Chapter 2
Knowledge and Beliefs Regarding Linear Perspective

Abstract The aim of this chapter is to deconstruct the notion that linear perspective formed a stable system of representation beginning in the Quattrocento. Doubts must be raised because the history of perspective is in fact quite conjectural due to the many lacunae scattered along its path; one crucial example is the exact nature of the contributions of Brunelleschi, Alberti, and Masaccio. A second obstacle is the fact that a multiplicity of approaches were in use from the end of the Duecento to the Cinquecento, when the academies formally introduced the teaching of perspective techniques. Between these two time points perspectivists explored numerous systems of perspective, introducing errors and variations that can be explained by the uneven distribution of knowledge regarding the laws of optics and geometry.

The challenge facing the practitioner in representing space may be summed up as follows: how can one apprehend and capture the three-dimensionality of a solid in the two dimensions of a plane? Among the strategies commonly used, some consist in decomposing the object into a series of partial views—the horizontal plane, elevation, and profile—from which one can, with a little practice, mentally reconstruct the spatiality of the object. Other strategies instead attempt to provide a visual synthesis that is capable of immediately evoking the three-dimensionality of the solid. Parallel axonometric projections (isometric, dimetric, trimetric) and oblique projections (cavalier and military), both of which conserve the parallelism of an object's straight lines, fall into this category. Perspective itself rejects the property of parallelism for the principle of a gradual reduction in size, reproducing as closely as possible the conditions of natural vision: i.e., two straight lines that are not confined to the frontal plane converge toward a vanishing point. Linear perspective is just one of the systems that respects this principle (since it holds true for the curvilinear and synthetic perspectives as well), but it is the version that is generally considered in discussions of perspective *tout court*. I will conform to this usage by discussing only the case of linear perspective here.

The argument that can be advanced is that the characterization of perspective space as a unitary, coherent and stable representation is not sufficient because it fails to take into account the wide range of practices that are known to have existed.

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Linear perspective constitutes an *open* rather than a closed *system*, one that reflected the mobilization over time of specific intellectual resources.

In the first part of this chapter, it will be shown that the work of Italian craftsmen at the beginning of the Quattrocento did not lead to a codified and homogeneous set of perspective practices (illustrating, in sociological terms, the effects of belief). In the second part it will be shown that the diversity of perspective conceptions in circulation can be explained differences in the optical-geometric resources available to the perspectivists (the effects of knowledge).

2.1 The Myth of Perspective

To begin, it will be useful to examine the supposedly stable nature of the perspective system. It is true that one finds, from Euclid[1] to Gibson,[2] unvarying expressions of the law of diminution in size as a function of distance. But the solidity of this principle has sometimes served as a pretext to impose the uniqueness of the perspective system and to reify it, particularly as far as the Renaissance is concerned, when in fact research on perspective often took the form of disparate and uncoordinated initiatives. Let us examine the contributions of Brunelleschi, Alberti and Masaccio, to whom have been attributed the invention, codification, and first major realization of the concept of perspective, respectively.

2.1.1 Filippo Brunelleschi

Filippo Brunelleschi (1377–1446) is usually credited with having realized the first rigorous work of perspective, in Florence around the year 1413. The documentation is scarce, but the artist apparently conducted an ingenious demonstration of the accuracy of his construction. He stood at a distance of three *braccia* (arm's lengths) from the main portal of the cathedral of Santa Maria del Fiore facing the Baptistery of San Giovanni, holding a mirror in one hand and a panel painting of the octagonal-shaped building in the other in such a way that he could observe, through a small hole pierced in the panel, the image of the painting reflected in the mirror. From his position he could see at the same time the image and the actual building, and thus judge the accuracy of his perspective drawing. The first difficulty regarding this experiment is that no material trace of it has survived. In particular, the

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[1]"Objects of equal size unequally distant appear unequal and the one lying nearer to the eye always appears larger/Aequales magnitudines inaequaliter expositae inaequales apparent et maior semper ea quae propius oculum adjacet," *Optica*, ed. J.L. Heiberg, Leipzig, 1895.

[2]James J. Gibson, *The Ecological Approach to Visual Perception,* Boston, 1979.

tavoletta (panel painting) has been lost and there is no way of knowing what perspective method was used by the architect.

The only description that has come down to us is a second-hand account attributed to Antonio di Tuccio Manetti, who was born a decade after the experiment took place. What is more, his account does not grant Brunelleschi's display the status that is generally ascribed to it of an experiment in optics. In fact, Manetti never employs the word "experiment" although the term is amply attested to both in medieval Latin and in the Italian vernacular.[3] He does couch his description in very concrete terms: "[Brunelleschi] put into practice" (*misse inatto*), "he displayed a panel" (*mostro una tauoletta*), "he made a painting" (*fecie una pittura*) … but from this one cannot strictly speaking infer either an experiment of a public nature conducted before eyewitnesses, nor the existence of an experimental set-up of any kind. Hence, there is no concrete proof that Brunelleschi carried out a demonstration in the doorway of the cathedral of Florence. What Manetti's biographical account does offer is a fairly detailed description of his painting of the baptistery.

Let us identify the crucial points relating to perspective in this account, which are conditions A (the vantage point of the viewer), B (the scene depicted) and C (the size of the eyehole). These three conditions as described by Manetti in fact contradict one another. It is a simple matter to calculate the theoretical field of vision based on conditions A and B: the point of view chosen for the viewer ("some three *braccia* inside the central portal of Santa Maria del Fiore/*dentro alla porta del mezzo di Santa Maria del Fiore qualche braccia tre*") and the painted scene ("up to the arch and the corner of the sheep [market] … up to the corner of the straw [market]/*insino all uolta e canto de Pecori … insino al canto alla Paglia*") dictate a theoretical field of vision of 54°. The actual field of vision can be calculated from condition C: Manetti stated that the diameter of the eyehole at the end facing the observer was 5 mm ("a lentil bean/*una lenta*"), widening to 30 mm at its posterior end ("a ducat, or a bit more/*uno ducato o poco piu*"). For the eyehole to form a truncated cone ("it widened conically like a straw hat/*si rallargaua piramidalmente come fa uno capello di paglia*"), the minimal thickness of the panel must have been about 15 mm. In this case the actual field of vision based on the distance of the crystalline lens from the anterior end of the eyehole[4] would have been between 13°

[3]One finds numerous references in the Latin and Italian translations of Ibn al-Haytham's *Kitāb al-manāẓir* (Alhacen's *De aspectibus/De li aspecti*). The terms that are attested to in Arabic, Latin and Italian are: *i'tibār* > *experientia-experimentatio* > *sperimento-sperimentatione; i'tabara* > *experimentare* > *sperimentare; mu'tabir* > *experimentator* > *sperimentatore*; cf. Abdelhamid I. Sabra, "The Astronomical Origin of Ibn al-Haytham's Concept of Experiment," *Actes du XIIe Congrès International d'Histoire des Sciences*, Paris, 1971, tome III.A, pp. 133–136.

[4](A) "In order to paint it, it seems that he stationed himself some three braccia inside the central portal of Santa Maria del Fiore/E pare che sia stato a ritrarlo dentro alla porta del mezo di Santa Marie del Fiore qualche braccia tre…," (B) "In the foreground he painted that part of the piazza encompassed by the eye, that is to say, from the side facing the Misericordia up to the arch and corner of the sheep [market], and from the side with the column of the miracle of St. Zenobius up to the corner of the straw [market]/Figurandoui dinanzi quella parte della piaza che ricieue l'occhio cosi uerso lo lato dirinpetto alla Misericordia insino alla uolta e canto de Pecorj cosi da lo lato della

and 19°, i.e. only one-fourth to one-third of the expected theoretical value. When Brunelleschi's "experiment" was reproduced in situ in April 1995, it was found that conditions A, B, and C were in fact mutually exclusive. The field of vision carves out a square measuring 7–8 m on each side corresponding precisely to the door of the Baptistery. Since all the lines lie in the frontal plane containing the façade, this is not a perspective image.[5] The results of a second experiment conducted in May 2001 as part of the 4th *ILabHS* were no more convincing as a demonstration of perspective.[6] Despite the many positive analyses of this episode that continue to appear, all serious attempts to reconstruct Brunelleschi's experiment have failed and for one simple reason: it is *physically impossible* to reproduce the tableau based on the conditions described by Manetti.

If one adds to this the fact that the only work of perspective extant that can be attributed with any probability to Filippo Brunelleschi—an engraving on a silver plaque of *Christ Casting Out a Demon* (Louvre)—does not follow the rules of linear perspective,[7] one is forced to conclude that Brunelleschi's contribution has been considerably overestimated. The doubts raised here do not concern his involvement in the development of perspective, which is incontestable, but the exact nature of this contribution, about which we know nothing. In truth only three pieces of evidence exist on the role played by the artist.

The first is a letter written by Domenico da Prato to Alessandro Rondinelli on 10 August 1413, in which Filippo Brunelleschi is described as "an ingenious man on perspective/*prespettiuo ingegnoso uomo*," but this reference could simply attest to the fact that the architect took a general interest in the subject of optics (*perspectiva* in Latin); rigorously speaking it certainly does not allow a *terminus ante quem* to be fixed for the invention of perspective.

(Footnote 4 continued)

colonna del miracolo di Santo Zanobi insino al canto alla Paglia…," (C) "The hole was as tiny as a lentil bean on the painted side and it widened conically like a woman's straw hat to about the circumference of a ducat, or a bit more, on the reverse side/El quale buco era piccolo quanto una lenta da lo lato della dipintura et da rouescio si rallargaua piramidalmente come fa uno cappello di paglia da donna quanto sarebbe el tondo d'uno ducato o poco piu…," Antonio di Tuccio Manetti, *Vita di Filippo di Ser Brunelleschi*, eds. H. Saalman and C. Engass, University Park, 1970, p. 43ff. The first reassessment of this account was made by Martin Kemp, "Science, non-science and nonsense: The interpretation of Brunelleschi's perspective," *Art History* 1 (1978): 134–161.

[5]The field of vision is fixed by the distance between the centre of the crystalline lens and the anterior opening of the eyehole, that is, $a_0 \approx 15$ mm in the case of an exophthalmic eye and $a_1 \approx 22.2$ mm in the case of a normal eye. This information allows us to calculate $\alpha = \arctan(d/a)$: $13° \, 05' < \alpha < 18° \, 54'$; see Raynaud, *L'Hypothèse d'Oxford*, pp. 132–150.

[6]Filippo Camerota, "Brunelleschi's panels," *The 4th International Laboratory for the History of Science*, Florence, 25 May 2001 and personal communication; *Idem*, "L'esperienza di Brunelleschi," *Nel segno di Masaccio*, Florence, 2001, pp. 32–33: "Ma date le dimensioni, non consentiva di vedere tutto il dipinto, bensì solo una porzione piuttosto limitata della facciata del Battistero" [that is, nothing else than the door].

[7]Raynaud, *L'Hypothèse d'Oxford*, pp. 73–75.

Secondly, around 1461 Filarete wrote in his treatise on architecture, "I *believe* this is the way that Pippo di Ser Brunellesco found this perspective, which had not been used before,"[8] a declaration that must be taken for what it is worth, as a statement of belief rather than an assertion of fact.

Finally, around 1480 Manetti asserted that: "[Brunelleschi] himself put into practice what painters today call perspective, because it is part of that science [i.e. optics],"[9] but this claim was based on an inappropriate interpolation of the text, and he makes no mention of an "inaugural experiment" nor does he provide a method that would permit the reconstruction of his perspective.

None of these references can be regarded as unambiguous and beyond them, the rest remains conjecture. It is necessary therefore to retain a more nuanced picture of the contribution of Brunelleschi; his role in the development of perspective is in fact quite obscure.

2.1.1.1 Leon Battista Alberti

In *De pictura*, Leon Battista Alberti (1404–1472) sets out what is generally recognized to be the first codified procedure for the representation of perspective. Even today his method is often qualified as *costruzione legittima*, a term that gained wide currency thanks to Erwin Panofsky, who wrote: "Trecento pictures after the Lorenzetti became, so to speak, progressively more false, until around 1420, when *costruzione legittima* was (as we may well say) invented."[10] The expression is replete with meaning, because it implies the existence of a law for the representation of space that is universally true. As a consequence, it imposes the notion of a unified vision of perspective that formed at the beginning of the Quattrocento and still holds today. And yet any law, to be legitimate, must meet two conditions: it has to be based on a rational order, and it must be applied. Let us examine these two points.

With regard to the foundations of the rule of perspective, on re-reading *De pictura* it becomes clear that Alberti's only intention in this text is to describe a series of *empirical* operations. He makes no attempt to justify these operations, either in terms of their correspondence to reality (perspective as the tracing of a visual experience) or their logical consistency (perspective as a system whose validity could be demonstrated).[11] The approach adopted by Alberti was strictly

[8]"Credo che Pippo di Ser Brunellesco trovasse questa prospettiva, la quale per altri tempi non s'era usata," Antonio Averlino detto Il Filarete, *Trattato di architettura*, eds. A.M. Grassi and L. Finoli, Milano, 1972, p. 653.

[9]"Misse innatto luj propio quello che dipintorj oggi dicono prospettiua perche ella e una parte di quella scienza…," Manetti, *Vita*, p. 43.

[10]Erwin Panofsky, "Die Perspektive als symbolische Form," *Vorträge der Bibliothek Warburg* 4 (1924/5): 258–331, *Perspective as Symbolic*, New York, 1991, p. 62.

[11]This question would not be raised in studies on perspective until much later. In 1585 Giovanni Battista Benedetti demonstrated that Alberti's construction was correct; Judith V. Field, "Giovanni

procedural, and the rational foundations for a *costruzione legittima* cannot be deduced from his text.

As for the eventual application of this rule, two facts must be pointed out. First, the study of a large body of perspective paintings from the Quattrocento shows that artists utilized various approaches in drawing their perspectives that were frequently erroneous, and did not follow the principles laid out by Alberti.[12] Secondly, recent research has shown that the use of the expression *costruzione legittima* to describe the pictorial representations of the Renaissance is in reality an anachronism. Not finding any trace of this term in texts from the Quattrocento, scholars initially believed that its first appearance could be identified in a treatise on perspective published by Pietro Accolti in 1625.[13] But in terms of occurrences this constitutes an approximation, because Accolti qualified as legitimate only the "planes" or "operations" that contribute to the construction of a perspective.[14] Only recently has it been discovered that *costruzione legittima* was in fact translated from the German term *legitime Verfahren*, an interpolation by Heinrich Ludwig, who employed it for the first time in 1882 in his edition of Leonardo da Vinci's *Trattato della pittura*. The expression was then taken up by Winterberg (1899), Kern (1915), and Panofsky (1924), with the consequences that we now know.[15] One cannot therefore liken *costruzione legittima* to a rule that was "applied" by Alberti's contemporaries.

Hence, as with Brunelleschi it is necessary to draw a more nuanced picture of the contribution of Alberti to the development of linear perspective. Three points emerge regarding the actual meaning that should be ascribed to the expression that

(Footnote 11 continued)

Battista Benedetti on the mathematics of linear perspective," *Journal of the Warburg and Courtauld Institutes* 48 (1985): 71–99.

[12]"There is not a single verified example of a painting done with the 'construzione legittima'," James Elkins, *The Poetics of Perspective*, Ithaca, 1994, p. 86: "We should note that in a large number of Renaissance paintings the perspective turns out to be incorrect in mathematical terms," Judith V. Field, "Alberti, the Abacus and Piero della Francesca's proof of perspective," p. 72; Raynaud, *L'Hypothèse d'Oxford*, pp. 49–120.

[13]Luigi Vagnetti, "La posizione di Filippo Brunelleschi nell'invenzione della prospettiva lineare," *Filippo Brunelleschi. La sua opera e il suo tempo*, Florence, 1980, p. 305; Field, "Alberti, the Abacus and Piero della Francesca's proof," p. 69.

[14]Pietro Accolti, *Lo inganno degl' occhi*, Firenze, 1625, pp. 19, 57–58: "… to find, by means of their *legitimate* respective plans, the true perspective design… among the two previous operations, only this can be *legitimate*, in which we estimate ourselves to be deceived/trouare, mediante le loro *legittime* respettiue Piante, il proprio, e vero prospettiuo disegno… delle due sudette operazioni, questa sola poter essere *legittima*, nel che noi stimiamo ingannarsi.".

[15]Leonardo da Vinci, *Das Buch von Malerei*, ed. H. Ludwig, Wien, 1882, vol. 3, p. 177. In particular, consider Pietro Roccasecca, "Punti di vista non punto di fuga," *Invarianti* 33/99 (1999): 41–49, who writes: "Finally, we would like to point out that the existence of a discussion of different procedures… dispels the myth that perspective in the first half of the Quattrocento was the work of a lonely hero/Vorremmo infine segnalare che l'esistenza di una discussione tra diverse procedure… sfata il mito che la prospettiva della prima metà del Quattrocento sia l'opera di un eroe solitario," p. 48. See also Carlo Pedretti, "Leonardo 'discepolo della sperientia'," *Nel segno di Masaccio*, Florence, 2003, p. 170.

has been used, ever since Panofsky, to describe Alberti's work: (1) *costruzione legittima* did not exist in the Quattrocento; (2) the first attempts to codify perspective emerged in the sixteenth century, as a matter of course to meet the requirements of academic teaching; and (3) the unitary conception of perspective space probably dates to no earlier than the end of the nineteenth century.

2.1.1.2 Masaccio

The third milestone in this process—the first application in a large-scale work of the laws of perspective invented by Brunelleschi and codified by Alberti—has been attributed to Tommaso di Ser Giovanni, detto Masaccio (1401–1428). The *Trinity* fresco, which was painted around 1425–1427 in the church of Santa Maria Novella in Florence, has traditionally been viewed as an exemplary application of the laws of perspective. It has formed the object of universal praise ever since the declaration by Panofsky: "… at any rate, Masaccio's *Trinity* fresco is already exactly and uniformly constructed."[16] Modern studies have led to a reassessment of his conclusion, although a handful of scholars can still be found who assert that the fresco conforms to the canons of true perspective.

Doubtful of judgments that were in reality impressions based on a simple visual examination of the work, Field, Lunardi and Settle[17] undertook the first rigorous study in which the lines of perspective in the fresco were measured in situ. They presented proof that in constructing his perspective Masaccio introduced some serious accidental errors, beginning with the coffered barrel vault whose receding lines converge only approximately toward a central vanishing point. In addition, the method used to convey the perspective view of the abacuses above the corner columns was found to be faulty. Finally, the positioning of the longitudinal ribs of the vault in relation to the construction lines presents numerous irregularities. The authors concluded that Masaccio probably drew on the conceptions of Brunelleschi, Alberti and Donatello, but his work does not possess the mathematical rigor that some have ascribed to it.

Other studies of the fresco conducted using photogrammetry and computer reconstructions[18] have yielded varying results. Based on the analysis of a photogrammetric outline, we recently showed that this fresco contains not only accidental errors, as pointed out by Field, Lunardi and Settle, but also fundamental *errors of principle* in the method of reduction applied. Many studies have attempted to determine where the viewer was supposed to stand and look at the picture, based on the assumption that the perspective line was correctly drawn. Such an exercise can be contemplated because, once the depth scale has been calculated, there is a

[16]Panofsky, *Perspective as Symbolic Form*, p. 62.

[17]Judith V. Field, Roberto Lunardi, and Thomas B. Settle, "The perspective scheme of Masaccio's Trinity fresco," *Nuncius* 4 (1989): 31–118.

[18]Volker Hoffmann, "Masaccios Trinitätsfresko: Die perspektivkonstruktion und ihr Entwurfsverfahren," *Mitteilungen des Kunsthistorischen Institutes in Florenz* 40 (1996): 42–77.

single vantage point from which the painting should ideally be seen. An anomaly that ought to have raised doubts much earlier is that among fifteen studies conducted between 1913 and 1997, the calculated distance between the viewer and the painting varied from 210.5 to 894.2 cm.[19] How can such a dispersion of values be explained? If the fresco by Masaccio adhered to the rules of linear perspective, these values should have diverged only slightly, following a normal distribution and being solely attributable to errors in the graphic reconstruction. Such is not the case, which leads to the conclusion that the rules of linear perspective were not strictly applied in the *Trinity* fresco. The error has since been identified in the receding lines of the coffered vault, the only part of the fresco that allows an evaluation of the reduction method used. Between the perspective drawn by Masaccio and the theoretically correct one there is a disparity of more than 12 cm in the positioning of the orthogonals corresponding to the ribs of the vault. None of this can be ascribed to an accidental error or to an "adjustment" in the line for purely aesthetic reasons; it reflects instead an indifference to the principles of perspective reduction.

The conclusions that can be drawn at this point are: (1) the *Trinity* fresco does not follow the rules of linear perspective; (2) it does not represent an application of *costruzione legittima*; and (3) the search for the ideal vantage point, which only makes sense in the case of a linear perspective, is therefore destined to remain an exercise without a solution.[20]

The data as reviewed above regarding the work of Brunelleschi, Alberti and Masaccio (and many other contributions of the same nature) expose the fact that the modern interpretation of the development of perspective is founded, in the final analysis, on *ideological premises*.[21] The received version according to which linear perspective was invented by Brunelleschi based on his initial experiment and codified by means of *costruzione legittima* into a set of laws by Alberti, which were then applied by Masaccio, all share a point in common: they accentuate the thesis of a revolution (with its attendant components) that led to a complete change in the method of representing three-dimensional space.

The divergence between the historical evidence and the modern reconstruction of this process offers a case study in the sociology of knowledge, raising in a fresh context the question of the nature of beliefs and why they are adhered to. Many factors appear to be responsible for the firm attachment to the notion that perspective was codified and applied *ab origine* in a literal fashion:

– The "effect of authority," which has long conditioned the reading of Vasari's *Lives of the Most Excellent Painters, Sculptors, and Architects*. But how much

[19]Hoffmann, "Masaccios Trinitätsfresko," p. 75.

[20]See Chap. 4.

[21]If we set aside all adventitious hypotheses, there remain two possible inaugural dates: from a practical point of view, the first correct perspective was the fresco in Assisi *Christ among the Doctors*, attributed to the atelier of Giotto (ca. 1315); the first theoretical treatment was the demonstration of perspective in Piero della Francesca's *De prospectiva pingendi* (ca. 1475).

evidential weight can be given to a work that was written to glorify the reign of the Medici?

– The quest to define the pillars of Western civilization, which has led us to identify (and, subconsciously, to venerate) the key milestones in its evolution;
– Economic interests in the art world, which may inadvertently be maintaining mythologized or hagiographic versions of the history of art.

To these may be added factors specific to the Italian context:

– The historic rivalry between Florence and Rome for the title of cultural capital of Italy, leading to centuries of contention between the two cities;
– A separate ministry for the conservation of Italy's cultural heritage was not established until 1998, before which time the *Soprintendenze per i beni culturali ed ambientali* were subsumed under the Ministry of Tourism.

These are all elements that could help to explain the persistence of "the myth of perspective" in the face of rational arguments and obvious lacunae in the chain of evidence. The abiding belief in the centrality of the Renaissance has been ensured up to now by a complex set of disposition and communication effects, in particular what sociologists refer to as "relay effects."

2.2 Perspective and Knowledge

Once it is allowed that the unitary vision of perspective is in fact a myth, it remains to explain the many variations in the conception and techniques of perspective that emerged during the course of two centuries. I will argue that these variations can be linked to the specific notions of optics and geometry available to the individuals concerned.

2.2.1 Geometry and the Perspective of the Circle

To show how a knowledge of geometry could influence conceptions of perspective, it suffices to consider the case of the perspective of the circle. It is a simple matter to extract from Apollonius of Perga's *Conics* the property that the perspective view of the circle is an ellipse (proposition I, 13).[22] Nevertheless, the theory of conic

[22]*Apollonii Pergaei quae graece extant cum commentariis antiquis*, t. I–II, ed. J.L. Heiberg, Leipzig, 1891–3. After showing in Book I, prop. 9, that no oblique section of a cone is a circle, Apollonius sets out the three cases of the parabola (prop. 11), the hyperbola (prop. 12) and the ellipse (prop. 13). He then demonstrates that the projection of a circle onto a plane that is not parallel to the circle will be an ellipse or a conic section. Exact copies of the figure on which he based his argument were used by Commandino, Benedetti and others in the sixteenth and seventeenth centuries.

sections would not be applied systematically to the problem of perspective until the late sixteenth and early seventeenth centuries with the work of Commandino, Benedetti, Guidobaldo del Monte and Aguilonius (Fig. 2.1).[23]

This explains the proliferation of empirical methods for depicting the circle in perspective before this date—from gibbous to ovoid figures, from an oval with four centers to a rectangle flanked by two semicircles, etc. Let us study the differences between those who adopted such approximations and those who sought to draw a true ellipse.

The application of the ellipse as the perspective view of a circle seems to have been unknown to Masaccio; one need only examine the astragals of the capitals in the *Trinity*. Lorenzo Ghiberti was equally unaware of this geometrical notion and in the bas-relief *Joseph* on the Florence Baptistery's Gates of Paradise he used a semicircle (*EG*) and two gibbous forms (*AB* and *CD*) to create an ellipse (Fig. 2.2).

The case of Albrecht Dürer is more atypical, because he correctly identified the ellipse (*die linie ellipsis*) but gave it an ovoid shape.[24] In contrast, one finds the true ellipse in certain works by Piero della Francesca[25] (*Chalice 1758A*), in the notes of Leonardo da Vinci (*Ring*, *Codex Atlanticus*, 263ra) and in the circle of Antonio da Sangallo (*Mazzocchi 830A, 831A, 832A*) (Fig. 2.3).

What do these differences stem from? The response would not be the same for all artists. Let us attempt to differentiate between them.

Piero della Francesca (1420–1492) can be distinguished from his predecessors because of his mathematical approach to perspective; it was he who first demonstrated that a perspective could be constructed based on the distance point using

[23]In his edition of *Claudii Ptolomaei liber de analemnate*, Rome, 1562, Francesco Commandino studied the projection of the circle and showed that the perspective view often appeared in the form of an ellipse. Giovanni Battista Benedetti, *Diversarum speculationum mathematicarum et physicarum liber*, Turin, 1585, proved the theorem that the intersection of a cone by two parallel planes will produce similar conic sections. Guidobaldo del Monte, *Perspectivae libri sex*, Pesaro, 1600, studied the projection of a circle on an inclined plane and the similar problem of the figure that casts the shadow of a sphere on a plane. Franciscus Aguilonius, *Opticorum libri sex*, Anvers, 1613, studied the shadow of the sphere and determined geometrically the position of the axes of the elliptical projection of a circle.

[24]"The Ancients showed that one could cut a cone in three ways and obtain thusly three different sections… The erudite called the first section an ellipse: it cut the cone obliquely and drew nothing from the base of the cone," Albrecht Dürer, *Géométrie*, ed. J. Peiffer, Paris, 1995, p. 174. Dürer then described point by point the construction of the "egg line or ellipse" (sic) by means of a double projection, that is, by transferring onto its face the points of intersection recorded on the plane and profile.

[25]*Mazzocchi* 1756A, 1757A, 1758A has traditionally been attributed to Paolo Uccello, but there is no evidence to support this apart from an inconclusive reference in Giorgio Vasari's *Vite de' più eccellenti pittori,* stating that he possessed "… a mazzocchio drawn only with lines, so beautiful that nothing save the patience of Paolo could have executed it/un mazzocchio tirato con linee sole, tanto bello, che altro che la pacienza di Paulo non lo avrebbe condotto" (sic).

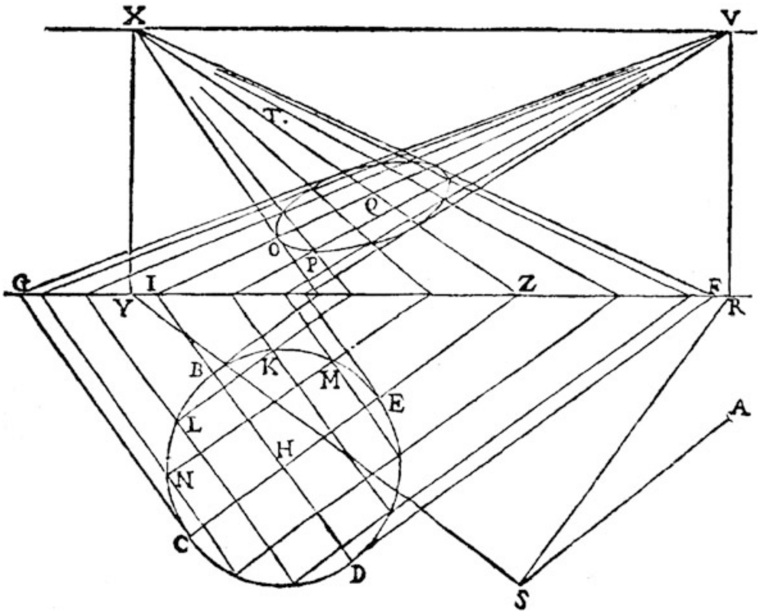

Fig. 2.1 Perspective of the circle, Guidobaldo del Monte, *Perspectivae libri sex*, Pesaro, 1600, IV, 24, p. 217

similar triangles. Only three treatises by Piero della Francesca have come down to us: *Trattato d'abaco*, *Libellus de quinque corporibus regularibus* and *De prospectiva pingendi*.[26] *Libellus* of course introduces the five regular polyhedra—the tetrahedron, the cube, the octahedron, the icosahedron, and the dodecahedron—but this material only takes up Book I. Book III also treats problems in stereometry (how to measure the volumes of solid figures), including sixteen exercises involving the sphere and the cone. These assume a knowledge of conics, which

[26]Piero della Francesca, *Trattato d'abaco*, ed. G. Arrighi, Pisa, 1970; *idem*, *De prospectiva pingendi*, ed. Nicco-Fasola, Florence, 1984; *idem*, *Libellus de quinque corporibus regularibus*, ed. F. P. di Teodoro, Florence, 1995. On Piero della Francesca's mathematics, see Marshall Clagett, *Archimedes in the Middle Ages*, vol. 3, Philadelphia, 1978; Menso Folkerts, "Piero della Francesca and Euclid," *Piero della Francesca tra arte e scienza*, eds. M. Dalai Emiliani and P. Curzi, Venice, 1996, pp. 293–312; Judith V. Field, *Piero della Francesca, A Mathematician's Art*, New Haven, Yale University Press, 2005; Pietro Roccasecca, "Dalla prospettiva dei pittori alla prospettiva dei matematici," *Enciclopedia italiana di scienze, lettere ed arti. Il Contributo italiano alla storia del pensiero*, Roma, Istituto della Enciclopedia italiana, 2013, pp. 137–144.

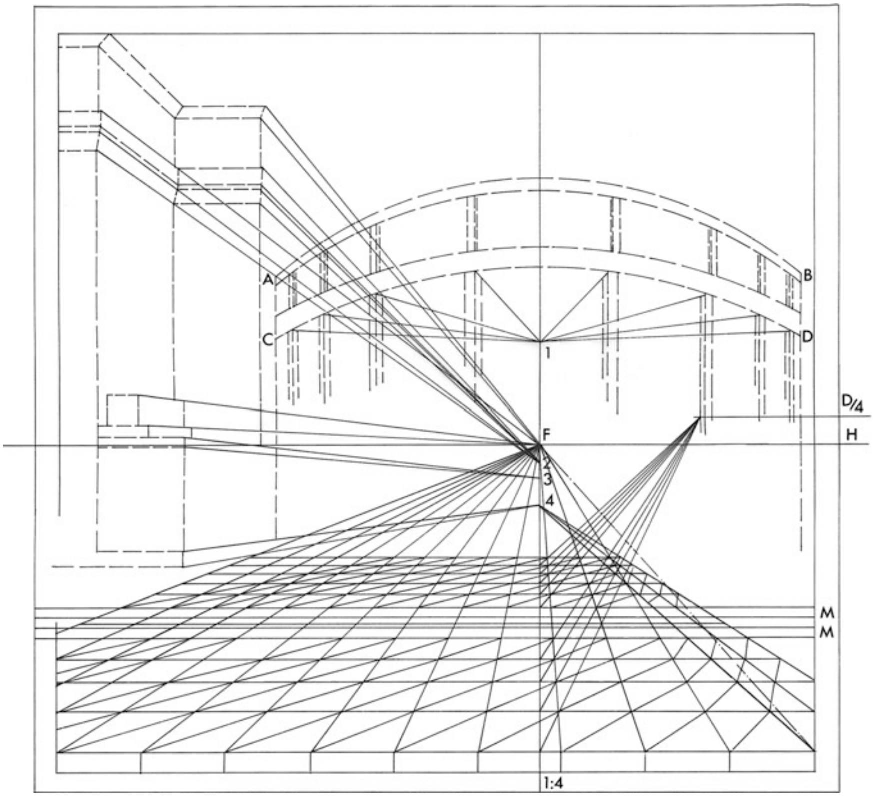

Fig. 2.2 The circle depicted as a gibbous figure, Lorenzo Ghiberti, *Storia di Giuseppe,* 1425–52 (Firenze, Museo dell'Opera di Santa Maria del Fiore), author's reconstruction

Piero della Francesca must have possessed at least through Archimedes' work *On Conoids and Spheroids*, for it is known that he owned a copy of the treatise (which subsequently passed into the possession of the dukes of Urbino).[27]

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[27]*Archimedis de konoidalibus et speroidibus figuris* (Urbinato latino 261, fol. 44v–45r). Archimedes provides definitions at the beginning of his treatise that are comparable to those of Apollonius: "If a cone be cut by a plane meeting all the generators of the cone, the section will be either a circle or an ellipse… And if a cylinder be cut by two parallel planes meeting all the generators of the cylinder, the sections will be either circles or ellipses," *De la sphère et du cylindre, La mesure du cercle, Sur les conoïdes et les sphéroïdes*, ed. Ch. Mugler, Paris, 1970, p. 158. He then determined the area of the ellipse by comparing it to the area of a circle with the same diameter as the long axis of the eclipse. The ratio between the two areas would be equal to the ratio between the rectangle circumscribing the ellipse and the square circumscribing the circle or, in what comes to the same thing, as the ratio of the short axis of the ellipse to the diameter of the circle, pp. 166–170. The *Divina proportione* (1509) by Fra' Luca Pacioli, a part of which was copied from *Libellus*, also addresses the problem of the ellipse: if one takes a square and transforms it into a rectangle of the same length, whose height is equal to the diagonal of the square,

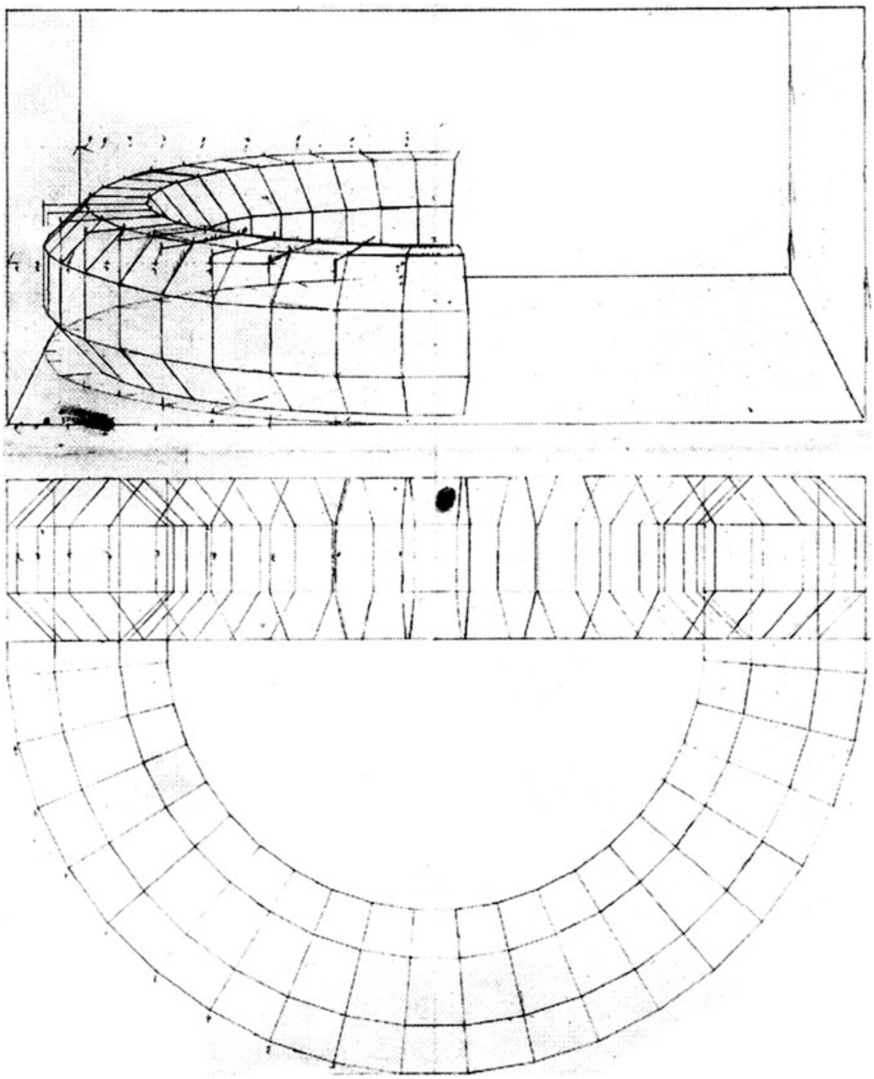

Fig. 2.3 The circle represented as an ellipse, Cerchia di Sangallo, *drawing of a mazzocchio* (Florence, Gabinetto Disegni e Stampe degli Uffizi), inv. 832A, from Christoph L. Frommel and Nicholas Adams, *the architectural drawings of Antonio Da Sangallo the younger and his circle*, Cambridge, MIT Press, 1994, vol. I, p. 150

(Footnote 27 continued)

every point of the circle inscribed in this square will correspond to a point on the ellipse that is inscribed in the rectangle. In this way Fra' Luca Pacioli obtained the "*proportioned circle/circulo proportionato*". The same method was adopted by Dürer, who did not, however, link it to the drawing of an ellipse, Dürer, *Géométrie*, p. 70.

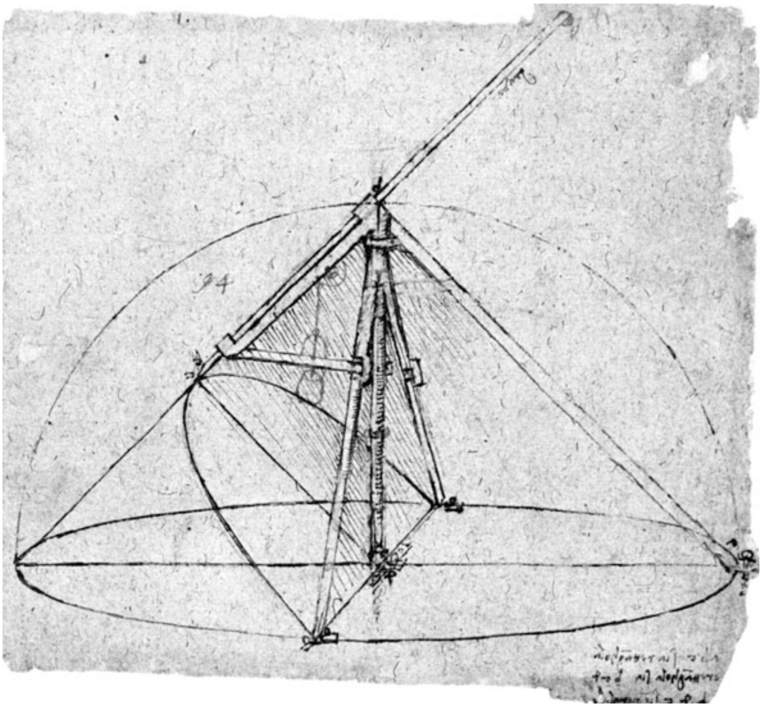

Fig. 2.4 Leonardo da Vinci, Parabolograph, 1478–1518 (Milan, Biblioteca Ambrosiana, *Codex Atlanticus*, fol. 1093r, ed. Hoepli, Florence, 1894, olim 394ra)

Leonardo da Vinci (1452–1519) understood that the ellipse must be used to represent a circle in perspective. He sometimes resorted to the discontinuous drawing of the ellipse by projecting horizontal chords obliquely across a circle and transposing the lengths of these chords onto perpendiculars raised at each point of intersection with the oblique line.[28] But his perspective view of the circle also sprang from his knowledge of conic sections, to which he devoted several notes in the *Codex Arundel*. Two instruments designed by him for the continuous drawing of a conic section should also be mentioned. The first was an ellipsograph (*seste da far l'ovato*), which is known to us through a drawing by Benvenuto della Volpaia preserved in the Biblioteca Marciana in Venice.[29] The other was a parabolograph, a sketch of which appears in the *Codex Atlanticus*[30] (fol. 349ra, Fig. 2.4).

[28]*Codex atlanticus*, fol. 115rb (ca. 1510), Carlo Pedretti, *Léonard de Vinci architecte*, Paris, 1983, p. 302.

[29]Venice, Biblioteca Marciana, MS. It. 5363, fol. 18r.

[30]Pierre Sergescu, "Léonard de Vinci et les mathématiques," *Léonard de Vinci et l'expérience scientifique*, Paris, 1952, pp. 73–88; Otto Kurz, "Dürer, Leonardo and the invention of the ellipsograph," *Raccolta vinciana* 18 (1960): 15–25; Gino Arrighi, "Il 'compasso ovale invention di

On comparison one notes that these are in fact exact equivalents to mathematical instruments described by al-Qūhī and al-Sijzī and by their twelfth-century successors al-Baghdādī and al-Ḥusayn. In particular, Leonardo's ellipsograph exactly corresponds to al-Sijzī's description of "the perfect compass."[31]

The *mazzocchi* associated with Antonio da Sangallo and his circle provide another interesting example of the application of geometric concepts to problems of perspective. After detailed study of the material traces of these drawings, certain historians have formulated the hypothesis that he used a method based on conic sections. Their thesis is supported by a drawing (830A) from the *Gabinetto Disegni e Stampe* of the Uffizi in which, to trace the outline of his *mazzocchio*, Sangallo derives an ellipse from the section of a conical pyramid composed of thirty-two faces (an admissible approximation of the cone). But the architect's knowledge of conics did not stop here, because drawing 1102A presents an ellipsograph (*sesto per fare avovati*) that is equivalent in every way to the one utilized by Leonardo.[32]

The most striking trait in the work on the perspective representation of the circle conducted by Piero della Francesca, Leonardo Da Vinci, and Antonio Sangallo is that they all derived correct projections from the theory of conic sections, geometric notions which their contemporaries were either ignorant of (Masaccio and Ghiberti) or had misunderstood (Dürer). This demonstrates clearly how geometric concepts could be applied to resolve problems of perspective.

(Footnote 30 continued)

Michiel Agnelo' dal Cod. L.IV.10 della Biblioteca degl' Intronati di Sienna," *Le Machine* 1 (1968): 103–106; Paul L. Rose, "Renaissance Italian methods of drawing the ellipse and related curves," *Physis* 12 (1970): 371–404; Carlo Pedretti, *Studi vinciani*, Genève, 1957; *Idem, Léonard de Vinci architecte*, p. 336; *idem*, "Leonardo discepolo della sperientia," pp. 184–185; Pedretti believed that Leonardo based his knowledge of conic sections on his reading of *De rebus expetentis* by Giorgio Valla (1501). This was a possible source for the notes in *Codex Atlanticus*, fol. 394va, dated 1513–1514. All the same, an identical diagram dated ca. 1480 appears on fol. 32ra, with the note "a youthful study". Leonardo therefore drew on an earlier source that still remains to be identified.

[31] Roshdi Rashed, "Al-Qūhī et al.-Sijzī: sur le compas parfait et le tracé continu des sections coniques," *Arabic Sciences and Philosophy* 13 (2003): 9–43. The close parallels that exist between the *seste da fare l'ouato* of Leonardo and al-Sijzī's compass cast doubt on the thesis that the ellipsograph was an Italian invention. A borrowing by way of a Latin translation constitutes a credible hypothesis, Raynaud, "Le tracé continu des sections coniques à la Renaissance. Applications optico-perspectives, héritage de la tradition mathématique arabe," *Arabic Sciences and Philosophy* 17 (2007): 299–345.

[32] Pietro Roccasecca, "Tra Paolo Uccello e la cerchia sangallesca," in *La prospettiva. Fondamenti teorici ed esperienze figurative dall' antichità al mondo moderno,* ed. Rocco Sinisgalli, Fiesole, 1998, pp. 133–144. A direct transcription from the Arabic cannot be excluded: Antonio da Sangallo is known to have made a drawing of an astrolabe, "Strolabio egyptizio daritto e da riverso" (Cabinet of Drawings and Prints of the Uffizi 1454A) in which the divisions on the limb, mater and rete are marked in Arabic characters.

2.2.2 Optics and Binocular Vision

The preceding discussion can be reproduced point for point with regard to the influence that a knowledge of optics had on the practice of perspective.

Let us consider the case described in some texts as "two-point perspective". Such representations are similar to those with a central linear perspective, but rather than receding towards a single vanishing point, the lines converge on two vanishing points located on the same horizon. About thirty works whose perspective is based on this principle are known,[33] including *The Trial of Pietro d'Abano*, a fresco by Altichiero in the Palazzo della Ragione in Padua (ca. 1270–1280). The groins of the vault in this painting form two sets of converging lines, with the pencil on the left extending toward point F' on the right, and the pencil on the right extending toward point F on the left. The vanishing points F and F' have been correctly placed on the same horizon line (Fig. 2.5).

These perspective traces admit a priori of more than one interpretation. The lateral walls could be slightly convergent rather than parallel to each other, occasioning two sets of lines that do not meet in a single, central vanishing point.[34] If the two pencil of lines, rather than continuing towards points F and F', ended along the central axis AF, the view would be similar to the "axial perspective" interpreted by Panofsky and White in terms of a curvilinear or synthetic perspective.[35] It is also possible that Altichiero unintentionally introduced a deviation in the lines while executing the drawing, creating two artificial vanishing points that in fact can be resolved into one, which would mean that this fresco is an example of central linear perspective.[36]

Various hypotheses may be proposed to interpret this drawing in perspective and the correct one must be chosen based on credible criteria. Further on it will be shown that such two-point perspectives do not correspond to any of the most widely known forms of perspective and, even if they bear certain points of similarity to linear perspective, they could in actuality be the result of an application of *binocular vision*.

Two-point perspective was used from the end of the Duecento up to Classical times. One can even find examples from the mid-seventeenth century. The approach has attracted little attention up to now due to the prevailing belief that the rules of

[33]See for instance: Giusto de' Menabuoi, *Christ among the Doctors* (1376–1378), Stefano di Sant'Agnese, *Madonna with Child* (ca. 1390), Taddeo di Bartolo, *The Last Supper* (1394–1401), Lorenzo Monaco, *Adoration of the Magi* (ca. 1421), Lorenzo Ghiberti, *Christ among the Doctors* (ca. 1415), Niccolò di Pietro, *St. Benedict Exorcising a Monk* (ca. 1420), Gentile da Fabriano, *The Crippled and the Sick Cured at the Tomb of St. Nicholas* (1425), Giovanni di Ugolino, *Madonna with Child* (1436). A corpus of about thirty works displaying two-point perspective was identified for study; the process by which they were selected is described in Chap. 8 and the results of the analysis are discussed in subsequent chapters.

[34]This hypothesis is discussed in detail in Chap. 8.

[35]See Chaps. 9 and 10.

[36]See Chap. 8.

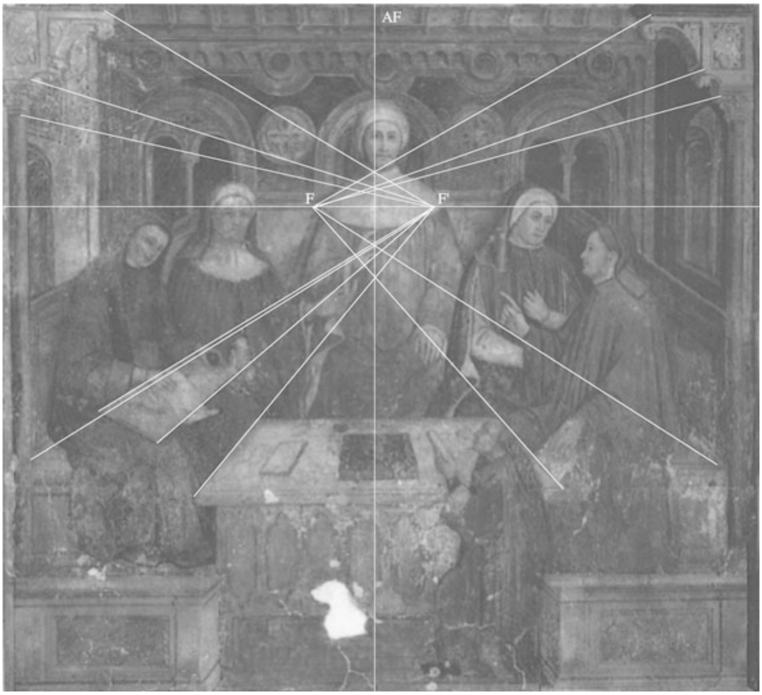

Fig. 2.5 Perspective drawing of Altichiero's *Trial of Pietro d'Abano*, ca. 1370–80 (Padua, Palazzo della Ragione), author's reconstruction after Giampiero Bozzolato, *Il Palazzo della Ragione*, Roma, 1992, plate XLIII

linear perspective were codified and rigorously followed from the Quattrocento onward. And yet, contrary to all expectations, references to two-point perspective—which has been retroactively judged to be quite heterodox—can be found even at a relatively late date. Vignola and Danti, for example, in 1583 refuted the notion that a perspective could be constructed based on two vanishing points, arguing that because visual sensations are fused to the optic chiasma they produce a single image, which implies a single vanishing point.[37] The very fact that these authors felt it necessary to devote a long critique to the use of two-point perspective shows that the construction was still in widespread use around 1583. However heterodox they may have become, the foundations of two-point perspective were no less rational than those of single-point perspective and deserve to be examined more closely.

The text by the architect Vignola and the commentary provided by the mathematician Danti furnish in this regard a promising path of investigation which this book intends to pursue: the two-point construction of perspective could bear points

[37] *Le Due Regole della prospettiva pratica di M. Iacomo Barozzi da Vignola,* Roma, 1583, pp. 53–54.

of affinity with the principles of binocular vision (*hauendo l'huomo due occhi …*). In fact the postulate of monocular vision imposed by linear perspective was regularly violated, both *before and after* its presumed invention by Brunelleschi.[38] How can the fundamental principles of two-point perspective be retraced? One strategy that will be adopted here is to systematically compare knowledge of the science of optics with the perspective practices of the period. Ghiberti, for example, who utilized the perspective construction based on two principal vanishing points (Appendix B, No. 25), provides an invaluable first-hand source of information on the knowledge of optics among perspectivists in fifteenth-century Italy. His *Commentario terzo* is a compilation of the most widely read treatises of the period, and includes the works of Ibn al-Haytham (known in the West as Alhacen), Bacon, Pecham and (to a lesser degree) Witelo.[39] In this compilation Ghiberti reproduces Ibn al-Haytham's chapter on binocular vision *almost in its entirety*. Following the Arab scientist's exposition[40] of the conditions for the fusion of images, Ghiberti utilized a similar experimental set-up to examine the case of diplopia, and came to similar conclusions.[41] As we will discover, the textual sources of the period provide all of the necessary elements to construct a perspective with two vanishing points. What follows is a question that will constitute a central theme in this book: Why did Ibn al-Haytham and Egnatio Danti draw such different conclusions regarding how binocular vision operates?

This difference appears to be the result of the assimilation of different sets of knowledge. The response to the question of binocular vision and how two images come to be fused into one is not the same if the problem is approached by way of optics (as in the case of Ibn al-Haytham and his Latin successors) or anatomy (as with Egnatio Danti, a mathematician who was in this case reasoning as an anatomist). The arguments in support of the *constant* unification of visual sensations stem directly from anatomical studies of the optic tract—the *chiasma* or *decussatio*

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[38]Although the painting by Brunelleschi has been lost, some information can be gleaned from Manetti, who wrote in his biography: "It is necessary that the painter postulate beforehand a single point from which his painting must be viewed/Il dipintore bisognia che presuponga *un luogo solo* d'onde s'a a uedere la sua dipintura," Manetti, *Vita di Filippo di Ser Brunelleschi*, fol. 207v. The passages on the monocular postulate are quoted in Chap. 1.

[39]The most comprehensive study to date of the sources is provided by Klaus Bergdolt, *Der dritte Kommentar Lorenzo Ghibertis*, Weinheim, 1988. See also Raynaud, "Le fonti ottiche di Lorenzo Ghiberti," pp. 79–81.

[40]Abdelhamid I. Sabra, *The Optics of Ibn al-Haytham*, Books 1–3: *On Direct Vision*, London, 1989, vol. 1, pp. 237–240.

[41]"All those things we have described can be demonstrated by experiment, and once the proof has been seen, take a board of light wood… When therefore the experimenter has understood these lines and individuals [the wax sticks], in fact if there is not one line down the middle [of the board], but two appear… then the one and the other will appear to be doubled/Tutte quelle cose noi abbiamo dette si possono sperimentare, e veduta la certificazione tragassi una tavola del legno leggiero… Quando adunque lo sperimentatore arà compreso queste linee e gli individui, veramente non è se non è una linea nel mezzo, ma paiono due… allora l'uno e l'altro apparirano due," Lorenzo Ghiberti, *I Commentari*, ed. O. Morisani, Naples, 1947, pp. 144–147; Bergdolt, *Der dritte Kommentar*, p. 330.

—whereas Ibn al-Haytham and his Latin commentators held the disparate images to be normal and subscribed to the thesis of a *conditional* fusion of images depending on their degree of disparity. As heirs to the geometric school of optics, the early perspectivists clearly chose to ignore the teachings of the anatomists.[42] This shows that different pieces of optical knowledge could lead to different conceptions of perspective space.

2.3 Conclusion

If one excludes a handful of general principles such as the law of the reduction in size, a unitary conception of perspective does not exist. Perspective is an open system reflecting the optical and geometric knowledge available at a given time. This observation is not without importance to the socio-historical study of systems of representation. An explanation for the birth of perspective has long been sought in social factors such as the role played by the Florentine bourgeoisie, the rivalry between Italian city-states, the humanist movement, and so on. However, *stricto* sensu none of these factors is capable of providing a satisfactory explanation for the development of perspective during the Renaissance. The rise of the bourgeoisie or the competition between city-states could have contributed to the development of the arts (through the bias of the art patron or of the type of work commissioned), but it does not explain why artists focused their attention on perspective rather than some other mode of representation. Likewise, the chronology of humanism and the rediscovery of the texts of antiquity is not consonant with the facts regarding the development of perspective. The study of the mathematical texts of the Greeks did not begin until relatively late, in the sixteenth century.

An analysis of the textual parallels in the treatises of the Quattrocento demonstrates that the optical-geometric sources most often cited were not the mathematicians of ancient Greece but those of the Middle Ages; in general Euclid was known only through medieval commentaries. In comparison to the traditional theses regarding the invention of perspective, *explaining such a disruptive innovation in terms of the mobilization of the resources most pertinent to the development of this innovation* might appear to be somewhat bland. In point of fact, however, it opens up fresh paths of investigation and raises fewer difficulties because it focuses directly on the objective phenomenon to be explained, that is, on perspective rather than on pictorial representation or the arts generally. It therefore provides a simple (and verifiable) explanation for the variety of forms observed (for example, the perspective view of a circle might be rendered as an ellipse or a gibbous figure depending on the optical-geometric knowledge available in a certain milieu).

[42]See Chap. 5.

The above reflections have led to a research study that lies at the intersection between sociology and the history of the sciences, and whose objectives may be summarized as follows:[43]

1. To understand the processes involved in the *appropriation of knowledge*. This requires in particular that one pay greater attention to what the *errors* committed by perspectivists can reveal about the development of that science. Such errors often denoted a misunderstanding of the problem, or of the time that might be required to master it. This is why a considerable number of false perspectives in Renaissance art have been identified.
2. To assess the *availability of knowledge* at a given time, beginning with a study of the networks through which knowledge spread. It is a fact that not all knowledge is equally accessible and studying the inhomogeneous distribution of resources as a function of distance and social milieu may help to clarify the cognitive bases on which a disruptive innovation may have been conceived and thus the relationship between the representation of perspective and its optical-geometrical foundations.

All of this leads to the conclusion that *no specific and unitary conception* of perspective space exists, precisely because so many variations can be found.

If one attempts to retrace the shared origins of the many and diverse solutions to the problem of perspective that were being explored from the late Duecento onward, two main blocks of knowledge can be identified that made possible the gradual emergence of the perspective system:

– Euclidean geometry, which was rediscovered in Europe in the twelfth century through translations of the Greek mathematician's work from the Arabic (the works of Adelard of Bath, Robert of Chester, Gerard of Cremona, etc.)[44] and the keen interest in practical geometry (for example, Abraham bar Ḥiyya Savasorda's *Liber embadorum*, Leonardo Fibonacci's *Practica geometrie*, and John of Muris's *De arte mensurandi*);[45]
– the optics of Alhacen, which was introduced into Latin Europe through a translation by the school of Gerard of Cremona, and in parallel the optics of the Latin scholars Bacon, Pecham and Witelo.[46]

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[43]These issues are addressed in *L'oeuvre et l'artiste à l'épreuve de la perspective*, eds. M. Dalai Emiliani, M. Cojannot Le Blanc, and P. Dubourg Glatigny, Rome, 2006.

[44]See the works of Hubert L.L. Busard.

[45]Maximilian Curze, *Der Liber Embadorum des Abraham bar Chijja Savasorda in der Übersetzung des Plato von Tivoli*, Leipzig, 1902; Baldassare Boncompagni, *Leonardi Pisani Practica geometriae*, Roma, 1862; Hubert L.L. Busard, *Johannes de Muris. De Arte mensurandi*, Stuttgart, 1998.

[46]Sabra, *The Optics of Ibn al-Haytham*; David C. Lindberg, *Roger Bacon and the Origins of Perspectiva in the Middle Ages*, Oxford, 1996; *Idem*, *John Pecham and the Science of Optics*, Madison, 1970; *Opticae thesaurus… Item Vitellonis Thuringopoloni libri X*, New York, 1972.

This body of optical-geometric knowledge did not *immediately* coalesce into a definitive conception, which seems to have been the result on the one hand of the gradual acquisition of these texts and on the other to the codification brought about by the academic teaching of linear perspective.[47] As a result of these factors, it is improbable that perspective contributed in any way to the modern conception of space as infinite, homogeneous, and isotropic.[48]

If therefore, despite what has been shown by recent and more rigorous analyses, the present conception of perspective—which is based on a mistaken interpretation of the contributions of Brunelleschi, Alberti and Masaccio and completely ignores the alternatives to linear perspective that were in widespread use until the Cinquecento—remains so profoundly reified, it will be necessary first of all to examine the errors in perspective that can be observed in the works of the period, in order to be able to identify, characterize and classify these deviations in relation to the canons of linear perspective.

[47]The *Accademia*—the seat *par excellence* for the codification of perspective—reduced the plethora of uncoordinated initiatives to a single method. Therefore, the problem is not to justify the existence of heterodox practices lying on the margins of the "pure type" of linear perspective, but rather to explain the procedures by which distinct conceptions were gradually separated out and evaluated in order to allow the rise of a single orthodox conception.

[48]In *Perspective as Symbolic Form*, p. 70, Panofsky proposed the thesis that a conception of space as "infinite, homogenous and isotropic" emerged during the Renaissance. This thesis was supported by successive scholars, such as Manfredo Tafuri and Rudolf Wittkower, who transposed the concept to architecture. The thesis runs up against various logical and empirical difficulties, however. (1) The type of reasoning that characterizes perspective does not consist in working within a space considered to be of unlimited extent, but in the manipulation of figures, i.e. finite bodies. With regard to the projective geometry of Desargues, Michel Chasles wrote that it consisted of an exercise in "reasoning on the properties of figures," *Aperçu historique sur l'origine et le développement des méthodes géométriques*, Bruxelles, 1837, p. 74. (2) The concept of "perspective space" itself was anachronistic in the fifteenth century because it assumed a codification that had not yet been formulated. The notion was applied to architecture by August Schmarsow at the end of the nineteenth century, and taken up again by Panofsky, Jantzen, Frey and Badt. For more on this filiation, see Roland Recht, *Le croire et le voir*, Paris, 1999, pp. 44–45.

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