adoration of the Magi* emerging from the current restoration of the painting.

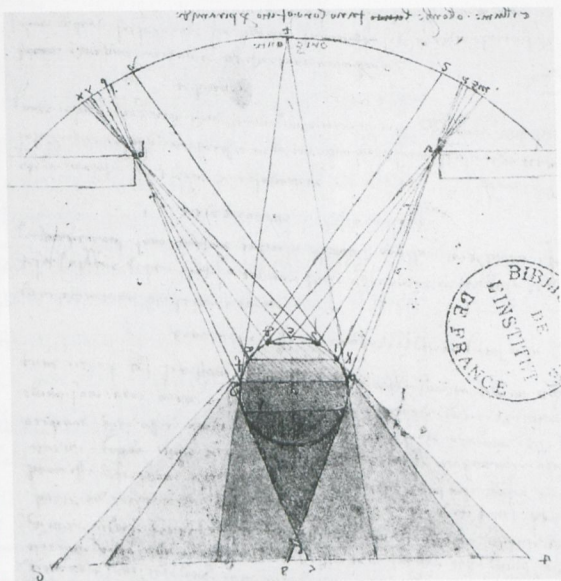
Finally, the issue of Leonardo's sources comes up again in relation to Alhacen's *De aspectibus*, an author Leonardo never mentioned in his notes, but whose influence has often been regarded as essential to Leonardo's optics. Through different methodological approaches and looking at different materials, Dominique Raynaud and Francesca Fiorani both suggest that Leonardo's optical research was heavily based on Alhacen's *De aspectibus*. Raynaud examines Leonardo's language of the anatomy of the eye and demonstrates that Leonardo unmistakably devised it from Alhacen's *De aspectibus* rather than from other medieval optical texts, while Fiorani suggests that Leonardo was familiar with the text of the Arab philosopher since the 1470s.

It is the hope is that this collection of essays, which considers Leonardo's optics from the point of view of ancient rhetoric, ophthalmology, philosophy, painting practice and modern technical analysis, will facilitate future systematic consideration of how Leonardo translated his optical theory into painting and drawing techniques and, vice versa, how his painting practice inspired his optical investigations.





Leonardo da Vinci, *Virgin of the Rocks*, oil on canvas, 1483-1486, Paris, Musée du Louvre



Leonardo da Vinci, *Manuscript A*, 1492 circa, Paris, Bibliothèque de l'Institut de France (Manuscript 2185), fol. 14r