Optical Theories and the Development of Linear Perspective in Fifteenth-Century Italian Renaissance Art was written by a senior majoring in History and Art History for a course entitled *Science in Intellectual History* (NASC 400), which the author took to satisfy a requirement of the General Honors program. The author tells us that the assignment eliciting this term paper was to write "on the evolution of an idea in the 'scientific' community prior to A.D. 1700." In reviewing the paper, the author identifies History, Art History, Optics, and Geometry as disciplines whose concepts, methodologies or modes of inquiry, and/or perspectives are integrated or synthesized. "I looked at how a scientific idea of applying geometry to explain optical processes led to the artistic development of one-point perspective."

Optical Theories and the Development of Linear Perspective In Fifteenth-Century Italian Renaissance Art

The Florentine, Leon Battista Alberti, published his treatise on linear perspective, *Della pittura*, in 1435. Alberti's treatise remained a standard reference for painters and architects into the seventeenth century. In this treatise, which was essentially a manual for painters, Alberti discussed a new way to represent the natural world on a two-dimensional surface in a realistic manner. Prior to the *quattrocento*, or fifteenth century, most European artists represented elements of the natural world in a more rigid and stylized fashion, with no codified system of reproducing perspective or proportion. The concerns of the medieval world focused on the hereafter, and realistic representation of the physical world was not desired in painting, sculpture, or other modes of artistic expression. The Western world met with far-reaching artistic, philosophical, and scientific changes starting in the fifteenth century. Artists, natural philosophers, and writers drew heavily from ancient Greek and Roman sources. For this reason, the time period is referred to as the Renaissance, or rebirth, and marks the beginning of the modern world.

Alberti claims in *Della pittura* that he created the system of linear perspective.[1] However, Alberti incorporated the study of ancient science and mathematics, as well as major non-Western sources on optics, the science of sight. Alberti arrived at his theory only out of a synthesis of artistic, scientific, and mathematical ideas. Long before Alberti wrote his treatise natural philosophers debated on the nature of sight. The Atomists

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[1] Cecil Grayson, introduction to *De Pictura* and *De Statua*, by Leon Battista Alberti, (London: Phaidon, 1972), 8.

attempted to describe sight in the physical sense. Plato and Aristotle added to and argued with theories of the Atomists. Euclid, Pythagoras, and Ptolemy applied mathematics to their theories of vision. In the early Middle Ages, Arabic scholars translated and preserved the optical works of ancient Greece and Rome. Furthermore, Arabic natural philosophers formulated new theories of vision, which Alberti later incorporated in his treatise. Arabic optics made their way to early Renaissance Italy through the writing of some medieval thinkers, known as the Perspectivists. Optical theories from the ancient and medieval worlds provided the scientific knowledge used in the creation of linear perspective in fifteenth-century Florence.

Twentieth-century scholars have argued over the different ways that Renaissance artists arrived at linear perspective. Theories are varied, and subject to much disagreement. Scholars have shown difficulty in deciding on which primary sources can be used, and to what extent. The scholars Samuel Edgerton, James Burke, and David C. Lindberg assert that optical theories had a definite role in the creation of linear perspective. Other authors, like Martin Kemp, have tried to show alternative explanations for the development of linear perspective. Evidence for the incorporation of scientific ideas into linear perspective is not always clear in certain instances. However, on the whole, it is easy to see that the science of optics was used in the development of linear perspective and realistic artistic representation in the Renaissance.

Before analyzing the actual ideas presented by Alberti in 1435, it is necessary to discuss the history of optical theories in order to appreciate their role in the development of linear perspective. By doing so, the links between science and art will be made apparent. Writings pertaining to the relationship between optics and art in the late

Middle Ages will also be discussed, along with a description of the scientific and cultural climate of early Renaissance Florence. The perspective work of Filippo Brunelleschi and Alberti can then be better understood in a scientific context. The development of linear perspective has many links to the scientific theories that came before it. Linear perspective resulted in radical consequences for the practice of art. The artistic concern of linear perspective parallels the Renaissance scientific concern of empirical observation, and the effort to gain a better understanding of the natural world.

The first optical theories of the Western world proposed by the Atomists were physical explanations of the process of vision. Natural phenomena, such as the rainbow, along with blindness and eye disease may have motivated the debates on optics of early Greek natural philosophers.[2] Although early Greek optical theories differed on the physiology and anatomy of the eye, the themes of extramission and intromission appeared in many of the known early philosophical works. Proponents of intromission argued that all physical objects in the world emitted certain visual forces into the eyes of the viewer. Advocates of the extramission theory argued visual force, or beams of light emanated from the eye and made things visible. The ideas of extramision and intromission are significant in that they were transmitted to Islamic civilization, and also to Christendom.[3]

The Atomists reduced vision to a physical touch. Democratis, born c. 460 BCE, was one of the first natural philosophers to describe the atomic theory of vision. He proposed that all objects emitted a physical force, which combined with the air to make

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[2] David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler*, (Chicago: University of Chicago, 1976), 1-2.
[3] Ibid, 2.

an impression on the eye. The process of emanation was conceived as continuous, that is, objects constantly emitted particles in all directions. Four hundred years after Democratis proposed the atomic theory of vision the Roman natural philosophers, Epicurus and Lucretias, refined the atomic theory. Lucretias described sight through a process he called *simulacra*, or films. All visible objects emitted thin films, which were exact reproductions of the objects themselves. Lucretias used examples of the natural world to clarify this idea when writing, "visible things…throw off bodies, sometimes loosely diffused abroad, as wood throws off smoke and fire heat…"[4] These films, floating through the air, make contact with the eyes, disrupt the eyes' atomic structure in the pupil, and produce an image.[5]

In the *Timaeus*, Plato (c. 427-347 BCE) described the theory of extramission. This school of thought competed with the intromission theory for the place as the most prominent explanation of vision. Extramission describes the proposed process of the eyes sending out a visual current of their own, instead of only receiving films. Plato drew on the work of Empedocles and Theophrastus to develop the extramission theory.[6] Plato describes in the *Timaeus* a particular sort of fire within the eye, which emanates into the air to combine with sunlight to ultimately coalesce with another emanation from the observed object, thus producing the sense of sight. Plato describes the fire within the eye and the process of extramission:

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[4] Lucretias, *On the Nature of the Universe*, translated by R.E. Latham, (London: Penguin, 1951), 101.
[5] Ibid, 103.
[6] Lindberg, 4.

> Such fire has the property, not of burning, but of yielding a gentle light…Accordingly, so when there is daylight round the visual stream, it falls on its like and coalesces with it, forming a single uniform body in the line of sight.[7]

Plato's pupil, Aristotle (384-322 BCE), introduced his own theory of vision, in which he argued against the idea of fire being emitted from the eye. Instead, Aristotle proposed that a medium was necessary for the process of vision to occur. A transparent medium between the object and the observer, such as air or water, was absolutely necessary for the process of vision. To uphold this argument, Aristotle described the situation that when an object was placed directly on the eye it became invisible.[8] Therefore, for an object to be visible a medium was required to carry the image of that object. Aristotle never fully adopted the ideas of extramission of rays of light from the eye, or intromission of films from other objects. Instead, he proposed that light had no physical properties and was not restricted by temporal and physical change.[9] Despite his place as the major scientific authority for the medieval world that followed him, his optical theories did not hold the same prestige.

The Hellenistic medical doctor, Galen (c. 129-129 CE), proposed his own theories of vision, which he developed using the ideas of the Stoics, and the medium of Aristotle. Much of his work on optics dealt with the physiology of the eye. The Stoics upheld the extramission theory, and Galen added to it by proposing the existence of *pnuema*, a visual force. The eye emitted *pnuema*, which then made contact with the surrounding air. The air acted as a visual instrument for the eye in that the *pnuema* caused vibrations, which made contact with objects in the physical world, and then vibrated back to the eye. Once

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[7] Plato, *Timaeus*, translated by Desmond Lee, (London: Penguin, 1965), 62.

[8] Lindberg, 7.

[9] Ibid, 7.

in the eye, the image brought by the vibrations in the air traveled through the hollow optic nerve and into the soul of the viewer.[10] To demonstrate his theory, Galen wisely used the analogy of a walking stick, through which one feels in the hands the contact made with the ground by the end of the stick.

Mathematical theories of vision are those that ultimately had the most influence on the development of linear perspective. Around 300 BCE Euclid wrote his *Optica*, in which he formulated several mathematical assumptions about optics. His geometrical theorems assumed that: all rectilinear rays proceeding from the eye diverged indefinitely, things seen under a larger angle appear large, those under a smaller angle appear small, and those under equal angles appear equal.[11] Euclid's significance for Alberti and Brunelleschi is that vision was reduced to geometrical principles that could be described and located mathematically.

The Hellenistic cartographer, Claudius Ptolemy (fl. 127-148 CE) extended Euclid's geometric analysis of vision. Most important for the development of linear perspective were Ptolemy's discovery of the central axis and the theory of the visual cone. The theory of the central axis found its way to the Arabic optician, Alhazen, and eventually to Alberti. Ptolemy formulated the central axis theory to show that vision becomes less acute in areas in the visual cone far from the central ray.[12] Like Euclid, Ptolemy used the term *ray* in the abstract, geometrical sense. Rays extending from the eye were not physical beams of fire or light. These geometric rays extended in the shape of a cone in one continuous bundle. No spaces existed between the rays.

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[10] Ibid, 11.
[11] Ibid, 14.
[12] Ibid, 15.

The intromission theory of vision appeared in the work of the Atomists long before the Arabic natural philosopher, Alhazen, put forth his idea of intromission in his twenty books on optics. Alhazen lived from 965 to 1039 CE, and was patronized by a powerful Islamic ruler in Egypt. In Egypt, he wrote extensively on the science of optics, and became familiar with *Geographia*, a work by Ptolemy. In the very beginning of one of his books, *Optica*, Alhazen argued the extramission theory with simple reason:

> We find that when the eye looks into exceedingly bright lights, it suffer greatly because of them and is injured; for when an observer looks at the body of the sun…his eye experiences pain because of its light…[13]

Also, Alhazen uses the afterimages left in the eye caused by bright light or bright color, to prove that visual force moved only into the eye; no visual force emitted from the eye to the outside world.

Alhazen described the process of vision mathematically as well, for his rays were not physical beams, but a geometric concept. He theorized that light is emitted from all objects in all directions. These rays obey the laws of geometry, and only those hitting the cornea of the eye perpendicularly pass through the optic nerve and allow us to see.[14] Furthermore, Alhazen described the scope of vision as that of a visual pyramid, not unlike Ptolemy's visual cone. In the visual pyramid, the central ray of Ptolemy retains its significance as the place where visual accuracy was at its highest. Alhazen succeeded in formulating a fresh optical theory that relied on geometry. The theory of the visual pyramid directly influenced Alberti, and possibly that of Brunelleschi as well.

The material in the historical record that first links scientific theories to artistic concerns appears in the works of medieval opticians, often called the Perspectivists.

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[13] Ibn Al-Haytham (Alhazen), *Optics*, translated by A.I. Sabra, (London: University of London), 3.

[14] Samuel Edgerton, *The Renaissance Rediscovery of Linear Perspective*, (New York: Basic, 1975), 73-74.

Medieval European scholars successfully incorporated the theories of Alhazen from the east into their work. The discipline of optics in medieval Christendom, known then as *perspectiva*, was less concerned with theological mysteries than other sciences, and brought together Greek, Roman, Arabic, and Christian thought.[15] Writings on *perspectiva* provided the link from ancient science to Renaissance linear perspective for early *quattrocento* artists.

In an edict of 1277, the archbishop of Paris banned the works of Aristotle because the ancient Greek had described a universe that was finite. This ban had far reaching consequences, for it served as the impetus for new scientific inquiry.[16] The thirteenth century witnessed a gradual growth in secular thought. The Parisian archbishop probably planned the exact opposite. The Franciscan monks Roger Bacon and John Pencham added their own theories to optical history in this century. Not only did the two monks theorize about Alhazen's visual pyramid, but they also used the secular concern of optics as an analogy for moral behavior. Bacon illustrates the synthesis of morality and optics when he writes:

> For in the perfectly good the infusion of grace is compared to light incident directly and perpendicularly, since they do not reflect from them grace nor do they refract it from the straight course...But sinners, who are in mortal sin, reflect and repel from them the grace of God...[17]

Bacon also applied *perspectiva* to the visual arts. In his *Opus magus*, he pleaded to the pope to order artists to master geometry to better illustrate the world god created. This shows that Bacon noticed the lack of a codified system to represent three-

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[15] Ibid, 65

[16] Ibid, 19.

[17] Roger Bacon, quoted in Samuel Edgerton, *The Renaissance Rediscovery of Linear Perspective*, (New York: Basic, 1975), 74-75.

dimensional space on a two-dimensional surface.[18] Bacon asked from artists a more scientific and ordered approach based on the laws of optics and geometry. Pencham and Michele Savanarola (granduncle of the more famous Girolamo who burned at the stake) stressed the importance of optics and the possible relations to visual art. Savanarola placed great emphasis on optics, and referred to it as the "eighth" liberal art.[19]

Medieval artists concerned themselves with the representation of the realm of God. Individual features of figures and images of land and space received less attention. This is not to say that medieval artists lacked any skill to do so, or that they possessed no knowledge of perspective. Medieval painters suggested atmospheric perspective by using lighter and darker hues in order to show depth. They lacked any unified system for representing space linearly, and had to do so with their own intuition. With the gradual growing concern for the natural world, artists grew more occupied with their physical surroundings and wanted to represent it as realistically as possible. The incorporation of optics eventually allowed them to do so.

Giotto di Bondone (c1277-1337) painted several fresco panels in the tiny Arena Chapel in Padua, Italy around 1300 (fig 1). The frescoes show the artist's understanding between visual space and its representation on a two-dimensional surface.[20] The artist attempted to clearly define physical space and to depict actual buildings and features in the landscape. Also, Giotto incorporated oblique views and foreshortening. He did all of this with no system of linear perspective, which is why his buildings recede into the background without a vanishing point and appear awkward to the twentieth-century viewer. Brunelleschi and Alberti created the vanishing point over a hundred years after

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[18] Edgerton, 18-19.
[19] Ibid, 61.

Giotto completed his frescoes, and did so with the help of optical theories. Perhaps it is more than coincidence that the Arena Chapel was in a Franciscan monastery, the same order as Bacon, Pencham, and Savanarola, who had argued for more naturalistic representation.

Florence, in the early *quattrocento*, was a city obsessed with order and efficiency. The *contado*, or countryside, consisted of efficiently organized plots. The city of Florence thrived on trade from the East and the West. Many such examples of early Renaissance Florence show how the people used mathematics and organization to yield increasing profits. The efficient banking industry was led by the ruling Medici family, who utilized double-entry bookkeeping. In a society permeated by numbers, educated people needed to be adept at handling sums, and students of all occupations received education in mathematics and accounting at the *abacchi* schools.[21] It is also not coincidental that linear perspective developed in a city so involved with numbers as Florence.

As Florentine society grew increasingly occupied with numbers, their worldview also changed for other reasons. An itinerant Greek diplomat from Byzantium, Chysoloras, settled in Florence and taught at the university in the fourteenth century. He introduced the scientific work of Ptolemy along with his map of the world. Most importantly, Chysoloras helped intellectuals take notice of classical learning. Latin and Greek scholarship soon were placed at the forefront of higher education and intellectual discussions.

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[20] Frederick Harrt, *Italian Renaissance Art*, forth edition, (New Jersey: Abrams, 1994), 79.
[21] Ibid, 41.

Another figure who brought scientific learning to *quattrocento* Florence was the elusive medical doctor, mathematician, geographer, and optician Paolo del Toscanelli (1397-1482). He studied medicine at the University of Padua, where he learned mathematics like all medical students in order to understand astrology. Scientific thought was especially advanced in Padua at the time. An Italian optician, Blasius of Parma, taught at Padua just before Toscanelli arrived. Blasius wrote on Perspectivist theory and commented extensively on the work of Alhazen.[22] Toscanelli left Padua for Florence in the 1420s, where he is cited in a book of prominent Florentines of the time as author of books on perspective. He is also cited as a good friend and working partner of architect Filippo Brunelleschi in Vasari's *Lives of the Artists*.[23]

Art historians and historians of optics agree that Brunelleschi was the first to discover the rules of linear perspective. Filippo Brunelleschi earned his living as an architect—one of the most famous architects in Florentine history. Since the fifteenth century, Brunelleschi's most famous credit has been the completion of the massive dome over the Cathedral of Florence, *Il Duomo*. He received most of his formal education in an *abacchi* school, and seems to have lacked any university education. Despite not going through a university like his friends Alberti and Toscanelli, Brunelleschi mastered complex engineering and mathematical skills.[24] So adept at engineering was Brunelleschi that he invented the enormous cranes and other machines used in the construction of the dome. While not engaged in the building of monumental architecture, Brunelleschi involved himself in optical and artistic concerns.

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[22] Ibid, 62.
[23] Ibid, 63.
[24] Isabelle Hyman, *Brunelleschi in Perspective*, (New Jersey: Prentice-Hall, 1974), 2.

Exactly how Brunelleschi arrived at an example of linear perspective remains a subject of debate. Brunelleschi apparently designed an experiment involving the baptistery directly across from *Il Duomo*. In this experiment, Brunelleschi used a mirror and painted onto a panel the reflection of the baptistery. A viewer could look through a hole in the back of the panel at the actual baptistery in the background. A mirror was then placed between the viewer and the background. The viewer saw a reflection of the painting, which matched line for line with the actual baptistery (fig 2). Brunelleschi succeeded in representing the natural world with the laws of linear perspective.

The panels Brunelleschi allegedly used in his demonstration of linear perspective are lost. Therefore, no direct primary evidence survives relating his methods to his images.[25] A colleague of Brunelleschi, Antonio di Tuccio Manetti, recorded the events of the baptistery experiment in the 1480s, nearly fifty years after the fact. By 1480 the systematic rules of linear perspective were firmly established. Despite the lack of written evidence from the same time as Brunelleschi's experiment, some elements of the science of optics appear in his methods of reproducing the natural world.

Manetti described in detail the dimensions of the panel used in the experiment as one and a half *braccia*^{2}. One *braccio* is equal to twenty-three inches. Brunelleschi must have had some scientific knowledge to find the dimensions needed to produce realistic likeness of the baptistery. For example, Brunelleschi knew that to get the edges of the mirror to align with the edges of the panel the dimensions of the mirror had to be exactly half that of the panel.[26] Furthermore, he had to know that mirrors doubled the effective distance of the images they reflect. The effective distance refers to the distance not only

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[25] Martin Kemp, "Science, Non-Science, and Nonsense: The Interpretation of Brunelleschi's Perspective," *Art History* 1, no. 2 (June 78): 136.

from the pupil of the eye to the mirror, but also includes the distance from the mirror to the panel. This means that if Brunelleschi held the mirror 14.5cm from the panel, the effective distance was really 29cm. Other evidence of Brunelleschi's scientific knowledge shows that he must have known that the visual angle for viewing the baptistery had to be 90 degrees.[27]

Exactly how the architect arrived at such calculations remains an area of speculation. Whatever optical and geometric sources Brunelleschi used, they certainly worked. His placement of the viewing hole lined up directly with the imagined vanishing point on the horizon line in his painting, and in the natural world. A colleague of Brunelleschi, Toscanelli, was very familiar with the optics of *perspectiva* and Alhazen. Although no direct evidence supports it, Toscanelli could have worked with Brunelleschi to make the proper calculations, and use optical theories to do so. The centric ray so important to Alhazen's theories is the same imagined line used to determine the vanishing point, the exact place where all parallel lines converge.

Brunelleschi developed a scientific and artistic breakthrough, but his method still did not help the problem facing painters on how to reproduce the natural world realistically on a two-dimensional surface. No codified system was included in Brunelleschi's panel. Reproducing the image of a building required direct observation and did not suit the needs of artists painting frescoes deep within the recesses of cathedrals.

About ten years after Brunelleschi painted his panel in a doorway of *Il Duomo*, Alberti published his treatise on linear perspective, *Della pittura*, in 1435. Artists finally

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[26] Ibid, 140.
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received the answer to the problem of representing physical space, and because Alberti published in Italian as well as Latin, they could consult easily his codified system of perspective. Brunelleschi arrived at linear perspective through empirical observation and experimentation. Alberti's developed his system of linear perspective along more theoretical lines. Although Brunelleschi incorporated scientific ideas, the optical theories used by Alberti are traceable to particular natural philosophers. Unlike Brunelleschi, the aristocratic Alberti received a classical education, through which he gained familiarity with optics and natural philosophy. Alberti's use of optical material illustrates how optics led to the formulation of a codified linear perspective system.

Alberti incorporated the optics and mathematics of Alhazen, Bacon, Euclid, and Ptolemy. In Book One of his treatise, Alberti discusses the scientific elements of vision and painting. He declares to his readers that his treatise will not only instruct artists to paint pictures of what the eye sees but as the eye sees.[28] Alberti proposes that artists should approach their painting by mimicking the actual visual process of sight.

In describing the process of sight, Alberti favors the intromission theory, although he leaves out that term. Also, Alberti describes the process of sight in the same manner as Alhazen and Ptolemy:

> It is usually said that sight operates by means of a triangle whose base is the quantity seen, and whose sides are those same rays which extend to the eye from the extreme points of that quantity. It is perfectly true that no quantity can be seen without such a triangle.[29]

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[28] Edgerton, 88.

[29] Leon Battista Alberti, *De Pictura* and *De Statua*, translated by Cecil Grayson, c. 1435, (London: Phaidon, 1972), 43.

After describing the visual pyramid in detail Alberti discusses its importance to the artist. Alberti writes that the surface of the painting, or picture plane, is exactly like a plane intersecting the visual pyramid:

> Therefore a painting will be the intersection of a visual pyramid at a given distance, with a fixed center and a certain position of lights, represented artistically with lines and colors on a given surface.[30]

In addition to describing the visual pyramid, Alberti places importance on the central ray, which he repeatedly refers to as the "prince of rays." The central ray used by Alberti is the same central ray as in Ptolemy's visual cone. Ptolemy noted that the clearest vision occurred near the center of the field of vision. From the central ray, Alberti constructed the vanishing point.[31] By applying Euclidean geometry to the visual pyramid and the central ray, Alberti constructed a graph of perspective that accounted for receding space on a two-dimensional surface (fig. 3).

In the discussion of his diagram Alberti states that the vanishing point, positioned on end of the centric ray furthest from the viewer, is located at the very center of the painting.[32] To illustrate three-dimensional space, lines from the bottom of the picture plane are then represented as converging on the vanishing point. This represents parallel lines receding back into the distance like floor tiles. Alberti writes that the width between each line at the bottom of the picture represents one *braccio* (23 inches), and three *braccia* equaled the average height of a man. This made it easy to calculate the size of a figure standing at the very front of the picture plane.

The vertical lines of Alberti's diagram could be established without advanced geometric knowledge because the widths at the very front were all equal. Finding the

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[30] Ibid, 45.
[31] Edgerton, 89.

widths of the horizontal lines proved more difficult. When the lines receded back into space the distance between each had to decrease as they approached the vanishing point. Alberti developed his "distance point" method to calculate the placement of those lines. To do that, he incorporated the geometry of Euclid (fig 4). In proposition 11 of *De visu*, Euclid describes the decreasing length of line segments being intersected by a variety of angles originating from the same point:

> ...since GD is seen with the rays AG and AD, and DE is seen through the rays AD and AE, GD appears higher than DE. Similarly DE will appear higher than BE, for objects seen by higher rays appear higher.[33]

A comparison between Alberti's distance point method (part *b* of fig. 3) and Euclid's eleventh proposition (fig. 4) reveals that the two operations are almost identical.[34]

From Ptolemy, Alberti borrowed another significant scientific element, proportion. In *Geographia*, Ptolemy instructed his readers on the importance of a grid made of uniform dimensions. With the use of a grid, the cartographer could reproduce geographic features in proportion to one another and measure distances. By way of Chrysoloras, the works and world map of Ptolemy came to Florence, where they received a considerable amount of intellectual attention. Ptolemy applied optics to geography to compensate for distortion, and Alberti borrowed that idea to compensate for distortion in representing size and distance in a painting. Alberti instructed painters to construct a flat grid on the picture plane on top of the perspective construction. This way, objects of the natural world could be transferred in proportion onto the picture plane. However simple the idea may seem in the twentieth century, Alberti made popular the assumption that

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[32] Alberti, 49.
[33] Euclid, quoted in Lindberg, 152.
[34] Lindberg, 152.
[35] Edgerton, 88.

large things could be represented smaller, but maintain their proportion to all other objects in the painting.[35]

Alberti did not stop with the technical description of linear perspective. He also justified its worth with moral purpose. Like Bacon, Alberti related morality to optics. Alberti described the *istoria* as the Christian moral message that each painting should have. He argued that a precise frontal view in linear perspective was the best way to communicate that moral message. The central ray had not only visual, but also didactic force.[36] The technical and moral example illustrated by Alberti's system of linear perspective remained a dominant source of artistic theory for 150 years after its publication.

Florentine artists succeeded in integrating a vast body of knowledge in order to develop a codified system of linear perspective for painters. By combining optical and geometric theories from ancient Greek and Roman thinkers, Arabic opticians, and medieval philosophers Alberti and Brunelleschi formulated a major characteristic of Renaissance art. Optics and natural philosophy, as much as artistic theory and moral philosophy played significant roles in the development of a codified system of linear perspective. The optical theories form the ancient and medieval worlds provided the scientific knowledge necessary for the formulation of that perspective system.

Each optician or natural philosopher mentioned here contributed in some way to linear perspective. Ideas of vision were challenged, altered, and expanded throughout history. Greek and Roman thinkers proposed many optical theories, including intromission. Unknown to Europeans for a period of time, classical natural philosophy

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[36] Ibid, 86.

was preserved and translated by Arabic scholars. Alhazen provided a new, geometric explanation of the intromission theory. Late medieval thinkers passed on and added to the work of Alhazen, and also related optics to the visual arts. With the rediscovery of Ptolemy's cartography, Alhazen's optics, and Euclid's geometry, Alberti was able to provide a scientific and reproducible system for artists to represent the natural world in a convincing manner.

Linear perspective constitutes one of the many developments from the Renaissance that altered the worldview of the West. Human interests and the natural world received critical amounts of attention. The supernatural realm was not utterly abandoned for more worldly concerns, but rather natural philosophy gained ever more attention along side theology. Alberti and Brunelleschi, in addition to helping painters, augmented the popularity of the science of optics. In 1493, artist Antonio Pollaiuolo sculpted an allegorical figure of Prospectiva as one of the liberal arts on the tomb of Pope Sixtus IV (fig. 5). Linear perspective stimulated new notions about pictorial illusion and the processes of the natural world.