The Role of Visual Representation in the Scientific Revolution: A Historiographic Inquiry

RENZO BALDASSO*§

Abstract. This article provides a strategic history of the role assigned by modern historians to visual representation in early modern science, an aspect of historiography that is largely ignored in the scholarly literature. Despite the current undervaluation of images and visual reasoning, historians in the 1940s and 1950s who established the 20th century concept of the Scientific Revolution, also assigned a conspicuous role to images, claiming 15th century art as a chapter in the history of science and identifying the first modern scientists in artists such as Brunelleschi and Leonardo. My analysis of the writings that shaped the discourse on visual representation—by giants such as George Sarton, Herbert Butterfield, and Alexandre Koyré—shows that the handful of concepts introduced in these early discussions formed the foundations of the subsequent scholarly approach to early modern scientific images. However, close scrutiny during the 1970s defined these concepts as interesting but not as key elements for the emergence of modern science proposed earlier. The wave of social studies of science in the 1980s further diminished the importance of images, to the point that recent surveys of early modern science neither consider the role of visual representation nor include figures in their narratives. Several recent publications with suggestive titles such as *The Power of Images in Early Modern Science* promise to recover a significant role for images in the Scientific Revolution. The present inquiry into the earlier discourse seeks to clarify the historiographic framework into which these new efforts fit.

In their efforts to legitimize the Scientific Revolution as a historical category, historians of science originally assigned an important role to images and visual representation.[1] For instance, in 1949 Herbert Butterfield identified the Renaissance artist as a parent of the modern scientist and proposed that developments in 15th-century art might also be considered a chapter in the history of science. In the following decade, George Sarton proclaimed that it was the printed image that saved science from scholastic and bookish scholarship, forcing thinkers to look at natural phenomena. Alexandre Koyré posited a visual turn in the Renaissance, making this transformation in mentality a prerequisite for the achievements of Copernicus, Galileo, and Newton. In short, 50 years ago, historians thought of the visual as a fundamental category to understand the birth of modern science. In stark contrast to their convictions, recent surveys of the Scientific Revolution largely ignore its visual dimension. In spite of the unimportant role accorded to visual representation in current opinion about the Scientific Revolution, the assertive title of a collection of essays

*Department of Art History and Archaeology, Columbia University, New York, NY, USA.
§Unit of History and Philosophy of Science, University of Sydney, Sydney, New South Wales, Australia.
E-mail: rb843@columbia.edu

CENTAURUS 2006: VOL. 48: PP. 69–88; doi:10.1111/j.1600-0498.2006.00042.x

published in 2003, *The Power of Images in Early Modern Science* (Lefèvre 2003), is a clear indication that scholars are ready to reconsider the role of images and visual reasoning in the practice of early modern science. In the present study, I present a *strategic* history of the role assigned to images in the historiography of the Scientific Revolution and attempt to provide a framework into which the growing number of publications concerned with 'early modern art and science' can be fit. By identifying and examining the fundamental issues around which the earlier discourse took shape, including notions such as scientific naturalism and graphic accuracy, I hope to clarify the lessons learned as well as the changes intrinsic to the engagement of the visual as historical evidence.

The reader of this essay should be immediately alerted to the fact that one of these challenges inherent in an examination of the visual dimension of early modern science concerns language. The difficulty of finding appropriate terms to evaluate images and their use readily emerges from the quotations reported below, and it certainly should not be underestimated as a significant factor in the progressive inhibition of historians of science to consider the visual dimension. This language problem deserves separate treatment. Here, I simply want to clarify it by considering the example of 'scientific illustration'. If adopted to label a drawing by Leonardo picturing a botanical specimen or a figure in Otto Brunfels' *Herbarium Vivae Eicones* (1542), the phrase 'scientific illustration' poses two problems that cannot be easily resolved. First, what value, if any, had such a drawing or printed image from the perspective of Renaissance natural philosophy? Second, to 'illustrate' a plant carries implications about the relationship between image and accompanying text and between image and natural specimen: the former assumes the visual to be subservient to the verbal, while the latter considers the illustration to be a two-dimensional imprint of its subject. In either case, to posit an absolute objectivity for images and visual representation is naive (Gombrich 1960). If the sophistication attained by decades of scholarship on visual culture makes these and other linguistic pitfalls evident, it also underscores that they cannot be easily resolved. Certainly, any English-language historian engaging the visual dimension envies those writing in German. *Bild* is a truly efficacious and enviable umbrella term that implicitly includes the notions of picture, image, illustration, and visual artifact. While it does not preclude further differentiation, it prevents both confusion and erroneous characterizations. More importantly, the word *Bild* is neutral from the aesthetic perspective. The study of the visual dimension in early modern science should be primarily *Bildgeschichte*: images occupying center stage, while their aesthetic value remains secondary, as it was in the eyes of those who prepared and used these images.

1. Origins

Herbert Butterfield, the historian who set the term 'Scientific Revolution' on firm ground, carving its place within the larger scope of the history of Western Civilization, was also the first to call attention to the role of visual representation for the development of early modern science. The original presentation of his ideas on the Scientific Revolution took the form of a series of lectures that he delivered at Cambridge University in 1948, later revised for publication in a book entitled *The Origins of Modern Science, 1300–1800* (1949). In the section on medicine, Butterfield pointed to the decisive contribution of art and images to the progress of science: 'In regard to anatomy . . . one factor intervened to produce important changes in the situation, and that was the actual development of the visual arts and the sharpened kind of observation which the eye of the artist was able to achieve' (Butterfield 1949, p. 34). Although this quotation suggests that he sought a connection only between art and anatomy, other passages in the same chapter (and even more explicitly in its slight expansion in the second edition of 1957) clarify Butterfield's view on the importance of images for science more generally. In the later edition, the sentence opening the long paragraph on 15th-century medical advances presents the bolder and the more general claim that 'there is a sense in which the art of fifteenth-century Italy may claim perhaps to stand as a chapter in the history of modern science' (Butterfield 1949, p. 38).[2] Although not supported by detailed arguments, these quotes show that already in Butterfield's articulation of the development of early modern science, visual representation was considered an important ingredient for the development and presentation of crucial results and theories in the early stages of the Scientific Revolution.

To expand and clarify the brief statements included in the first edition of *The Origins of Modern Science*, Butterfield presented a fuller account of his views in 1954, publishing an article dedicated to the relationship between art and science in the Scientific Revolution entitled 'Renaissance Art and Modern Science'. In it, he situates the topic within the discussion of the contribution of the 15th century to the history of science—a century that seemed to offer no great new theory when compared to the 14th-century introduction of *impetus* or 16th-century developments in astronomy, but certainly a period of consequence for the arts. Challenging the notion that the Quattrocento is an irrelevant period from the standpoint of the history of science, Butterfield argues that it was in this century that artists developed a scientific approach to visual representation. He substantiates his claim by considering the examples of Ghiberti, Brunelleschi, Donatello, Alberti, Masaccio, and Leonardo and by finding supporting quotes in the writings of eminent art historians. A case in point is the quotation from Kenneth Clark: 'the scientific basis of renaissance naturalism was the one way in which the artists of the early renaissance believed they might surpass antiquity' (Butterfield 1954, p. 28). Beyond 'scientific naturalism', Butterfield emphasized the importance of mathematics within Alberti and Leonardo's theory of painting. In addition, Butterfield points to Florentine Quattrocento artists' interest in anatomy and their belief that precise knowledge of the human body is necessary to draw figures realistically. He interprets this as the development of accurate observation, making it 'a primary stage in the development of the Scientific Revolution'. Embracing the notion of scientific naturalism, Butterfield arrives at the conclusion that

> it is perhaps legitimate to envisage the art-history of the Renaissance in its aspect as a chapter in the history of science. We may ask whether the Florentine painter of the fifteenth century is not as

> much a parent of the modern scientist as was the natural philosopher in the schools. The fact that artists studied nature in so direct and methodical a manner was itself not without significance in this connection. (Butterfield 1954, p. 33)

Indeed, only in a few pages later he states: ‘If the scientist of modern times is a blend between the artist, the artisan and the natural philosopher, the Florentine painter of the fifteenth century is almost a trial combination of the various elements’ (Butterfield 1954, p. 35). By the close of the century, in Butterfield’s eyes, the probationary character of the artists’ contribution vanishes and he can confidently find all these characteristics perfectly expressed in Leonardo, making his graphic oeuvre and ideas about art a reference point for discussing visual representation in Renaissance science.

2. *Leonardo*

Leonardo deserves special attention in the present historiographic inquiry because the study of his contribution reflects more general trends in the approach of historians to visual representation in early modern science. Because of the superior quality and complexity of his oeuvre, Leonardo was recognized as an extraordinary artist already in the Renaissance. When scholars turned to his scientific research in modern times, they privileged his anatomical and botanical drawings, and invested heavily in the notion of ‘scientific naturalism’, which was partially supported by the artist’s professed emphasis on direct observation. Such a focus relegated to the background issues concerning the visual analysis of natural processes in spite of the fact that these issues were also forcefully suggested by his graphic studies of natural and mechanical motion and by his theoretical writings. Moreover, the prevailing myth of Leonardo the genius favored making him into a turning point and a clear link between ‘progress’ in the sciences and in the visual arts. It is in these terms that the historian of medicine Arturo Castiglioni hailed the artist. In the lectures he delivered at the Johns Hopkins University in 1934, he remarked that ‘in the rebirth of human thought, it [medicine] goes hand in hand with art . . . the great artist is an anatomist and a physician’ (Castiglioni 1934, p. 16). Following this line of thought, Castiglioni could only conclude that ‘Leonardo is then the first truly great scientist of the Renaissance’ (Castiglioni 1934, p. 27).

The boastful language of this claim was common in the pioneering writings of 20th-century historians describing the Scientific Revolution, but the triumphal tone undermined the importance of the subject. In fact, once it was recognized that, however impressive, Leonardo’s graphic achievements failed to have a direct impact on the development of early modern science, scholars no longer felt it necessary to consider his momentous proposition that visual representation and graphic analysis might be legitimate alternatives to the syllogistic and verbal framework of scholastic thinking in natural philosophy. The subsequent preference to concentrate on Leonardo’s machines and technical drawings while ignoring the larger questions concerning his efforts to formulate a graphic, visual alternative to a verbal approach for the study of nature, reveals also the difficulty of examining visual evidence from the perspective of intellectual history. In fact, such a choice appears an even greater retreat in light of the fact that Alexandre Koyré made Leonardo into a reference point for understanding the shift in mentality and mode of thinking of the Renaissance, which he considered crucial in preparing the way for the 16th- and 17th-century revolutions in astronomy and physics.

In his closing remarks for the conference and later for the book entitled *Léonard de Vinci et l'expérience scientifique au seizième siècle*, Koyré (1953) stressed this last point precisely because despite being self-evident in his view, it had not received its due in the scholarship. He reminded his audience that

> combien grande est la différence de notre mentalité *visuelle* — mentalité de gens qui lisent sans parler et qui apprennent *par les yeux* — de celle des gens du xv et encore du xvi siècle qui lisaient à voix haute et qui apprenaient *par l'oreille.* (Koyré 1953, p. 329)

While the mentality in which Leonardo was formed, 'mentalité de gens pour lesquels non seulement *fides*, mais aussi scientia etaient *ex auditu*', gave him access to medieval natural philosophy and ancient science and mathematics, Koyré recognized the artist's innovative commitment to the study of nature and to communicating his findings and theories through graphic representation, '*par les yeux*'. More importantly, Koyré underscored that quite apart from the impressive artistic quality and precision of Leonardo's anatomical drawings, the artist's professed aims were to 'decouvrir la structure interne mèchanique du corps humain, pour rendre accessible a l'obervation directe, c'est-à-dire à la vue'. This point led Koyré to generalize that 'Il me semble qu'à travers Léonard et avec lui, pour la première fois peut-être dans l'histoire, l'*auditus* est relégué à la seconde place, le *visus* occupant la première' (Koyré 1966, p. 115). For his part, Leonardo believed that painting and, more generally, visual representation are not only superior to the other arts but can also be trusted to represent things and understand them better than verbal descriptions. Yet, for Koyré the novel supremacy of visual representation defines an even more important point from the perspective of the history of science: 'le replacement des *fides* et de *traditio*, du savoir des autres, par la *vue* et l'*intuition* personnelles, libres et sans contrainte' (Koyré 1966, p. 115).

Before considering the views of other noteworthy historians, it seems important to assess the impact of these early statements. In fact, understanding the conditions that made visual representation an important element for the study of nature not only became a subject of great interest in the early descriptions of the Scientific Revolution, but by the mid-1950s, it was also recognized as a 'crucial' problem for the entire discipline of the history of science. At the famous conference convened in Madison, Wisconsin, in 1958, Giorgio de Santillana contributed an essay entitled 'The Role of Art in the Scientific Renaissance'. In it, he tried to make a case for considering Brunelleschi—and not Leonardo—as the artist who first approached theoretical and scientific problems through visual and graphic means and also laid the foundations for the achievements of later Renaissance artists who made mathematics and science the basis of their undertakings. de Santillana's article demonstrates above all the challenges faced by historians concerned with issues in the 'no man's land between art and science' (de Santilliana 1959, p. 34). He himself recognized that the material is intellectually elusive because it involves 'art'. However, in the opinion of this author, the primary difficulty rests not in the aesthetic dimension but in the art's visual nature. Much of the evidence that concerns the role of visual representation in the Scientific Revolution is written in the language of mathematics—to paraphrase Galileo—that is, through geometric figures and diagrams. Only by considering graphic evidence on a par with verbal statements we can bring light to the visual dimensions of Renaissance science and to the contribution of images to the development of early modern science.

3. Scientific Naturalism

The interpretations of Leonardo's extraordinary achievements made us temporarily loose sight of scientific naturalism, a key notion in the early development of the historiographic discourse on the role of images in early modern science. As mentioned above, this notion was dear to Kenneth Clark, the noted British art historian and long-time director of the National Gallery in London. Although he never properly defined or carefully discussed it, the expression recurs in virtually all his major publications and, because of his influence and stature, deserves special attention. For instance, in his *Leonardo da Vinci* (1939), Clark considers scientific naturalism to be one of the two main achievements and legacies left by 15th-century Florentine painting, a tradition initiated by Masaccio and epitomized by the works of Verrocchio and Leonardo—the other being the tradition of linear grace and fancy championed by Lorenzo Monaco and Botticelli (Clark 1939, p. 63). Positing the very same opposing elements in Leon Battista Alberti's discussion of the theory of painting, Clark contrasted Alberti's scientific naturalism with the classicizing and stylistic components evident in his work (Clark 1945, p. 15). Specifically, these opposing attitudes concern Alberti's 'scientific study of anatomy' and the academic approach to the human body, evident in contemporary painters through the Pollaiuolo brothers (Clark 1956, p. 193). Clearly, for Clark, the attribute 'scientific' is simply the opposite of stylized and academic. The notion of scientific naturalism he helped to establish does not imply natural philosophical knowledge but reflects primarily an assumed direct and accurate observation of natural specimens and forms by Renaissance artists.

Though common in the 'art and science' literature of the 1950s, the notion of scientific naturalism was firmly planted in the history of science by the influential book of Charles Gillispie. Chapter 2 of *The Edge of Objectivity* (1960) bears the title 'Art, Life, and Experiment' and opens by noting that if the engine of the Scientific Revolution was Galileo's physics and the mathematization of dynamics, the emergence of modern science was a more complex process in which naturalism proved an essential element in the new scientific outlook developed in the Renaissance (Gillispie 1960, p. 54). Recognizing the artistic roots of the naturalism appropriated for the study of nature, Gillispie introduced Leonardo not only as the artist who epitomizes the interest in exporting naturalism from the visual arts into the study of nature, but also as an intellectual who perceived geometric forms in the natural world, thus implicitly anticipating Galileo's tenet that nature is coded in the language of mathematics (Gillispie 1960, p. 56). Despite recognizing in Leonardo the individual who successfully connected scientific naturalism and mathematization of nature, Gillispie opposed making the artist into a hero of the history of science precisely because his brilliant insights were not to have an impact on contemporary or future natural philosophers. In Gillispie's view, it was Andreas Vesalius who established naturalism in science (Gillispie 1960, p. 57), when he worked closely with the artist making the anatomical woodcuts for the *De humani corporis fabrica* (1543) 'to perpetuate the graphic realism of his method in print' (Gillispie 1960, p. 62).

Despite its ubiquity in the accounts of the Scientific Revolution during the 1960s, naturalism moved to the background over the course of the next decade; this notable shift was determined by developments in the characterization of this concept as well as in the field of the history of science more generally. Historians were then absorbed by discussions over the various models of scientific progress proposed by philosophers of science. Certainly, it was significant that Thomas Kuhn and other eminent philosophers of science did not engage the visual aspects of the development and presentation of discoveries and theories in the original sources. Also, Kuhn championed the idea that all observations were theory-laden, an epistemological thesis that undercut the possibility of an 'naturalistic' approach. In addition, the debates surrounding Kuhn's work stressed further the emphasis that historical accounts already gave to theoretical and experimental work in physics and astronomy, while obscuring larger issues such as the coupling of graphic naturalism with the mathematization of nature. Not surprisingly, in this scholarly environment, historians of science lost sight of the suggestions offered earlier by another important study of the interaction between artists and natural philosophers. I am referring to the slim volume by Erwin Panofsky, *Galileo as a Critic of the Arts* (1954). Fortunately, its valuable insights have been recently rediscovered by those interested in early modern art and science (Damianaki 2000).

4. Galileo

Unlike his earlier work on Northern artists which assigned a consequential role to perspective, Panofsky's book on Galileo presented no specific claim about the history and the role of images in early modern science. However, by focusing on the actual interaction of artists and scientists at both the human and intellectual level, it showed to art and science historians alike the unexploited riches of this subject as well as the need to study the aspects of visual thinking embodied in the early modern practice of science. Panofsky's title fits only the contents of the first part of the essay where Galileo's innovative theory of the *paragone* between painting and sculpture is analyzed in detail.[3] If the first part appealed to art historians who had hitherto ignored Galileo's important contribution to the discourse on *paragone*, the second half intended to demonstrate the influence that aesthetic ideals had on Galileo's astronomy. In a nutshell, in the book's second part Panofsky argues that Galileo's rejected Kepler's elliptical planetary orbits because of an aesthetic prejudice—specifically, that celestial motion must follow circular paths (Panofsky 1954, p. 31).

More important than the specifics of Panofsky's two case studies is his tenet that in the early modern period art and science were inextricably connected, and that they interacted in the actual practice of science beyond the level of cognitive categories (Panofsky 1954, pp. 38–41). Panofsky also introduced Giovanni Battista Agucchi as another example of an intellectual whose notable contributions to the art and science of his times cannot be studied separately but only by considering principles pertinent to both spheres—his analysis of Agucchi's case is not exhaustive but more an invitation to pursue further research on the topic. Accordingly, Panofsky reminded art and science historians that the study of either one discipline for the 17th century cannot be separated from the study of the other: 'If Galileo's scientific attitude is held to have influenced his aesthetic judgment, his aesthetic attitude may just as well be held to have influenced his scientific convictions; to be more precise: both as a scientist and as a critic of the arts he may be said to have obeyed the same controlling tendencies' (Panofsky 1954, p. 20). Though over the past decade, several monographs and articles have appeared that confront the fertile ground indicated by Panofsky, his contemporaries left this line of inquiry to lie fallow, perhaps because their attention was turned toward the printed image. Rather than examining the intellectual processes at work behind visual representation, historians considered the effects of impersonal cultural forces like the printing press.

5. The Printed Image

The precise effects on science of the printing press and of the mechanical processes for reproducing images, such as woodcuts and engravings, have been —and continues to be— the subject of much scholarly contention. However, debates have centered on the printed text, with little consideration of images. Though there is disagreement on the exact nature of its contribution, no one denies that the printing press transformed the natural philosophical discourse, the programs of study in higher education, and the scientific practice and communications in general, for example, by making readily available standardized texts of both ancient and modern authors. Disagreements have actually deepened since the appearance of Elizabeth Eisenstein's masterful survey *The Printing Press as an Agent of Change* (1979), itself now the standard reference on the subject, despite remaining a highly controversial work (Grafton 1980; McNally 1987; Johns 1998; Johns 2002). In her concluding remarks, she states plainly that 'the communication shift altered the way

Western Christians viewed . . . the natural world. The printing press laid the basis . . . for modern science' (Eisenstein 1979, p. 704). Concerning images, Eisenstein's work at once substantiated and limited the contribution of woodcuts and engravings to the Scientific Revolution. Her considerations about printed images depend on the historiographic tradition which she adopted—the influence of which is measured by the fact that an economic historian of French culture decided to dedicate more than 400 pages of her survey of the printing revolution to science books, a subject in which she admitted to have limited expertise. In fact, earlier historians of science had sought a connection between the printing and the scientific revolution, striving to establish the significance of replicability of both texts and images.

The subject of the reproducible image was first considered within the history of prints, and an insightful analysis of graphic replication had appeared in the slim volume by William Ivins (1953), *Prints and Visual Communication*. Ivins considered the transformation generated by printing processes in matters of science only in passing; yet, the influence of his analysis of the larger subject continued for decades. One among those who appropriated Ivins's conclusions and extended the discussion of the subject is George Sarton. Though he concentrated his research on the 14th century, late in his career he also produced an introduction to the history of Renaissance science entitled *Six Wings: Men of Science in the Renaissance* (1957)—this volume drew upon his slightly earlier and more erudite *The Appreciation of Ancient and Medieval Science During the Renaissance (1450–1600)* (1955). Together, these two books made Sarton's views on the subject available to scholars while also palatable to a wider, popular audience. Although in both works Sarton was simply consolidating ideas already presented by himself and others, his stature and authority assured that even imprecise conclusions become cornerstones of the discipline's credo. Most importantly for the present inquiry, he decreed that 'the discovery of printing . . . one of the great turning-points in the history of mankind, . . . was of special importance to the history of science' (Sarton 1957, p. 3). In his opinion, the primary contribution of the printing press to the development of early modern science was the standardization of texts and of images within books, both equally consequential contributions. In fact, he explicitly places the introduction of engraving on par with the printing press as crucial developments for science, believing that engravings forced the modern author 'to be more precise that he could be, or wished to be, without them' (Sarton 1957, p. 117).

It is unfortunate that Sarton only argued this point with botanical figures, a subject that privileges scientific naturalism above all other qualities and effects of visual representation. Concentrating on figures that appeared in herbals, but aware that botany remained a marginal subject from the perspective of natural philosophers, Sarton, in *The Appreciation*, writes separate sections for both the development of naturalism and the printed image—revealing also that he believed that these matters deserve close scrutiny. However backward in the eyes of modern historians of early modern visual culture, his are important conclusions that standout as the clearest presented on either subject until then. In fact, in these pages, he makes two important points. First is the realization of the polarity—and difference—between artistic and scientific representations and therefore of the different aims underlying scientific and artistic 'naturalism'. Second, he insists on 'graphical accuracy', adding the claim that accurate representations 'close to the text must eventually lead to the correction of the latter' (Sarton 1955, pp. 86–87 and 88). Given these premises, and building on the work of Agnes Arber, Sarton confidently presented the chapter on the German fathers of botany as one of the most exhilarating in the history of science (Arber 1912; Arber 1953; Sarton 1957, p. 130). Sarton truly conveyed his enthusiasm as well as the importance of the topic by remarking 'What really happened—I consider this as one of the truly great events of the Renaissance—was that as some naturalists realized the need for illustrations made directly from nature, there grew up a class of draftsmen and woodcut makers who learned to this and did it well. Art and science came together and great was the result' (Sarton 1957, pp. 130–131). Similarly, earlier

> the printed image was the savior. As soon as scholars realized the need for illustrating the ancient texts by means of illustrations drawn from nature itself, the artists did their work and drove the philologists away. The main evil of Renaissance science was its love for words; that evil was finally compensated and redeemed by the love of clear and good images. Humanists had turned their back to nature, the artists did the opposite. Science was the winner. (Sarton 1955, p. 95)

These solemn words surely had a profound impact on the next generation of historians—as is clear from the surveys of early modern science of Marie Boas and Rupert Hall.

In her influential book *The Scientific Renaissance 1450–1630* (1962), Boas Hall followed what had become received opinion in the previous decade, as epitomized by Sarton's work. Thus, the printing press is confirmed as an important element in the history of Renaissance science, and a crucial one for the development of the biological sciences. In the case of anatomy, botany, and zoology, she limits its contribution to the dissemination of identical illustrations, particularly helpful for identification purposes and also crucial in rectifying centuries of incorrect visual reproduction by scribes who 'could draw flower illustrations accurately, but [who] had no notion of scientific exactitude' (Boas 1962, p. 29). On her part, Boas proposed a notable change in the aim and kind of illustrations between those appearing in incunables and 16th-century publications. In her view, from being an expedient to reach a semiliterate audience, illustrations in the 16th century became vehicles to

> convey what words . . . could not. There was as yet no technical language accurate in meaning and universally known, fit to explain in detail the necessary description of form. . . . Here a revolution took place as authors in despair at the inadequacy of purely verbal descriptions sought the aid of skilled draughtsman and artists trained to observe carefully and well. (Boas 1962, pp. 53–54)

From this quotation emerges an important tension that contributed to shaping the subsequent study of the role of visual representation in early modern science. On the one hand, Boas recognizes that 16th-century intellectuals studying the natural sciences understood the power of images and sought in visual representation a form of scientific communication that defied words, and this she counts as a revolution in itself. On the other hand, Boas establishes precise boundaries: this novel employment of visual representation pertains only to the 'soft' sciences and represents simply a developmental stage—botanists will do away with it in the 18th century. This perspective convinced her—and many of her readers—of the superiority of verbal over visual elements also in Renaissance zoology. Indeed, she concludes the paragraph following the last quotation by affirming: 'In any case, exact representation was less important. [...] Consequently the artistic caliber of most zoological illustration is low, and all through the sixteenth century it is the text, not the pictures, that claims the reader's attention' (Boas 1962, p. 55). The same conclusions emerge from her account of anatomical illustrations, for which she also notes a conspicuous transformation around the turn of the beginning of the 16th century. Not enchanted by the extraordinary figures drawn by Leonardo and engraved for Vesalius, Boas maintains throughout the superiority of verbal over visual renditions; her use of the term 'surface anatomy' to characterize anatomical illustrations epitomizes her judgment on the worth of these graphic efforts (Boas 1962, pp. 137–147). The way in which she concludes her remarks on *De Fabrica*'s figures is telling: 'It is almost a pity that the illustrations are so fine, for they are not as accurate as the text' (Boas 1962, p. 147). Boas's restrictions on which Renaissance intellectuals might have considered images a legitimate and useful means for studying nature discouraged historians from confronting more theoretical questions as well as cases in the physical sciences.

Eisenstein redirected the discussion of images away from a history of ideas wholly dependent on texts toward the material world of printing shops and printed pages, but she confronted the subject of the printed image after having absorbed the preconceptions set by Boas and other historians (whom she often quotes extensively, thus reiterating what was received opinion). Despite retaining an emphasis on the anatomical and botanical cases at the expense of those pertaining to the physical sciences, Eisenstein details the role of printers, publishers, editors, and early modern authors, whose commitment to printing, in her view, transformed the relationship between text and image in scientific publications. Unfortunately, by considering matters from the perspective of printing, she did not pursue the impact of printed woodcuts and engravings on the practices of the study of nature and on the modes of thinking in natural philosophy.

6. Science and the Arts in the Renaissance

While historians digested and pondered these statements in the 1970s and early 1980s, the subject of the interactions of art and science in the early modern period did not find a proper niche in the controversies between internalists and externalists that were at that time, consuming the history of science. The entire issue of the role of visual representation lost momentum. An attempt to relaunch it was made in 1977 by Alistair Crombie and the organizers of the Folger conference 'Science and the Arts in the Renaissance'. Crombie's convictions about the importance of images and the close relationship between artists and scientists emerged readily in his essay for *Science and the Arts in the Renaissance* (Shirley and Hoeninger 1985), but they are best summarized by one sentence in the paper he sent to recruit speakers for the conference:

> ‘Measurement, observation, experiment, and classification were extended to a variety of new areas, including the fine arts and the practical arts. Although less dramatic in its consequences than the revolution in astronomy and physics, the resulting revolution in the arts had a transforming effect on the understanding of the world of nature and the world of the arts’ (Shirley and Hoeninger 1985, p. 9).

Even though the participants did not adopt Crombie’s suggestion that the transformation of Renaissance intellectual culture ushered the revolution in art, the conference was a great success. The delayed publication of its proceedings was truly unfortunate because the edited volume included two important articles, each containing ideas and conclusions that shaped much of the subsequent thinking on the topics of the relationship between art and science and of scientific images.[4] James Ackerman’s paper presented an insightful analysis of the import of artistic and visual theories on 16th-century science, while Michael Mahoney meticulously debunked the foundations of Samuel Edgerton’s thesis that the development of linear perspective was a crucial element and a sort of precondition for the Scientific Revolution.

Ackerman’s ‘The Involvement of Artists in Renaissance Science’ is a study that deserves close scrutiny because it quickly became a point of reference for scholars, and still stands as a milestone in the literature on art and science. Ackerman opened this paper with a provocative statement: ‘Art and science in the fifteenth century were in a symbiotic relation’ (Ackerman 1985, p. 94). While not an absolute truth—both disciplines did after all accomplish much in complete autonomy from one another and their existence was not interdependent—Ackerman’s claim nevertheless challenges the reader to think about moments in which advances in science depended upon ideas born and developed within the artistic discourse. He identified two such moments in the 15th century: the writings of Leon Battista Alberti and Leonardo. However, the essay’s aim, ‘to define the ways in which the rationalized visual and intellectual perceptions developed by Renaissance artists as the basis of a new visual communication contributed to the definition and attainment of scientific goals in the Renaissance’, goes well beyond the thesis and domain implied by the article’s title and first sentence (Ackerman 1985, p. 94). It is not simply ‘the involvement of artists’ that Ackerman is pursuing. Implicitly privileging *Bild* over *Kunst*, he proposed a search for the introduction of a new visual language, a form of communication that shaped the goals, practices, and achievements in the study of nature. Unfortunately, when he subsequently navigates illustrated Renaissance texts with scientific content, he follows in the footsteps of those who had already considered these issues, concentrating his section entitled Scientific Illustration on anatomy and botany and forgetting his earlier and more general aims. Though anatomical and botanical illustrations were a well-trodden path, Ackerman’s careful analysis led him to the sweeping conclusion that these memorable images were consequential only at the didactic level. However, despite the fact that visual induction was at times a language shared by those representing and studying the natural world, in the end, scientific illustrations failed to integrate the astonishing naturalism presented by artists such as Leonardo and Albrech Dürer (Ackerman 1985, p. 112). In a nutshell, Ackerman's results dashed the hopes of the previous generation of historians: art as *Kunst* did not really influence Renaissance science.[5]

The article's conclusion merits detailed scrutiny. Informed also by the exchange between Mahoney and Edgerton, in it Ackerman outright denies that naturalism and perspective played an essential role in the rise of modern science. In a way, this result is not surprising: the practice of natural philosophy, based as it was on verbal description and dialectic argumentation, was also socially distant from the main artistic practices; yet, Ackerman maintained that the two traditions did share a 'perceptual attitude', which he defines as 'an attitude of respect for empirical observation and a will to devise systematic and repeatable techniques for recording the results of observation' (Ackerman 1985, p. 125). Thanks also to his authority, these conclusions proved influential, pointing scholars away from what had been the focus and the cornerstone of the study of the interaction between art and science and scientific images in the previous decades. Subsequent scholarship eliminated claims that naturalism and perspective were crucial for the rise of early modern science—and the point was reinforced by Mahoney's demolition of the Edgerton thesis.[6] Similarly, received opinion continues to assume that direct empirical observation gained ground in natural philosophy because Renaissance visual arts provided the graphic means to reproduce these experiences.

A consequence of the emphasis placed on the new possibility available to Renaissance intellectuals to make visual records of direct observations was the affirmation of an approach to images that considers them as mere illustrations of nature or better visualizations of the author's verbal account of his observations. Since many figures appearing in Renaissance scientific books performed that function, it follows that the replicability or printing of the image is significant, as is the realization that figures were not neutral but integral to the rhetoric pursued by each author. Approached in this way, images shaped the practice of natural philosophy in that authors could rely on the visual medium for 'convincing' their reader in ways that words could not. Moreover, printing images and texts afforded unprecedented circulation and thus maximum impact for the author's argument. This latter point is forcefully conveyed by Stephen Shapin and Simon Schaffer in their influential *Leviathan and the Air Pump* (1985). In it, they categorize illustrations within the literary technologies that made experimental phenomena available to those who were not direct witnesses to the experiments but who became virtual witnesses by reading the verbal report and imagining the experimental scene with the help of the figures included (Shapin and Schaffer 1985, pp. 25–26 and 60–62). Despite the peculiarities of the cases they studied, their approach to images has become and remains the predominant one. Accordingly, the various forms and instances of visual representation do not play a significant role in the accounts of early modern science, receiving at best a passing mention, as is the case, for example, in Paolo Rossi's (2001) survey. Generally, images are considered not as ideas, proofs, arguments, or means for understanding nature, but as rhetorical tools for writers. When singled out as cultural, artifacts, they are treated as byproducts of the interaction between high and low culture, or between natural philosophers and *mechanici* and other 'invisible' actors. Yet, considering images from this angle skirts the issue of whether visual representation shaped the practice of science at its core, that is, whether images and graphic means to devise visual analyses and arguments contributed to the actual understanding of nature and its processes.

7. Recent Work

Although it is difficult to identify what are or will prove to be influential studies for understanding the role of visual representation in early modern science, it is certain that in the past 15 years, a number of articles and several monographs have reconsidered the subject, studying specific groups of images with renewed methodological sophistication. Moreover, a wealth of pertinent material in archives and primary sources has come to light, legitimizing the historians' inquiry as well as the historical subject of the contested nature and potentials seen by early modern intellectuals in the application of visual representation for the study of nature.

Though broad in scope but not short on insight, several articles included in the volume *Non-Verbal Communication in Science Prior to 1900* (Mazzolini 1993) have raised and considered theoretical issues emerging from the analysis of the different kinds of images that should be acknowledged in accounts of the Scientific Revolution. From the passages the contributors of this volume brings to bear, it is clear that, whether in the writings of mechanical philosophers, in printed editions of mathematical texts, or in the drawings of Renaissance engineers, early modern intellectuals were conscious of the difference between verbal and visual representation and of the latter's potential for the study of nature. While presenting numerous specific instances of the employment of images within the practice of natural philosophy, these essays implicitly demonstrate the need for historians to establish a clear theoretical infrastructure for situating particular images within the larger cultural and intellectual framework: with the older model based on naturalism and perspective dismantled, a newer one is necessary to place visual representation in the master narrative that partially survives in the classroom.

Discussion of larger issues concerning visual representation together with the proposal of some necessary steps for the formulation of an infrastructure for confronting the use of images in early modern science are presented in the collection entitled *Picturing Knowledge* (Baigrie 1996). Aptly evaluating the situation, Bert Hall opened his essay by noting that 'The problems of early illustrations portraying scientific and technological topics remain among the most intractable aspects of the history of science and technology. . . . Images remain an unusual subject, peripheral to the mainstream of investigations and still largely unexplicated with respect to their broader cultural significance' (Hall 1996, pp. 3–4). Although Hall does not provide solutions to these problems, he discusses examples which substantiate the fact that in the early modern period scholars were thinking in pictures, devising visual arguments and graphic analyses in natural philosophy as well as in technical subjects; his discussion aimed at encouraging historians to study the mechanisms through which images acquired the power to persuade while bearing intellectual authority. These suggestions for a more detailed as well as broader historical inquiry are qualified by Martin Kemp (Kemp 1996) who argues for the irreducible complexity of the relationship between illustration and visualization during the Renaissance. He concludes that differences in the kinds and employment of images in the cases of Vesalius and Copernicus support neither a grand nor a progressive narrative for describing the role of images in early modern science; yet, such diversity endorses further study of each specific situation. Despite the valuable insights offered by these and other authors, the very language used in the volume's introduction and then occasionally throughout, retains the terms 'art' and 'illustration', blurring the aesthetic, scientific, and graphic dimensions, as well as the visual representation's dependence on verbal description. This demonstrates the persistence of outmoded and inadequate categories for confronting the role of visual representation in the practice of early modern science.

Most recent publications have discussed additional cases of the employment of images and instances of visual thinking in early modern science, with studies of Galileo and his context providing the most fruitful venues of inquiry (Reeves 1998; Bredekamp 2001; Biagioli 2002; van Helden 1996; Lefèvre 2001). In spite of some interesting titles, such as the collection *The Power of Images in Early Modern Science*, no integrated account has come to the fore—though the need for one is increasingly more pressing. This is further underscored by the wealth of material—original statements, images, and interpretations—presented by David Freedberg in his *The Eye of the Lynx* (Freedberg 2002). In fact, the members of the Accademia dei Lincei directly confronted methodological and epistemological issues concerning the value and role of visual representation in scientific endeavors. In a process that can also be followed through written statements, Prince Federico Cesi and his fellow academicians came to realize that, save in the case of anomalies and monstrosities visual representation was inadequate for classifying plants and animals; their respective relationships were to be understood through their modes of generation and reproduction.

The material and evidence from the Accademia dei Lincei not only clearly validate the study of the employment of images in the rise of early modern science, but it also demonstrates the complexity inherent in the subject. The recognition that the integration of visual representation in the practice of early modern science was a nonlinear, nonpositivistic, and nonprogressive process makes clear that it can be neither divided summarily along disciplinary boundaries nor evaluated according to the categories of naturalism and visual reductionism. Conversely, the reflections of Cesi and his friends show that pictures cannot be reduced to literary technologies and rhetorical elements of the presentation and consumption of early modern science, but that they are part of the means available for studying nature. Thinking in pictures and analyzing and representing natural phenomena graphically were elements of the infrastructure of Renaissance intellectual culture. Historians may not be able to uncover a universal grammar of this visual language, but verbal and visual evidence in the original sources can point to stations of its latent development and to relevant themes that persist through time.

8. Conclusions

While many of the excerpts quoted earlier show that the first generation of historians of the Scientific Revolution were very interested in the visual dimension of early modern science, and assigned an important role to images, the legacy of their efforts has actually proven detrimental to the study of the subject. These early attempts to reckon with the role of visual representation, efforts which in most cases were very sophisticated, reflected necessarily trends and positions held then by art historians—most of which are now outmoded. Yet, by borrowing methods, assumptions, and aims from art historians, for example, the concept of scientific naturalism, historians of science also privileged certain notions and kinds of images that created a skewed perspective for understanding how images and visual reasoning contributed to early modern science. Above all, historians of science focused on the effects of visual representation in the life sciences, in other words, botany, anatomy, and zoology, without confronting and detailing the counterpart situation of images in the physical sciences, that is, in astronomy, mathematics, and physics, which were the crucial disciplines in the early narratives of the Scientific Revolution. The life sciences were not only treated as less important disciplines, but also their crucial developments occurred during the 16th century and not during the 17th century. Consequently, the discourse on images remained confined to the 16th century, without the opportunity to engage the visual material and the dimensions in works by canonical figures such as Kepler, Galileo, Descartes, and Newton. Moreover, the emphasis on the life sciences centered the discussion on naturalism and graphic accuracy, promoting a contamination of the evidence by aesthetic concerns. As a result of a selective focus that privileged and spotlighted the relationships between images and phenomena and between images and texts, questions about the import of the visual for constructing arguments and for drawing inferences valid from the perspective of Renaissance natural philosophy were relegated to the background. In addition, the failures associated with the case of Leonardo, who epitomized the analytic and visual skills useful to analyze natural phenomena graphically, also brought to the fore the historical difficulties of transmitting such knowledge between the different social spheres of artists and natural philosophers. The difficulties of bridging learned and artistic culture had the double effect of downplaying the ‘visual turn’ of the Renaissance because of the elusiveness of the links between visual evidence and mentality, and of redirecting the discourse on the role of visual representation toward the printed image. While the quantitative arguments afforded by the printing press favored understanding images as literary technologies, they also obscured qualitative arguments that would engage the visual dimension in the practice of science and in the didactic environment, rather than simply in communication. It is to be hoped that the recent monographs that returned to the study of individual thinkers and specific groups of images will provide the stimulus for reconsidering the general role of visual representation in early modern science. Rather than concentrating on the role of images as mere records of natural observations or as vehicles for communicating fully formed scientific convictions, these new studies should examine the epistemological status of images and their value in the practice of science.

Acknowledgements

I would like to thank Wilbur Applebaum, Peter Barker, Floris H. Cohen, and David Freedberg for their suggestions and encouragement, and the Kress Foundation, for the generous support of my doctoral research. This article is adapted from the introduction of my forthcoming thesis.

BIBLIOGRAPHY

Ackerman, James
1961: "Science and the Visual Arts", in H. Howell Rhys (ed.), *Seventeenth Century Science and the Arts*, Princeton: Princeton University Press, pp. 63–94.
1985: "The Involvement of Artists in Renaissance Science", in J. W. Shirley and F. D. Hoeniger (eds.), *Science and the Arts in the Renaissance*, Washington: Associated Press, pp. 94–129.
Arber, Agnes
1912: *Herbals: Their Origin and Evolution, A Chapter in the History of Botany, 1470–1670*, Cambridge: Cambridge University Press.
1953: "From Herbalism to the Birth of Modern Botany", in E. Ashworth Underwood (ed.) Vol. 1, 2 vols, *Science, Medicine, and History: Essays on the Evolution of Scientific Thought and medical Practice in Honor of Charles Singer*, London: Oxford University Press, pp. 317–336.
Ashworth, W.
1991: "The Scientific Revolution : The Problem of Visual Authority", in *Conference on Critical Problems and Research Frontiers in History of Science and History of Technology*, Madison: University of Wisconsin Press, pp. 326–348.
Baigrie, Brian, ed.
1996: *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, Toronto: University of Toronto Press.
Baroncini, Gabriele
1996: "Note sull'illustrazione scientifica", *Nuncius* 11, 527–543.
Biagioli, Mario
2002: "Picturing Objects in the Making: Scheiner, Galileo and the Discovery of Sunspots", in W. Detel and C. Zitte (eds.), *Ideals and Cultures of Knowledge in early Modern Europe*, Berlin: Akademie Verlag, pp. 39–95.
Boas, Marie Hall
1962: *The Scientific Renaissance 1450–1630,* New York: Harper and Brothers.
Bredekamp, Horst
2001: "Gazing Hands and Blind Spots: Galileo as Draftsman", in J. Renn (ed.), *Galileo in Context*, New York: Cambridge University Press, pp. 153–192.

Butterfield, Herbert
1949: *The Origins of Modern Science, 1300–1800*, London: G. Bell and Sons.
1954: "Renaissance Art and Modern Science", *University Review* 1, 25–37.
Castiglioni, Arturo
1934: *The Renaissance of Medicine in Italy*, Baltimore: The John Hopkins Press.
Clark, Kenneth
1939: *Leonardo da Vinci: An Account of His Development as an Artist*, New York: Cambridge University Press.
1945: *Leon Battista Alberti on Painting*, Oxford: Oxford University Press.
1956: *The Nude: A Study in Ideal Form*, New York: Pantheon Books.
Cohen, Floris
1994: *The Scientific Revolution: A Historiographic Inquiry*, Chicago: University of Chicago Press.
Crombie, Alistar
1953: *Medieval and Early Modern Science*, 2 vols, New York: Claredon Press.
Damianaki, Chrysta
2000: *Galileo e le arti figurative*, Rome: Vecchiarelli.
Eisenstein, Elizabeth
1979: *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early Modern Europe*, New York: Cambridge University Press.
Freedberg, David
2002: *The Eye of the Lynx: Galileo, His Friends, and the Beginning of Modern Natural History*, Chicago: University of Chicago.
Gillispie, Charles
1960: *The Edge of Objectivity, An Essay in the History of Scientific Ideas*, Princeton: Princeton University Press.
Gombrich, Ernst Hans
1960 (1956): *Art and Illusion: A Study in the Psychology of Pictorial Representation*, New York: Pantheon Books.
Grafton, Antony
1980: "The Importance of Being Printed", *Journal of Interdisciplinary History* 11, 265–286.
Hall, Bert
1996: "The Didactic and the Elegant: Some Thoughts on Scientific and Technological Illustrations in the Middle Ages and Renaissance", in B. Braigie (ed.), *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, Toronto: University of Toronto Press, pp. 3–39.
Ivins, William
1953: *Prints and Visual Communication*, New York: Harvard University Press.
Johns, Adrian
1998: *The Nature of the Book*, Cambridge: University of Chicago Press.
2002: "How to Acknowledge a Revolution", *The American Historical Review* 107, 106–125.
Kemp, Martin
1996: "Temples of the Body and Temples of the Cosmos: Vision and Visualization in the Vesalian and Copernican Revolution", in B. Braigie (ed.), *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, Toronto: University of Toronto Press, pp. 40–85.
Koyré, Alexandre
1953: "Rapport Final", in *Léonard de vinci et l'expérience scientifique au seizième siècle*, Paris: Presses Universitaires de France.
1955: "Review of Galileo as a Critic of the Arts", *Critique* 100–101, 835–847.
1966: "Léonard de Vinci 500 Ans après", in *Etudes d'Histoire de la pensée scientifique*, Paris: Presses Universitaires de France, pp. 99–116.

Latour, Bruno
1990: "Drawing Things Together", in Michael Lynch and Steve Woolgar (eds.), *Representation in Scientific Practice*, Boston: Kluwer Academic Publishers, pp. 19–68.
Lefèvre, Wolfang
2001: "Galileo Engineer: Art and Modern Science", in J. Renn (ed.), *Galileo in Context*, New York: Cambridge University Press, p. 11.
2004: (Ed.) *The Power of Images in Early Modern Science*, Basel: MIT Press.
Mahoney, Michael
2004: "Drawing Mechanics", in W. Lefèvre (ed.), *Picturing Machines 1400–1700*, Cambridge: MIT Press, pp. 281–308.
Mazzolini, Renato, ed.
1993: *Non-Verbal Communication in the Science Prior to 1900*, Florence: Olschki.
McNally, Peter
1987: "The Eye of the Beholder. Opinions Concerning Elizabeth Eisenstein and the Printing Press as an Agent of Change", in *The Advent of Printing: Historians of Science Respond to Elizabeth Eisenstein's The Printing Press as an Agent of Change*, Montreal: McGill University, pp. 1–8.
Panofsky, Erwin
1954: *Galileo as a Critic of the Arts*, The Hague: M. Nijhoff.
Reeves, Eileen
1998: *Painting the Heavens: Art and Science in the Times of Galileo*, Princeton: Princeton University Press.
Rossi, Paolo
2001: *The Birth of Modern Science*, Oxford: Blackwell.
de Santillana, Giorgio
1959: "The Role of Art in the Scientific Renaissance", in M. Clagett (ed.), *Critical Problems in the History of Science*, Madison: University of Wisconsin Press, pp. 33–65.
Sarton, George
1955: *The Appreciation of Ancient and Medieval Science During the Renaissance (1450–1600)*, Philadelphia: University of Pennsylvania Press.
1957: *Six Wings: Men of Science in the Renaissance*, Bloomington: Indiana University Press.
Shapin, Steven
1996: *The Scientific Revolution*, Chicago: University of Chicago Press.
Shapin, Steven, and Schaffer, Simon
1985: *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life*, Princeton: Princeton University Press.
Shirley, John William, and Hoeniger, F. David
1985: *Science and Arts in the Renaissance*, Washington: Associated Press.
van Helden, Albert
1996: "Galileo and Scheiner on Sunspots: A Case Study in the Visual Language of Astronomy", *Proceedings of the American Philosophical Society* 140, 358–396.

NOTES

1. The term 'Scientific Revolution' is now contested among historians of science, but even those who criticize it continue to use it (Shapin 1996, p. 1). In this study, I use the term when it is employed by historians who themselves used it. Otherwise I employ the more neutral phrase 'early modern science'. For a comprehensive introduction to the historiography of the Scientific Revolution, see Cohen (1994). Concerning the role of visual representation in mainstream accounts of the Scientific Revolution, the words of William Ashworth (1991, pp. 326–348) remain true: 'we [historians of science] have paid

virtually no attention to the visual side of the scientific revolution'. See his essay "The Scientific Revolution: The Problem of Visual Authority", in *Conference on Critical Problems and Research Frontiers in History of Science and History of Technology*, Madison: University of Wisconsin Press, 1991, pp. 326–348; the passage is on page 326. Some useful remarks are offered by Baroncini (Baroncini 1996) and by Bruno Latour (Latour, 1990).

2. On the previous page, he stressed the role of the mechanical reproduction of pictures: 'Devices that were associated with printing—such things as woodcuts and copperplate engravings—put new instruments at the disposal of the scientific teacher. At least one could be sure that drawings and diagrams would be copied and multiplied with accuracy; and this, together with printing itself, made accurate recording and scientific intercommunication more practicable' (Butterfield 1949, p. 37).
3. Alexandre Koyré opens his long review of Panofsky's book noting the very same point and even suggesting a different title: 'Attitude esthétique et pensée scientifique chez Galileo Galilée' (aesthetic attitude and scientific thought in Galileo Galilei) (Koyré 1955, p. 835). This in-depth review demonstrates the complexity of Galileo's reasons for the rejection of Kepler's ellipses while it challenges Panofsky's simplified approach by presenting Galileo as a modern man committed to the values of classicism and opposed to the fanciful and playful forms of Mannerism.
4. The publication of only some of the revised papers originally delivered followed 7 years after the conference. Despite being contributions of eminent historians, this delay together with the change in the historiographic panorama prevented the volume from receiving the attention it deserves; notably, it was then reviewed only in two venues: in *Renaissance and Reformation* 10 (1986): 366–368 and by Martin Kemp, briefly in *The Times Literary Supplement* 4330 (28 March 1986): 320.
5. Ackerman (1961, pp. 63–94) had reached the same conclusion in his essay 'Science and the Visual Arts'. Specifically, in this article, Ackerman presented careful arguments against a link between caravaggesque naturalism and the new empiricism emerging in natural philosophy. Indeed, he maintained that moments of contact between science and art in this century were rather tenuous. See in particular, pp 64–65, 68–69, and 71.
6. In a recent article entitled 'Drawing Mechanics', Mahoney (2004) returned to this issue, extending the conclusions he presented more than 20 years ago in *Science and the Arts in the Renaissance*. Here, after demonstrating that by the later 17th century those concerned with the theoretical aspects of mechanics abandoned visual representation as irrelevant to a mathematical understanding, Mahoney rightly warns against reading into Renaissance machine drawings rudimentary theoretical principles of the science of mechanics that were developed only in the 17th and 18th century.