FS51x. Changing perspectives: the science of optics in the visual arts

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Art History is long intertwined with science and technology. The painter, to put what is seen by their eye onto flat canvas, has to grasp and solve technical problems. The brain will effortlessly create internal mental images of the three-dimensional surrounding world. But translating mental images into two-dimensional pictures – while retaining a sense of volume and depth, light and shadow, surface and texture – is hard. And so picture-making has long been perfused with optical science and technology – from early discoveries by Renaissance artists who labored to record the world with realism – to our cultural moment where every smartphone effortlessly captures and communicates visual experience. Here, we explore this story of art, picture-making, optics, and technology from the Renaissance to now. We ask how pioneering artists from van Eyck to Vermeer to modern photographers approached and solved problems in optical representation. How did artists across centuries capture visions of deeply-seen worlds in works that continue to captivate? **Prerequisites:** No prior training in art or science. We will learn how to paint and draw with pencils, brushes, and optical tools. We will learn the science and technology of picture-making by trial-and-error, not with math or physics.

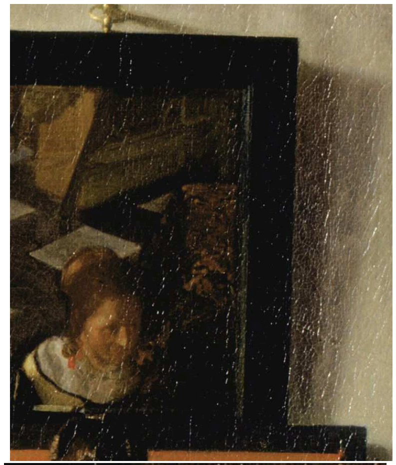
Figure 1: (Top) *The Astronomer* by Vermeer and its Link at Google Arts and Culture. (Bottom) *The Geographer* by Vermeer and its Link at Google Arts and Culture.

In Western Art History, the visual arts and optical sciences progressed side-by-side across centuries. Certain eras witnessed direct dialogues between science and art. One such dialogue occurred in one generation in one small country – the 17th century Dutch Republic. In that era, Christiaan Huygens (1629-1695) developed astronomical telescopes that enabled his discovery of Titan, Saturn's largest moon; and Antonie van Leeuwenhoek (1632-1723) developed the first microscope that could see and discover microbial life. While Dutch scientists advanced optics, Dutch artists advanced 'opticality' in painting. Vermeer (1632-1675), born in the same year and town as Leeuwenhoek, achieved unprecedented levels of optical realism. Vermeer approached photographic quality in capturing light and shadow, reflection and refraction, geometry and three-dimensional perspective. Leeuwenhoek might be the young man in Vermeer's *Astronomer* and *Geographer* (Fig. 1) – but even if not, Vermeer's celebration of scientists who also labor to capture careful images of deeply-seen natural worlds might reveal his own sympathy. [1]

[1] Arthur K. Wheelock. Vermeer becoming Vermeer. *Artibus et historiae*, (84): 307, 2021

Updated: February 10, 2025

Humans are visual animals. Optical effects naturally command visual attention. Artists have long known to add visual interest to paintings by including eye-grabbing optical effects like sunlight reflected off water or refracted through glass. Vermeer filled paintings with optical effects, capturing the play of light and shadow with subtlety and precision. Take the *Music Lesson*, among his finest works. Doubled shadows are cast by the mirror frame onto the wall, just what happens when light projects from multiple directions and windows. The surfaces of the curved pitcher capture glinting images of sunlight through windows that smoothly modulate into shadows. The entire scene obeys mathematical laws of linear perspective – the parallel lines of the tiled floor, walls, and ceiling converge to a common point near the lady's right arm – the precise geometrical outcome of optically flattening a three-dimensional scene onto a flat view. The painted mirror not only reflects the scene in front of us, but also the world of the painter and viewer, seen in the legs of the painter's own easel.



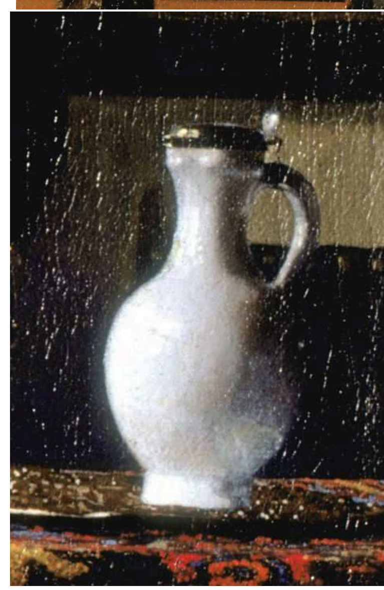


Figure 2: *The Music Lesson* by Vermeer c.1662 - 1665.

Hockney Thesis: Optical Tools

David Hockney, contemporary artist and provocateur, is deeply inspired by optics and Old Master paintings like *The Music Lesson.* His own *Ready-made with Skull and Mirrors* (Fig. 4) is a 'photographic drawing' that shows a complex ensemble of objects and mirrors in an invented (but optically convincing) three-dimensional space. Hockney is a classically-trained and talented artist. He can do much with just pencil or paintbrush. But Hockney uses technology without shame to work more quickly, easily, and effectively. When Hockney saw optical objects like lenses and mirrors in paintings by Vermeer and others, he speculated how those same objects could be used as optical *tools* to speed and simplify the problem of achieving photographic realism. His 'Hockney Thesis' is that artists like Vermeer were not just *inspired* by optics but *used* optical tools to paint and draw. In 2001, Hockney hosted a symposium to debate this idea at NYU's Institute for the Humanities. He then published his controversial perspective in *Secret Knowledge* (Fig. 3). The book cover shows Hockney drawing with a *camera lucida*, a prismatic drawing device invented in the 1800s.

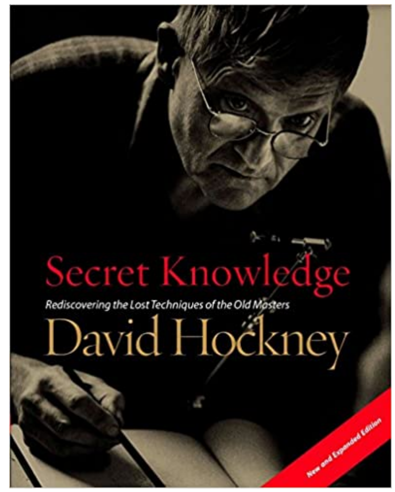


Figure 3: David Hockney using a camera lucida on the cover of his book.

Figure 4: *Ready-made with Skull and Mirrors* by David Hockney. The skull is a *memento mori*, a symbolic trope appears in paintings from the Renaissance onward, a reminder of the inevitability of death.

Steadman Hypothesis: Camera Obscura

Philip Steadman – architect, Emeritus Professor at University College London, and admirer of Vermeer – attended Hockney's symposium. Steadman was struck by an architectural quality of every room in Vermeer's domestic scenes (Figs. 5, 6, 7). Steadman conjectured that Vermeer was translating the *same* room from image to canvas, with slightly different decor from painting to painting. Steadman suggested that Vermeer used a camera obscura – not just to frame his subjects or to study optical effects, as others propose – but as a tool to mechanically translate a scene onto canvas.

Steadman made dollhouse versions of Vermeer's domestic interiors. He calculated the viewpoint that might lead to the geometry of each painting – where the observer should stand to see the room precisely as depicted. These reconstructions revealed remarkable consistency across Vermeer's paintings. Steadman proposed that Vermeer might have used a primitive camera – the camera obscura – at the back of his studio, where he might have sectioned off a darkened closet. Inside the camera/closet, a lens could cast an image that Vermeer could trace (albeit upside down and inverted). Two hundred years later, chemists invented the light-sensitive films that would turn the camera obscura into the modern-day photographic camera.

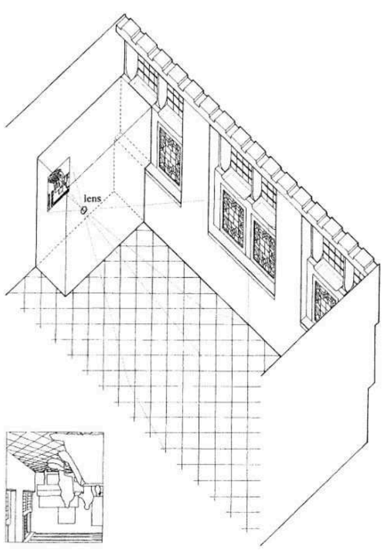


Figure 5: *Lady Standing at a Virginal* by Vermeer. Link to painting at Google Arts and Culture

Figure 6: *The Girl with the Wine Glass* by Vermeer. Link to painting at Google Arts and Culture

Figure 7: *Soldier and a Laughing Girl* by Johannes Vermeer. Link to painting at Google Arts and Culture

Updated: February 10, 2025

This course is not about answering questions, but asking them. Seeing and knowing the world are central to both art and science. This course is an invitation to look at how artists responded to their visual world across centuries, both in terms of what they depicted and how they solved technical problems in depiction. Whether you agree with Hockney or Steadman, artists across centuries *have* seen more deeply and worked more effectively with scientific and technological insight. Together, we will explore this intersection between Art and Science from the Renaissance to now.

Figure 8: *Seedling Palace* by Ethan Murrow, 2023. Graphite on paper.

Our journey will include:

- **Making Art**. Many students might not be artists. We will learn about painting and drawing from artists who use optical tools to make art – Ethan Murrow, a Boston-based muralist (Fig. 8) and Abe Morell, a camera obscura artist (Fig. 9) – and artists who don't – Nard Kwast, a Dutch painter who incorporates 'Old Master' techniques (Fig. 10).
- **Science Experiments**. Appreciating the interplay between optics and art requires scientific intuition. We will gain this intuition about optics – mirrors and lenses, reflection and refraction – with experiments, not equations.
- **Field Trips**. We will visit nearby museums, the Harvard Art Museums, the Gardner Museum, and the MFA. We will study original artworks, evaluate optical qualities, and think about the skill and technology that might have gone into their making.

Figure 9: *The Baptistry in Florence* by Abe Morell, photograph taken with tent camera obscura.

We will usually meet in Harvard Art Museums 0600. Except for field trips when we Uber to museums. We will sometimes use HAM's Art Study Center to look closely at works in Harvard's collection. We will sometimes use HAM's M-Lab, its maker space, to make art. We meet Thursdays from 12:45–2:45 PM.

Figure 10: Nard Kwast in the Dutch reality television show *Het Geheim van de Meester* on a team painting Rembrandt's *Night Watch* with old materials, old techniques, and working next to the original in the Rijksmuseum.

Reading and writing assignments will be assigned each week. Each week, students will read one or two short papers or book chapters. Each week, students will write a short essay (2-3 pages) that responds to readings and classroom discussions.

We will be successful if understanding science and optics deepens our appreciation and interest in pictures and paintings, pushes us to look more carefully at the world around us, and encourages our own picture-making.

Updated: February 10, 2025

Contents

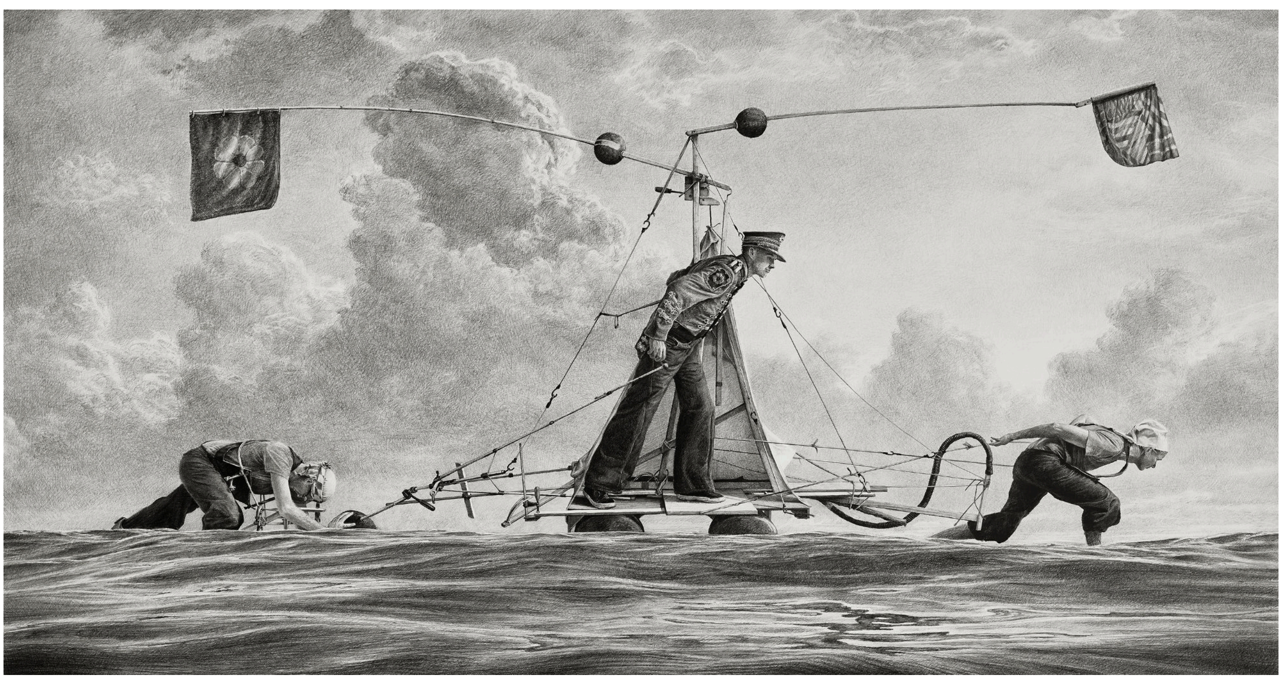


Figure 11: *For All Intents and Purposes* by Ethan Murrow. Graphite on Paper, 52" x 100".

Updated: February 10, 2025

Dramatis Personae

Aravi Samuel '93 studied physics and biophysics at Harvard as an undergraduate and graduate student with Prof. Howard C. Berg. Berg, a microscopist of microorganisms, introduced Aravi to Leeuwenhoek, Vermeer's contemporary. Aravi's email: samuel@physics.harvard.edu.

Claire Swadling '26 studies physics and has studied Studio Art. She will help with art and science experiments, and is available to chat during the week. Contact her about course material, scheduling and transportation, and other questions. Claire's email: cswadling@college.harvard.edu.

Christine Zhang '27 took this class last year! Christine is an accomplished painter who will help with art and science experiments. Contact her about course material and other questions. Christine's email: xczhang@college.harvard.edu.

Chris Stokes, at the Rowland Institute at Harvard, built most of the optical devices that we explore in this course, including the camera obscura and camera lucida.

Daniel Davis, from the Harvard Science Center, supports our physics experiments and demonstrations.

Nard Kwast specializes in classical painting, portraits, still-lifes, and landscapes with the style, techniques, and materials of the Dutch Golden Age. Nard's website is here.

Abe Morell is a contemporary artist known for camera obscura photography. Abe pioneered the 'tent camera obscura' as a new form of landscape photography. Abe's website is here.

Ethan Murrow is Professor at The School of the MFA. He focuses on historical narratives, large scale wall drawings and murals. Ethan's website is here.

Penley Knipe is Philip and Lynn Straus Senior Conservator at the Harvard Art Museums. Penley is an expert in the history and techniques of American portrait silhouettes.

Joachim Homann is Maida and George Abrams Curator of Drawings at the Harvard Art Museums. Joachim acquired many of the original drawings made with optical tools for the Harvard museums.

Chris Atkins is Van Otterloo-Weatherbie Director of the Center for Netherlandish Art (CNA) at the MFA, a center for scholarship on Dutch and Flemish art.

Cammy Brothers is a Professor at Northeastern University where she holds a joint appointment in Architecture and in Art & Design. Cammy is an expert in Renaissance art and architecture.

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Figure 12: *School Class with a Sleeping Schoolmaster* by Jan Steen, 1672

Calendar

Class Meeting	Topic	Artists and Projects
Week 1. Jan 30	Reflecting on Mirrors	Hockney and van Eyck
Week 2. Feb 6	Seeing Perspective	Brunelleschi and Masaccio
Week 3. Feb 13	Florentine Fluorishing	Visit the Gardner Museum
Week 4. Feb 20	The Camera Lucida	Ingres
Week 5. Feb 27	Opticality in Dutch Art	Visit the MFA
Week 6. Mar 6	The Dutch Still Life	Painting with Nard Kwast
Week 7. Mar 13	The Dutch Still Life	Painting with Nard Kwast
Week 8. Mar 27	Impressions of Color	Monet
Week 9. Apr 3	Silhouettes	Penley Knipe at the Harvard Art Museum
Week 10. Apr 10	Drawing	Ethan Murrow in his Studio
Week 11. Apr 17	Photography	Abe Morell in his Studio
Week 12. Apr 24	What did we learn?	Wrap-up

Week One - Reflecting on Mirrors

Thursday, 30 January 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums 0600

'Paintings too perfect?' is how the *New York Times* titled the first article about the Hockney thesis. David Hockney, after seeing an exhibit devoted to the portraits of Jean-Auguste-Dominique Ingres (1780-1867), became suspicious about the French Neoclassicist's near photographic quality in drawing and painting (Fig. 15). Hockney knew how to draw. As a student at the Royal College of Art, Hockney was able to make anatomical studies by freehand that rival da Vinci (Fig. 13, 14). These anatomical drawings by Hockney and da Vinci are made with care, requiring close attention and superb eye-hand coordination. Hockney knew how much time and labor was needed for precise rendering.

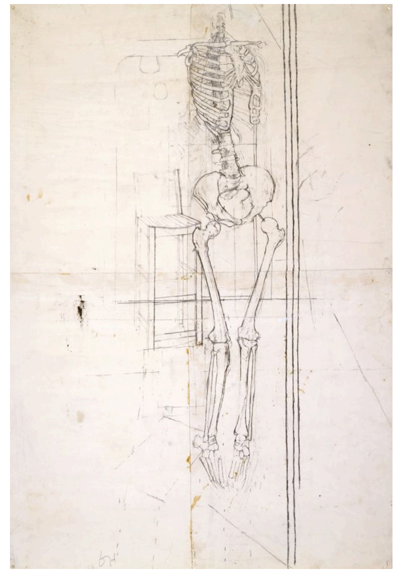


Figure 13: *Skeleton Study II*, David Hockney, 1959.

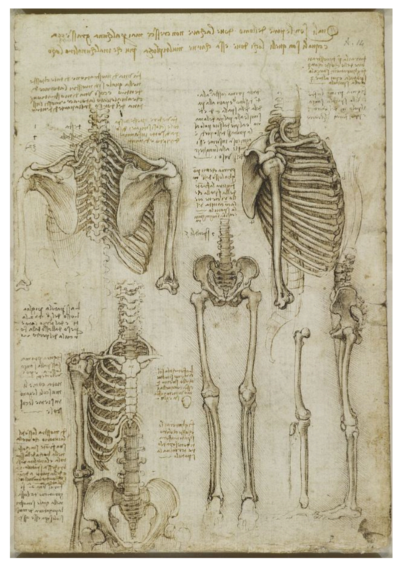


Figure 14: *Anatomical Manuscript A*, Leonardo da Vinci, c.1510-11.

Figure 15: *Portrait of Madame Charles Hayard and Her Daughter Caroline* by Ingres. [Link to drawing at the Harvard Art Museums]().

INGRES uses his pencil with lightness and surety. We also know that Ingres drew quickly. Before studio photography, hundreds of sitters paid the young Ingres to make these portraits that achieved photographic quality. But Ingres's photographic quality is also selective. Where precision is needed, Ingres is unerring, perhaps superhuman. No erasure marks. No stray mark. But the rest of the drawing is clearly sketched and "eyeballed", as Hockney puts it.

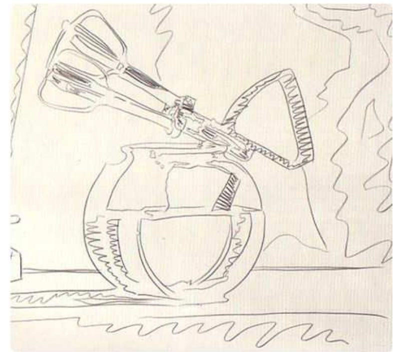


Figure 16: Hockney knew that Warhol traced the certain and unerring lines of this drawing using a projector.

ANDY WARHOL, whom Hockney knew personally, achieved superhuman precision with a pencil when he wanted to. But Hockney knew Warhol's secret – Warhol drew without mistakes when he had help – when he traced the contours of an optical projection!
Did Ingres get help from an optical device? In a historical coincidence, the camera lucida was invented during Ingres's life. The camera lucida allows the user to see a superposition of subject and drawing, allowing accurate tracing. Although there is no record that Ingres knew about or used a camera lucida, Hockney learned how to use one. Using a camera lucida, Hockney was able to speedily make 'photographic' portraits that rival the quality of Ingres (Fig. 18).

Figure 17: A camera lucida in the Harvard Museum of Scientific Instruments.

HOCKNEY SAW AN ARC of increasing photographic precision in Western Art from the Renaissance until the invention of photography. He saw certain quantum leaps in optical precision by certain artists who betrayed a certain enthusiasm for opticality in their art. Hockney projecting his own experience with the camera lucida on artists of antiquity. With his Hockney Thesis, he proposed that other artists also made quantum leaps in optical precision by learning how to use an optical tool.

Figure 18: *Camera lucida drawing of Martin Kemp* by David Hockney.

HISTORY RECORDS LITTLE EVIDENCE that famed artists owned or used optical projectors or devices like the camera lucida. But lack of historical evidence did not trouble Hockney. Because artists would jealously guard the tools of their trade, evidence would not be recorded. Thus, Hockney suggested that using optical tools in art-making has been *Secret Knowledge*, the title of his book. [2]

[2] David Hockney. *Secret Knowledge*. Viking Studio, New York, 2006. ISBN 978-0-14-200512-5

Jan van Eyck (c. ∼1390 - 1441) was a Flemish painter who made a sudden leap in achieving photographic realism in Early Netherlandish Painting. Giorgio Vasari (1511 - 1574) laid the first foundation of Art History with his *Lives of the Most Excellent Painters, Sculptors, and Architects.* Vasari credits van Eyck with inventing oil painting, discovering how to use linseed oil mixed with ground pigment. Before van Eyck, pigment was usually mixed into egg yolk (*tempera*) a permanent, fast-drying, water-soluble, and long-lasting medium. With tempera, the artist has to hurry, having to get things right before the hardening of the permanent and fast-drying paint. In contrast, linseed oil takes *weeks* to dry. An oil painter has the luxury of time to include, correct, and refine every detail in any painting. The invention of oil painting correlates with the sudden rise in photographic realism in the Early Renaissance.

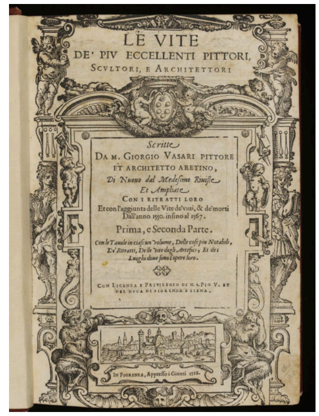
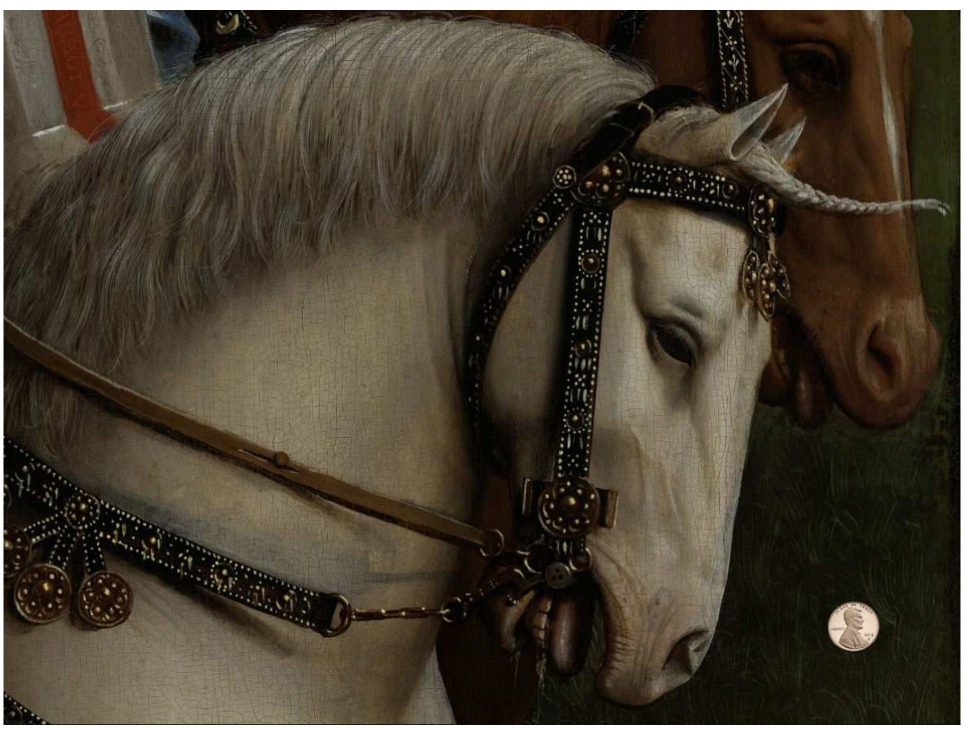

LE VITE
DE' PIV ECCELLENTI PITTORI,
SCVLTORI, E ARCHITETTORI
Scritte
DA M. GIORGIO VASARI PITTORE
ET ARCHITETTO ARETINO,
Di Nuouo dal Medesimo Riuiste
Et Ampliate
CON I RITRATTI LORO
Et con l'aggiunta delle Vite de'viui, & de'morti
Dall'anno 1550. insino al 1567.
Prima, e Seconda Parte.
Con le Tauole in ciascun volume, Delle cose piu Notabili, De' Ritratti, Delle vite degli Artefici, Et dei Luoghi doue sono l'opere loro.
CON LICENZA E PRIVILEGIO DI N. S. PIO V. ET DEL DVCA DI FIORENZA E SIENA.
IN FIORENZA, Appresso i Giunti 1568.

Figure 19: Title page of the first and second part of the 1568 edition of Vasari's *Lives*.

Jan van Eyck probably didn't *invent* oil painting, but he did pioneer its new possibilities. A career achievement was *The Ghent Altarpiece* polyptch, designed and begun by his brother Hubert in the 1420s and finished by Jan in 1432. Jan van Eyck's autograph works – including the *The Ghent Altarpiece* in 100 billion pixels – can be viewed in exquisite detail on the website Closer to van Eyck. In the *Milites Christi* panel, van Eyck captures single hairs of the horse's mane and drops of spittle from its mouth, painted with *microscopic* attention to detail (see penny at scale).



Updated: *February 10, 2025*

Figure 21: *The Ghent Altarpiece* by Hubert and Jan van Eyck.

The European Renaissance emerged from the Middle Ages, partly through new awareness of lost Greek and Roman achievement in science and art and partly through absorbing knowledge that had been preserved in the East. During the European Gothic Age – retroactively named to blame the Goth invaders that brought down the Roman Empire – the Arab world enjoyed its Islamic Golden Age. In Egypt, Ibn al-Haytham (Latinized as Alhazen) (965-1040) made important advances in mathematics, physics, and astronomy. In Europe, Alhazen's work was not widely known until 1200 when his *Kitāb al-Manāẓir* was translated into Latin as *De aspectibus* or *Perspectiva* (or the *Book of Optics* in English). His profound discoveries earned his reputation as the "Father of Modern Optics" – European scientists including Newton, Kepler, Copernicus, and Huygens would extensively cite Alhazen's work. Among his achievements, Alhazen established principles of reflection and refraction with differently-shaped surfaces and transparent objects. We do not know whether van Eyck directly read Alhazen's work – it would have been widely available – but van Eyck was well-educated and would have attended Latin school. Latin inscriptions abound on van Eyck's paintings.

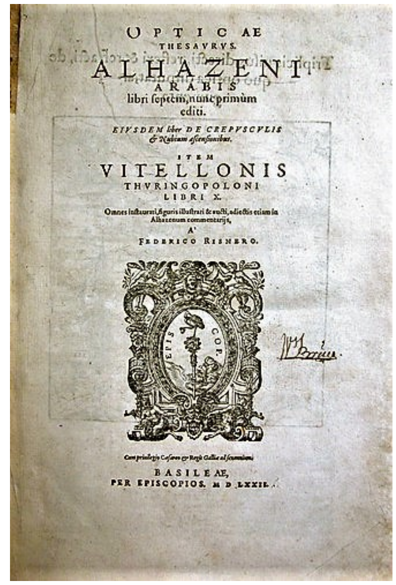
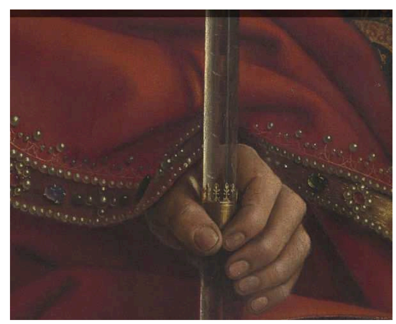


Figure 22: Cover page for Alhazen's *Book of Optics* in the print edition from 1572.

Was van Eyck only a careful observer of subtle optical effects? Or did advanced knowledge of reflection and refraction prepare van Eyck to better notice and incorporate optical effects into paintings? Seeing is believing, but believing can also precede seeing. van Eyck might have known what to look for, if he knew what to expect.



Consider the crystal staff wielded by the Deity in the Ghent Altarpiece. The light that falls on and through the crystal shaft is refracted as a bright line along the hand, evoking an effect of a cylindrical lens. Consider the glass and pearl beads hanging from his gold brocade. Specular reflections appear on the front surfaces of these curved beads, soft and diffuse on the pearl and sharp and pointed on the glass beads. Look behind the beads. Van Eyck not only paints their shadows, but also bright focal points.

Glass spheres behave like magnifying glasses and will concentrate an incoming beam of light. Two hundred years later, another Netherlander – Antonie von Leeuwenhoek – would discover how to use small glass beads as literal magnifying glasses, which he incorporated into his first microscopes that discovered the microbial world.

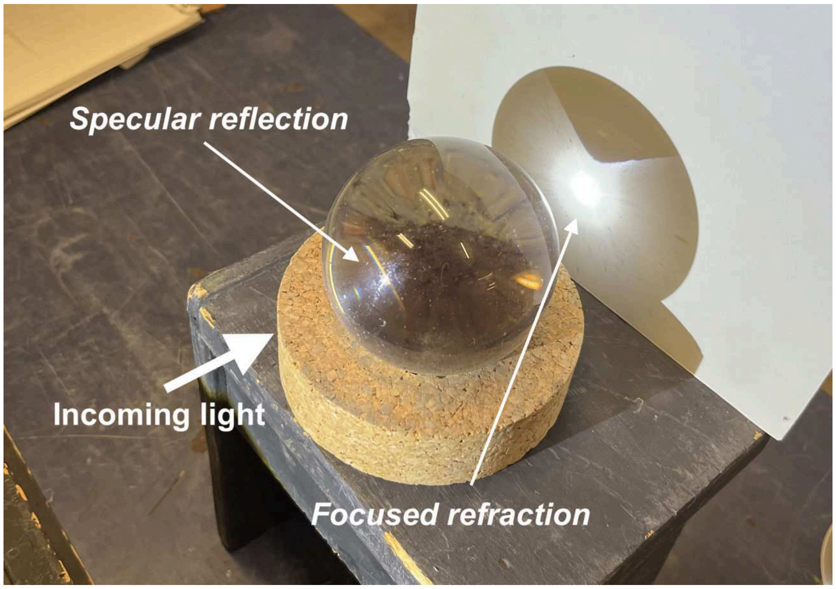


Figure 23: Shining a flashlight onto a glass sphere will create a spot of specular reflection, a shadow, and spot of focused refraction. The spot of focused refraction occurs at the focal point of the glass sphere.

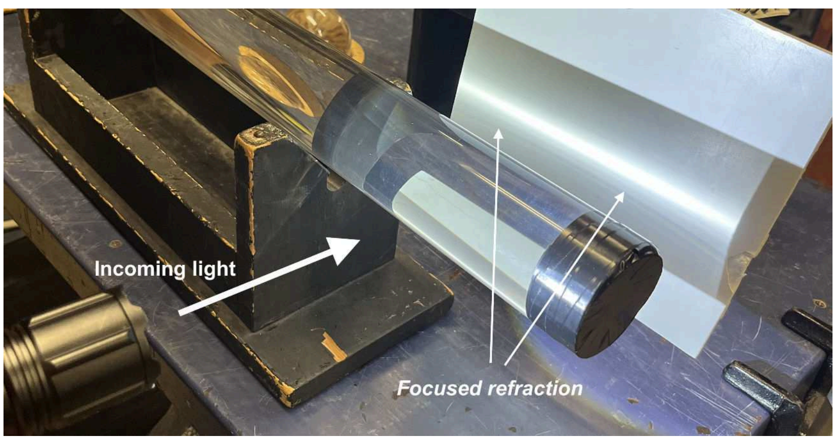


Figure 24: A cylindrical rod will create a bright and focused line by refracting incoming light.

The Arnolfini Portrait is further evidence of Jan van Eyck's obsession with optics. Van Eyck uses perspective to give a sense of depth to the depicted scene. Like Vermeer in his *Music Lesson*, van Eyck adds a mirror that reflects the scene in front of us, but also the scene in front of the painting. Look carefully, and see that the artist includes himself in the reflection.

Hockney marveled at the spherical mirror, not just as a virtuoso display of painterly skill and the artist's deep interest in optical effects, but as evidence of availability of high-quality mirrors. Van Eyck's spherical mirror is so carefully painted that the room can be estimated from its curved reflections (Fig. 25).

Hockney ventured that if van Eyck could *paint* a spherical mirror, he could have *used* a spherical mirror as an art-making tool. Convex lenses like magnifying glasses will focus light. Concave mirrors also focus light. A good concave mirror can project a clear image of a brightly lit object onto a flat surface (see Fig. 27). Hockney experimented with concave mirrors, and convinced himself that they can also be helpful in drawing with photographic accuracy. On the other hand, David Stork – a scientist and Hockney skeptic – has calculated that, if van Eyck had used a concave mirror for the *Arnolfini Portrait*, the mirror would have been implausibly enormous. [3]

Figure 25: *The Arnolfini Portrait* by Jan van Eyck (1390-1441) in the National Gallery of London, and Link to all of van Eyck's Paintings.

Figure 26: BBC documentary, *Secret Knowledge*

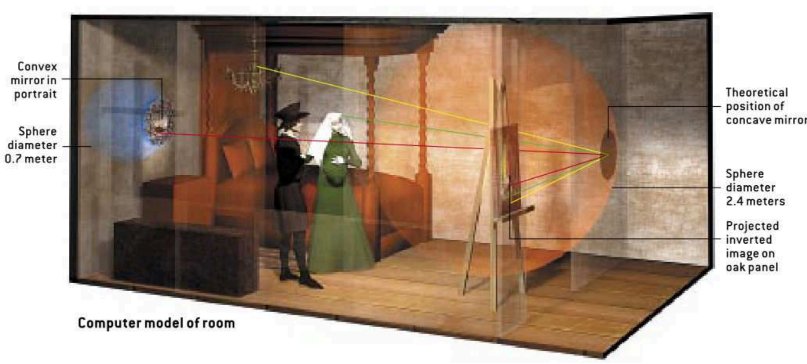


Figure 27: The room of the *Arnolfini Portrait* can be reconstructed using the reflection from the rear convex mirror, but would have required an enormous concave mirror to project onto canvas.

[3] David G. Stork. Optics and realism in Renaissance art. *Scientific American*, 291 (6):76–83, 2004

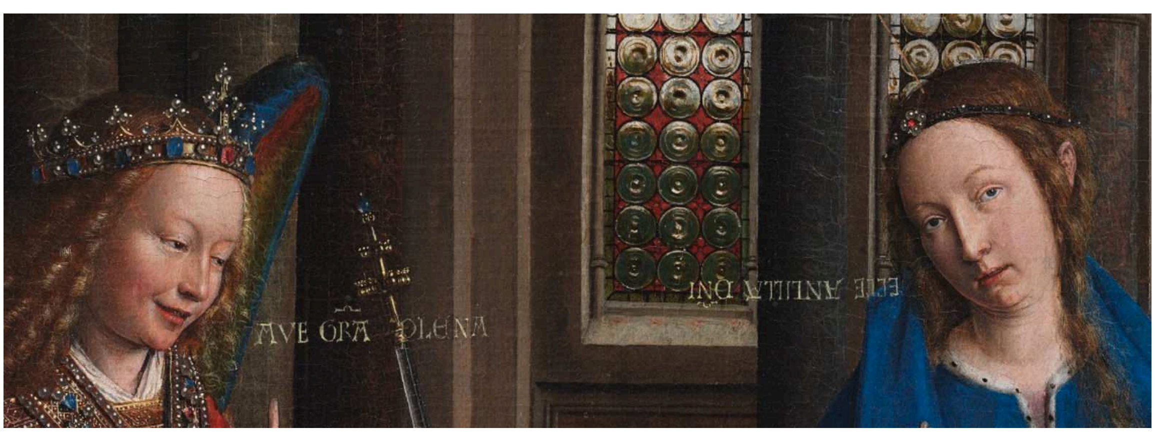
Updated: February 10, 2025

Updated: February 10, 2025

LINEAR PERSPECTIVE was discovered by Filippo Brunelleschi in Florence after 1410. The rules of linear perspective were first described and published by another Florentine, Leon Battista Alberti (1404-1472) in *De Pictura*, in 1435. Although van Eyck might have known about Alhazen's principles of reflection and refraction, he would not have known the mathematical principles of linear perspective that provide rigorous formulas for creating an accurate two-dimensional projection of a three-dimensional space. Van Eyck, like other European painters before Brunelleschi, had an intuitive sense of perspective. Parallel lines on ceilings slant downward and parallel lines on floors will slant upwards. To be geometrically correct, all parallel lines in a three-dimensional space should converge to central vanishing points. This convergence does not occur with mathematical precision in any van Eyck painting. Van Eyck includes geometric effects without the same level of precision that he applies to purely optical effects.

Figure 28: *The Annunciation* by Jan van Eyck, 1434-1436. Link to painting.

THE ANNUNCIATION by Jan van Eyck, 1434-1436, includes another kind of perspective. In this commonly-depicted scene in Early Renaissance paintings, the angel Gabriel tells the Virgin Mary that she will bear Christ. The inscription shows the words *AVE GRA PLENA* ('Hail, full of grace...'), she responds, *ECCE ANCILLA D[OMI]NI* ('Behold the handmaiden of the Lord'). The words are upside down because they are directed to God and inscribed with God's-eye view. Van Eyck used perspective, just not geometric perspective. He might have known enough Latin to read Alhazen and be aware of his optical discoveries, but Alberti would be too late to publish Brunelleschi's discoveries.



RENAISSANCE ARTISTS often made preparatory studies before starting on major artworks. Although we only have three surviving preparatory drawings by van Eyck, they have direct relevance to his methods and whether optical tools played any part.

David Hockney was struck by the painting of Cardinal Niccoló Albergati, made in 1431 (although whether this is Albergati or someone else is debated). Before making the oil painting on wood panel, van Eyck made a quick silverpoint sketch on paper on a short trip – we know that it is a preparatory sketch because it includes notes about the intended color of the final oil painting. But the final painting (340 x 275 mm in size) is also a magnification of the original drawing (214 x 180 mm). Optical magnification is easy to do, but the two images are not optically identical. There are measurable size differences in the mouth, shoulder, and especially the ear.

Hockney thinks that van Eyck used an optical projector when translating drawing into painting. He dismisses misalignment as minor accidents. Maybe van Eyck bumped the projector in the middle of the process. But wouldn't an artist with van Eyck's keen eye have noticed when drawn and traced pictures went out of alignment? Was he making mistakes? Or was he "photo-shopping" the final outcome?

Figure 29: *Cardinal Niccoló Albergati* by Jan van Eyck, 1431. Link to drawing in Dresden and Link to painting in Vienna.

ARTISTS often make copies of artwork. Two unsigned copies of *Saint Francis of Assisi Receiving the Stigmata* (c. 1430-1432) are attributed to van Eyck. The wood used in both panels comes from the same tree as another definitive work by van Eyck.

Figure 30: Top) St. Francis in Philadelphia, Bottom) St. Francis in Turin.

These paintings are nearly identical, but much different in size. The larger panel in Turin is 29 cm x 33 cm, the smaller panel in Philadelphia is 13 x 15 cm. We do not know which was made first. X-ray analysis reveals an underdrawing in the Turin panel that matches van Eyck's hand. Because the Philadelphia painting is made on vellum glued to wood, it is not technically possible to use X-rays.

Close comparison reveals subtle differences. St. Francis has individualized features that suggest portraits of real people, but they look different up close.

Optical projection also does not seem enough to explain stunning and microscopic details in both paintings. Consider the image of the boat on the Po river. In Philadelphia, this boat is not easily seen without a magnifying glass. But van Eyck captures each boater and their individual reflections on the water.

Figure 31: *St. Francis Receiving the Stigmata* by Jan van Eyck, 1430-1432, Left) Philadelphia panel, Right) Turin panel.

Writing

Your first Essay will be due Thursday, Feb 13. 500-1000 words. No penalty for longer.

Walk around the Harvard Art Museum and find a painting or drawing where it seems like the artist has reveled in some purely optical effect to increase the visual interest of their work. Describe the painting and its use of an optical effect. Do some online research about the painter, and see if optics is a recurrent theme in their work. Embed pictures in your essay that make your case..

Reading

- Lawrence Weschler. The looking glass. *The New Yorker*, 31 Jan 2000 Download PDF
- David G. Stork. Optics and realism in Renaissance art. *Scientific American*, 291(6):76–83, 2004 Download PDF

References

- *Van Eyck*. Thames & Hudson, London ; New York, New York, 2020. ISBN 9780500023457
- David Hockney. *Secret Knowledge*. Viking Studio, New York, 2006. ISBN 978-0-14-200512-5

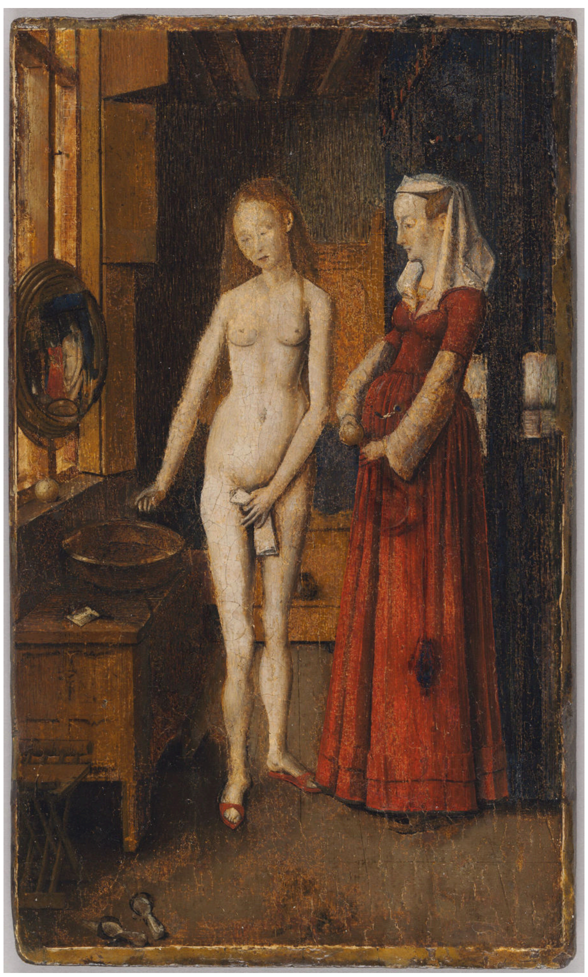


Figure 32: A contemporary of Jan van Eyck claimed that the artist painted a number of pictures like this one. Although these paintings are now lost, this panel, dating to the early sixteenth century, is believed to be a copy after one such work. Link to painting in the Harvard Art Museums.

Updated: February 10, 2025

Week Two - Seeing Perspective

Thursday, 6 February 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums 0600

Figure 33: The Duomo of the Santa Maria del Fiore, viewed from the Michelangelo Hill.

We see in three-dimensions using information that our eyes have flattened onto our retinas. Retinal information has to be *un*-flattened by the brain to recover our sense of depth. Our recovery of 3D spatial information from 2D visual information is both unconscious and effortless. But to make a picture, the artist has to *consciously* translate 3D information onto the 2D plane of a drawing or painting.

Before the Renaissance, artistic efforts to render 3D scenes onto 2D drawings and paintings were intuitive and arbitrary. A geometrically-consistent method for making flat pictures from a 3D view was first discovered by Filippo Brunelleschi (1377-1446), the Florentine architect who also designed the iconic dome of its Santa Maria del Fiore cathedral. At 375 feet, the cathedral still has the largest brick dome that has ever been constructed.

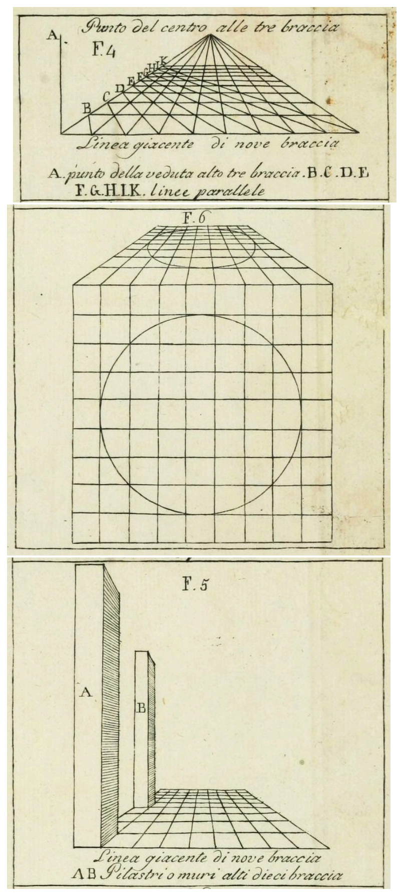


Figure 34: Figures from the 1804 edition of *De Pictura* showing the vanishing point; how a circle is projected as an ellipse; showing the diminishing size of pillars viewed at a distance.

Leon Battista Alberti (1404-1472) put Brunelleschi's discovery of "linear perspective" into print in his *De Pictura* (Fig. 34). Once codified and published, linear perspective exploded across Western art. Despite the sophistication of Greek and Roman geometry and science, there is no evidence that they discovered Brunelleschi's principles for linear perspective. But centuries after the discovery, artists would continue to consult guidebooks in their conscious efforts to make 2D sense of 3D space. Vermeer, for example, owned a copy of *The Book of Perspective* by Hans Vredeman de Vries,

Put simply, Brunelleschi simply discovered what happens to the view of a 3D world in front of a window, when every viewpoint is projected onto the window along lines that end at the fixed eye-point. When this is done, Brunelleschi discovered that parallel lines that are orthogonal to the viewing plane in the real world (lines that never meet in 3D space) will converge to one vanishing point on the picture plane (Fig. 35). Every other set of parallel lines also converges, but to a different unique point on the picture plane. If the parallel lines happen to form a 45-degree angle with the picture plane, then the physical distance between their lateral vanishing point and the central vanishing point is also equal to the physical distance between the eye-point and the picture plane. If you can locate the central and lateral vanishing point in many pictures, you can often calculate where to put your eye in the same location as the artist's eye.

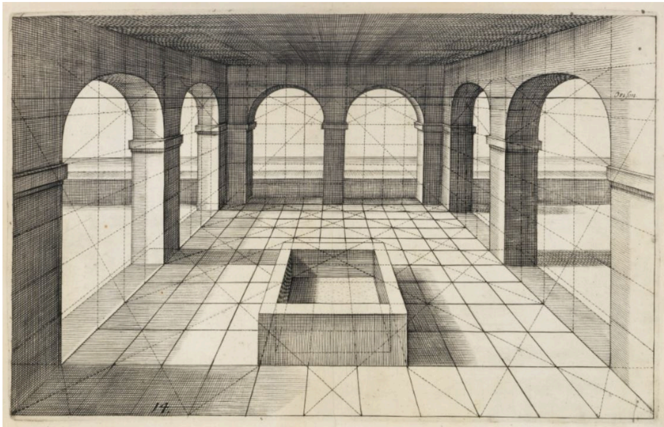


Figure 35: An engraving from *The Book of Perspective* by Hans Vredeman de Vries. De Vries wrote and illustrated a guidebook on perspective that artists of the day, including Vermeer, owned and consulted.

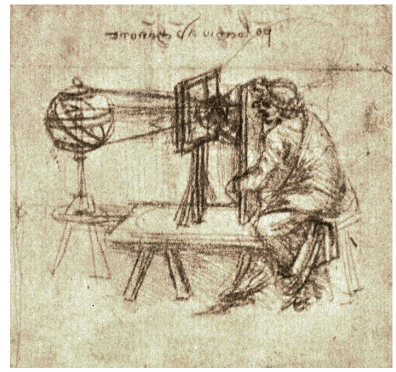


Figure 36: Leonardo's *Draughtsman using a Transparent Plane to Draw an Armillary Sphere*

Linear perspective requires geometric rigor to achieve in full. Because this is so hard to do, it was rarely done in practice. Leonardo da Vinci (1452-1519) and Albrecht Dürer (1471-1528) were both students and admirers of linear perspective. In drawings, they describe mechanical methods to transfer 3D information onto a flat surface. We do not know if da Vinci or Dürer used these tools, but they do suggest a theoretical interest in the principles of Brunelleschi's linear perspective.

> "Perspective must... be preferred to all the human discourses and disciplines. In this field of study, the radiant lines are enumerated by means of demonstrations in which are found not only the glories of mathematics but also of physics, each being adorned with the blossoms of the other." -Leonardo da Vinci

Figure 37: Albrecht Dürer. 1525. *Artist Drawing a Nude with Perspective Device.*

Figure 38: Albrecht Dürer. 1525. *Artist Drawing a Vase.*

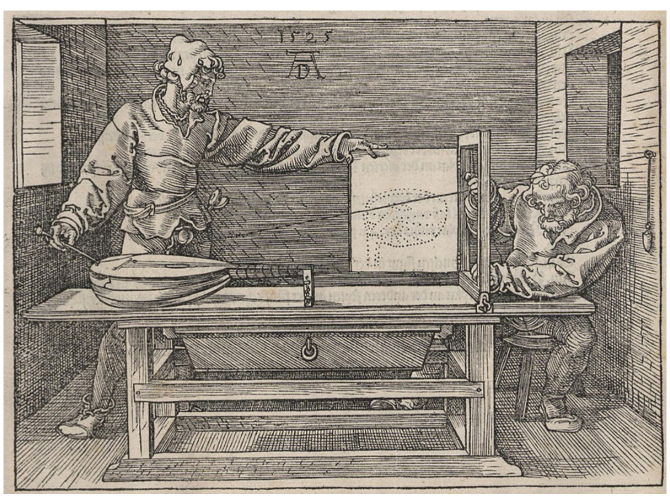


Figure 39: Albrecht Dürer. 1525. *Artist Drawing a Lute.*

An architect, not a painter, discovered the mathematical laws of linear perspective. This might not be surprising. Renaissance painting was dominated by biblical scenes. Without clearly drawn arrays of parallel lines, it is hard to use or visualize the mathematical result of linear perspective. But such lines abound in buildings and architects need to know what these 3D objects *look* like.

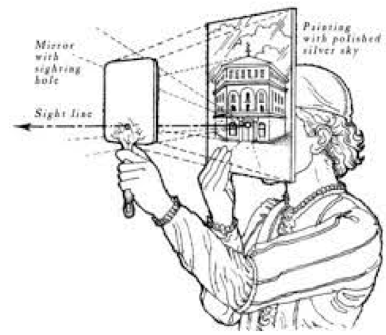


Figure 40: Schematic of Brunelleschi's demonstration panels.

Brunelleschi was well-versed in Euclidean geometry and adept with surveying tools. He likely discovered linear perspective by performing an experiment. Manetti, his earliest biographer, described these experiments as 'demonstration panels'. One set of demonstration panels was of the Baptistery in Florence, an octagonal building with many lines to contemplate. Brunelleschi drilled a hole in each panel at the intersection point with his line of sight. The viewer looked through the back of the panel toward a mirror held in front (Fig. 40). These demonstration panels seemed miraculous at the time. The viewer who raised or lowered the mirror was astonished by the similarity of the real and painted images. The peephole limited the viewer to an immersive view of the Baptistry, perhaps an early form of "virtual reality".

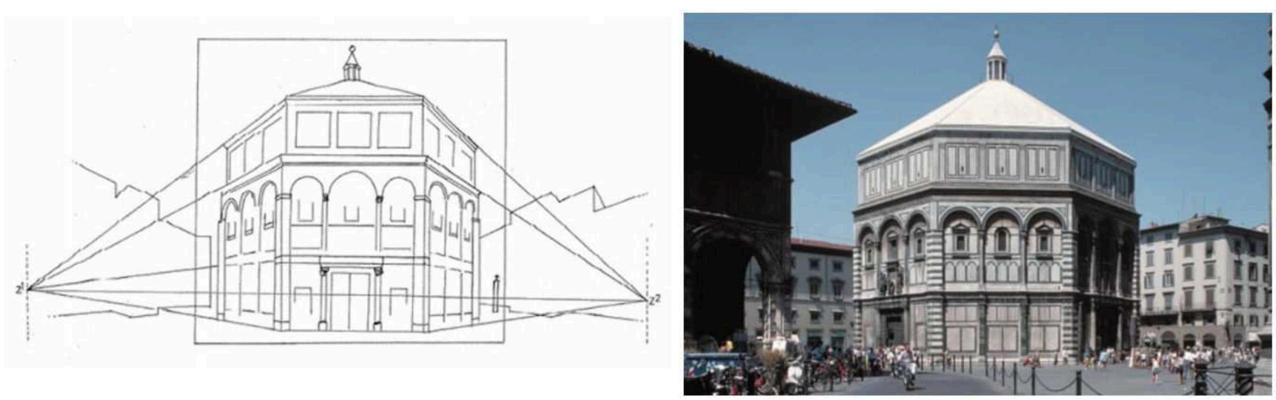


Figure 41: Brunelleschi's first demonstration of linear perspective used the Baptistery of the Florence Cathedral.

Linear perspective, strictly speaking, requires that the painter and viewer *look* at the image in exactly the same way – one eye in front of the same central point, standing at the same distance from the image – so that both painter and viewer *see* the image in the same way. Any difference between the location of the eye of the artist and viewer would lead to a difference in what they see. But if the viewer's eye and the artist's eye were fixed in the same position, the viewer would be treated to an illusion of the 3D space painted by the artist.

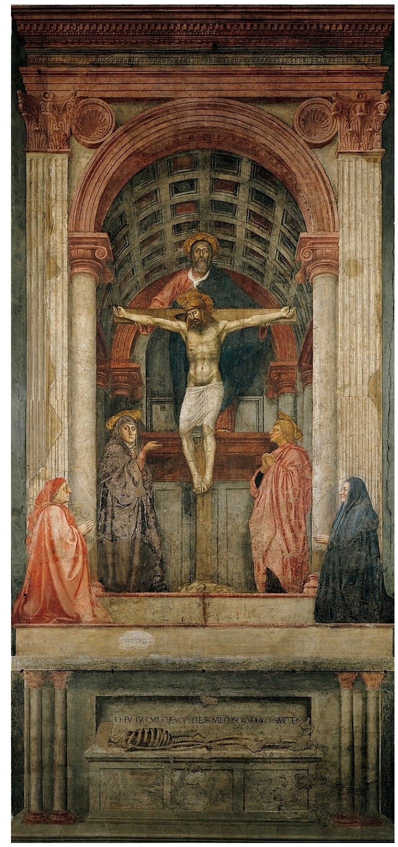


Figure 42: *The Holy Trinity* by Masaccio. Link to artist at Google Arts and Culture.

Masaccio (1401-1428), a younger friend of Brunelleschi, rigorously adopted the rules of linear perspective when painting his massive fresco of *The Holy Trinity* between 1425-1427 in the Dominican church of Santa Maria Novella in Florence. Masaccio was a prodigy who tragically died at the age of 27.

In the Holy Trinity, Masaccio is not transcribing a real visual scene, like what his friend Brunelleschi did with the Baptistery. Instead, Masaccio uses his mathematical and artistic imagination to invent a virtual 3D space in the upper section. Masaccio filled this virtual space with a vault with Jesus on the Cross, God the Father standing behind him, Mary and St. John standing on either side, and the donors (who paid for the painting) kneeling just outside the vault. Masaccio imagined the 3D space, and then predicted the 2D visual image that would be produced if he were kneeling at an altar in front of the huge fresco (263 inches x 125 inches). This altar – which originally divided the upper section from the lower section – is now gone. But the converging lines in the architecture of the upper section clearly defines the line-of-sight that would give the worshipper the illusion of looking into a vault that extends beyond the wall of the Santa Maria Novella cathedral. In the lower section, below the altar, a skeleton lies in a crypt below the vault floor.

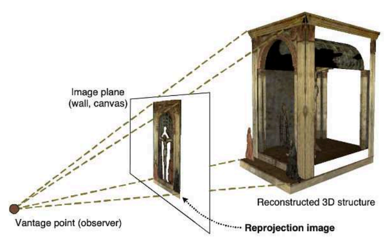


Figure 43: Reprojection image created by projecting the computer three-dimensional reconstruction onto the plane of a painting.

Because Masaccio painted a geometrically-coherent space following Brunelleschi's laws of linear perspective, one can go backward, using computer-based reconstruction to re-imagine the 3D space that first existed in Masaccio's imagination (Fig. 43).

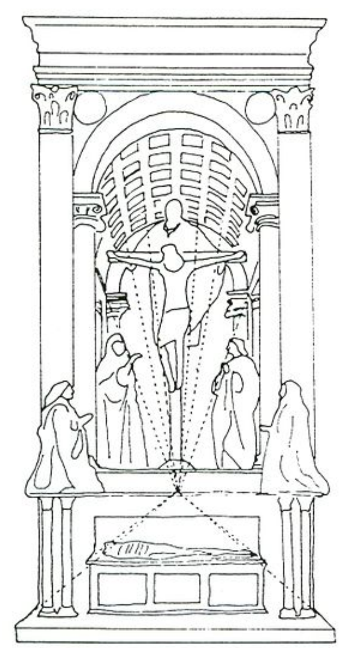


Figure 44: Piero della Francesca, *Resurrection of Christ*, 1465

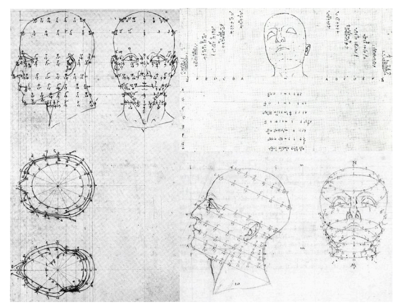


Figure 45: from Piero della Francesca, *De Prospectiva pingendi*, studies that are incorporated in his *Resurrection of Christ*.

LINEAR PERSPECTIVE allowed Masaccio and Brunelleschi to create optical illusions where the viewer might feel that he is looking at a real 3D space. Another way to use linear perspective is to create a realistic stage on which real events might play out. One such stage was created by Piero della Francesca (1415-1492) in *The Flagellation*. In this small painting (23x32 inches), della Francesca built a deep stage populated with actors, one zone for a trio discussing Christ's flagellation for the actors in the rear zone. The tiled floor is not a simple checkerboard, but a complex pattern of triangles, squares, rectangles, and parallelograms. Painting this floor would have required meticulous geometrical planning.

Why go through the trouble? The 3D configuration and shadowing with illumination from the left is hyper-realistic and consistent throughout *The Flagellation* except for the bright light surrounding Christ and the column to which he is bound. Christ is illuminated by a bright light from the right that only he sees. So the entire 3D study of Earth-bound perspective and shadowing is used to emphasize and celebrate a divine, God-given source of light.

Della Francesca must have met Brunelleschi in Florence. His workbooks reveal meticulous mathematical preparations to achieve realistic views of 3D objects. But few other painters after these early experiments by Masaccio and della Francesco used the laws of linear perspective with so little compromise.

Figure 46: *The Flagellation* by Piero della Francesco (1468-1470). Link to Wikipedia.

LINEAR PERSPECTIVE CONTINUED TO BE AN IMPORTANT TOOL in the Renaissance arsenal, but aesthetics and other considerations would win over slavish geometrical consistency accuracy. Leonardo's *Last Supper* depicts another imaginary three-dimensional tableau. The fresco is painted in the refectory of the Convent of Santa Maria delle Grazie in Milan. At 15 x 25 ft, the *Last Supper* covers the entire end wall of this dining room in the monastery. Leonardo favored oil painting which allowed him to work slowly, whereas a fresco (like Masaccio's **Holy Trinity**) is usually made by mixing pigment directly into wet plaster. Traditional fresco painting is long-lasting, but has to be done quickly. So Leonardo made his own medium by mixing tempera and oil. Leonardo's medium proved unstable and the *Last Supper*, revered as his masterpiece, has sadly decayed

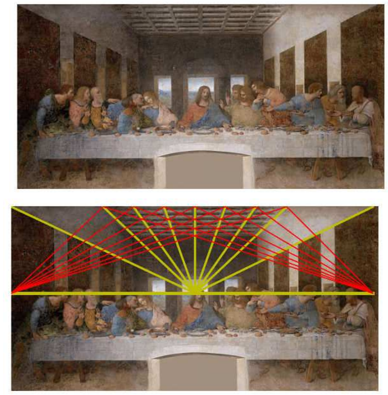


Figure 47: Analysis of *The Last Supper*. The vanishing point at Christ's head can be inferred from the coffered ceiling. Red lines indicate the focus of diagonals two coffers deep. If the coffers are rectangular, twice as wide as long, these foci convey the distance between viewer and image. Kemp (1990).

LEONARDO IMAGINES THE ROOM at the moment when Christ announces that one of the company will betray him. A dramatic scene ensues. Some disciples rush to protest. Others look imploringly to Christ. Peter pushes toward John to whisper in his ear, pushing Judas forward. Unlike the others, Judas does not look surprised, but suspicious. Leonardo gave a unique human reaction, posture, and motion to each apostle. Christ sits calmly in the middle of the storm.

THE ARCHITECTURE OF THE ROOM allows analysis of its linear perspective. Parallel lines on the coffered ceiling converge to the central point at Christ's head. In the actual painting, there is a small nail hole at the central vanishing point. Leonardo probably pulled a taut string from a nail to make the perfectly radiating lines that emanate outward. But the **Last Supper** is painted above the door of the refectory, much too high for any viewer to put their eye at the central line of sight. Leonardo did not intend an optical illusion, where the Last Supper occurs in a room that extends beyond the refectory wall.

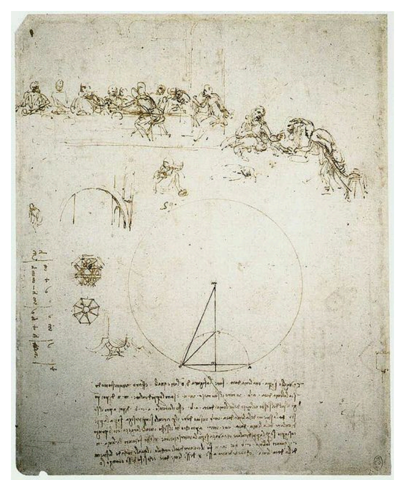


Figure 48: *Study for The Last Supper, with Method of Constructing an Octagon and Arithmetical Calculation*. Leonardo da Vinci.

GEOMETRY REVEALS OTHER AMBIGUITIES. The table is slanted downward, improving its view for the audience but making it difficult to eat from. If the ceiling coffers are square (as one might expect), then the room is much deeper than wide. Whether the coffers are rectangular or square, they allow one to calculate the proportional sizes of the wall tapestries. If the tapestries are the same size, the geometry of linear perspective predicts their relative sizes. But the painted tapestries violate Brunelleschi's laws. The tapestry widths diminish in size in the ratios $1{:}\frac{1}{2}{:}\frac{1}{3}{:}\frac{1}{4}$. In whole numbers, these ratios are 12:6:3, which are musical intervals: a musical fourth interval is 3:4; a fifth interval is 4:6; an octave is 12:6. In the margins of Leonardo's notebooks for the *The Last Supper*, Martin Kemp found a doodled arithmetical progression of these tonal harmonies (Fig. 48) [4]. Leonardo traded geometrical harmony for musical harmony, making little difference to the casual viewer but having some aesthetic meaning to him.

[4] Martin Kemp. *Leonardo da Vinci, The Marvellous Works of Nature and Man.* Oxford University Press, 2006

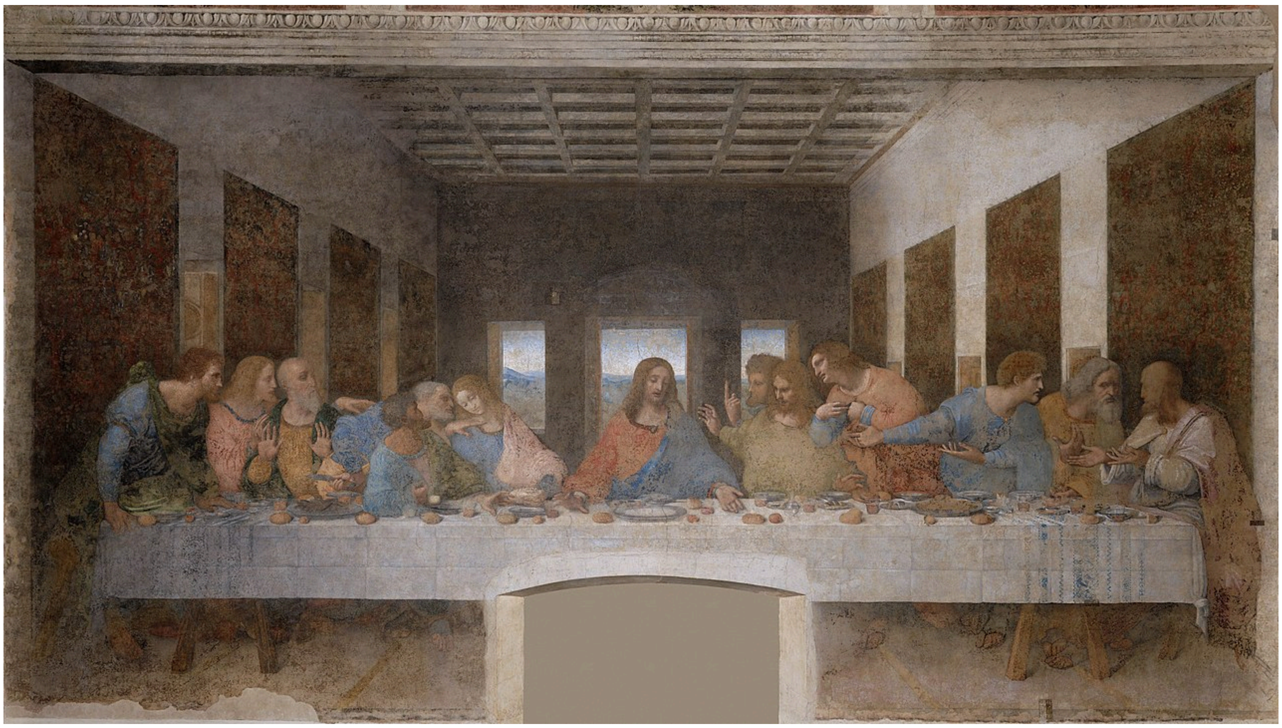


Figure 49: *Last Supper* by Leonardo da Vinci (1Two-1498). Link to official site.

Giovanni Antonio Canal (1697-1768), known as Canaletto, used linear perspective to make photographically accurate views of the Venice, souvenirs for British tourists. The view of Venice in the Harvard Art Museums depicts its principal square, Piazza San Marco, and the domes of the The Basilica of Saint Mark. The sense of linear perspective is strongly enforced by the lines of architecture and patterned pavement.

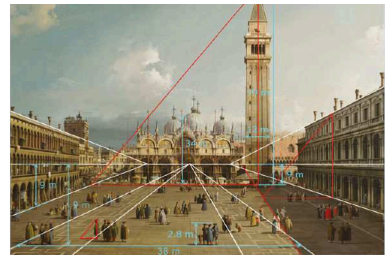


Figure 50: Analysis of Harvard's Canaletto by Erkelens (2019). White lines indicate perspective directions for the Procuratie Vecchie (left), geometric patterns (middle) and Procuratie Nuove (right). Red line and triangles are for analysis of shadows. Computed eye level, heights of the Campanile, Basilica and human figures, and outer width of the patterns are relative to heights of floors of buildings.

Geometric analyses of Harvard's Canaletto reveals both remarkable fidelity to perspective as well as deviations. The position of the vanishing point predicting the eye level of the painter, about 9 m above the Piazza. Canaletto would have needed to stand on a scaffold. The Basilica is painted too large, and has been artificially magnified. The geometric patterns on the Piazza are faithful to reality. Interestingly, the perspective lines converge to three different vanishing points, all on the horizon. This might be due to the fact that the Piazza San Marco is shaped like a trapezoid.

Figure 51: *Piazza San Marco, Venice* Canaletto, c. 1730-1734, Link to painting

Updated: February 10, 2025

PHILIP STEADMAN has compared modern photographs with Canaletto's sketches of extant buildings in Venice, uncovering remarkable fidelity. Most sketches have no ticks to indicate spacing. There are some guidelines, probably made with ruler. Elliptical curves of domes are drawn smoothly. None of this is definitive proof that Canaletto used a camera obscura. Suggestively, Canaletto's sketches take up entire pages, all the way to the edge. Buildings are cut off arbitrarily. One explanation might be that a standard size page in the sketchbook just caught what fell onto it from a camera obscura. If you were drawing freehand, you would probably automatically adjust the size of the image to fit nicely on the paper.

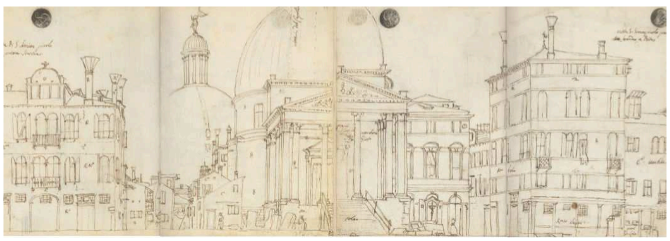


Figure 52: San Simeone Piccolo and adjoining buildings on the Grand Canal.

While 15th century Florentines were calculating and painting illusions of three-dimensional space, Eastern artists went in different directions (Fig. 53). Linear perspective is a choice, not a forward step in an evolutionary history of art. *The Story of Haftvad and the Worm*, painted in Iran in 1540, tells a story of Haftvad eating an apple in the shade of a tree, and who spares the life of the maggot in the fruit. Here, the story of the entire town is told in different areas of this painting. The artist makes no attempt to obey laws of linear perspective. If he had, he would have handicapped his story-telling ability. Although Persian mathematics and geometry were sophisticated when Dust Muhammad painted this scene, the artist did not limit himself by following rules of linear perspective.

Figure 53: *Story of Haftvad and the Worm*, c.1540, by Dust Muhammad in Safavid Iran.

CHINESE PAINTING during the Italian Renaissance continued their long tradition of sophisticated and convincing representations of three-dimensional space without the help (or handicap) of linear perspective. The Chinese artist Qiu Ying (1494-1552) painted architecture as it is experienced not seen. Lines that are parallel in the real world are drawn as parallel in the painted world. Instead of visual perspective, this artist chooses a 'tactile' perspective that is arguably more real. Objects are drawn to look like how they were made.

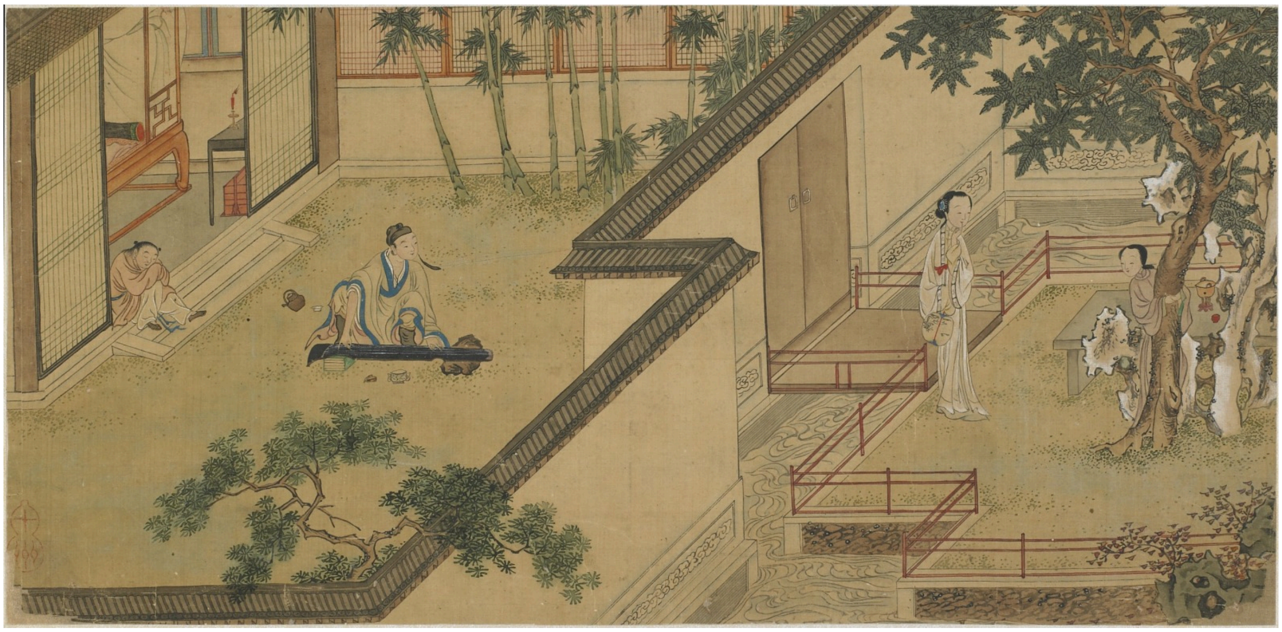


Figure 54: Scenes from *The Story of the Western Wing*, painted by Chinese artist Qiu Ying.

BYZANTIUM thrived for centuries between the Fall of Rome and the Italian Renaissance, preserving much of the scientific and artistic tradition of antiquity. Byzantine artists found their own ways to render space and volume. They often used 'reverse perspective', a technique that captures *more* than linear perspective. The lines of perspective in the *Enthroned Madonna and Child* on the throne and footstool converge towards the viewer, not towards a central vanishing point as in linear perspective (Fig. 56). The result is an intentional and simultaneous view of all planes of the object. Reverse-perspective hints at cubism that would be invented in later centuries. The perspective is called 'reversed' because the depicted objects are between the projective point and the viewing plane, not behind the viewing plane as in linear perspective (Fig. 55).

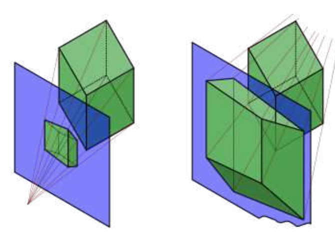


Figure 55: Linear perspective of a cube (left) and reverse perspective (right). The viewing plane is shown in blue, with the projection point where the red lines meet. Link to Wikipedia

Figure 56: *Enthroned Madonna and Child*. Byzantine, 13th century. Link to painting at Google Arts and Culture

DAVID HOCKNEY learned about Byzantine perspective from Martin Kemp, and found ways to incorporate its effects into modern painting. *The Avenue at Middelharnis* by Meindert Hobbema uses trees along an avenue to define strongly converging lines of linear perspective. This landscape is painted within a three-dimensional grid that controls the entire scene. David Hockney made his own version in 2017, *Tall Dutch Trees After Hobbema (Useful Knowledge).* Hockney dissected the scenes onto different panels, turning some panels inside-out by painting them in reverse perspective (Fig. 58)!

Figure 57: *The Avenue at Middelharnis* by Meindert Hobbema, 1689, Link to National Gallery.

Figure 58: *Tall Dutch Trees After Hobbema (Useful Knowledge)* by David Hockney, 2017.

DAVID HOCKNEY quipped that "Photography is all right if you don't mind looking at the world from the point of view of a paralyzed Cyclops." Becoming a paralyzed Cyclops is what happens when the viewer is locked into seeing linear perspective like Brunelleschi. Hockney recognizes that we don't typically look at the world from a single, static viewpoint.

> When a human being is looking at a scene the questions are: What do I see first? What do I see second? What do I see third? A photograph sees it all at once – in one click of the lens from a single point of view – but we don't. And its the fact that it takes us time to see it that makes the space.

Our visual systems not only integrate information from two eyes, but also integrate information over time, dynamically building an internal representation of external scenes as our eyes wander over space. Beyond seeing three-dimensions with geometry, we use additional evidence like shade, luminosity, and context. To 'discover' linear perspective, Brunelleschi forced himself to see like Hockney's paralyzed Cyclops.

Hockney's experiments with reverse-perspective were his conscious efforts to break away from linear perspective. Another experiment was his photocollage of a chair, combining views from different perspectives into one image, retaining the shape of the chair and sense of depth (Figure 59).

Figure 59: *Chair Jardin de Luxembourg* (1985) by David Hockney

Writing

Your second Essay will be due Thursday, Feb 20. 500-1000 words. No penalty for longer. Read Lawrence Weschler and David Stork's articles from Week One. Summarize respective views and disagreements.

Reading

- Martin Kemp. *Visualizations : the nature book of art and science*. Oxford University Press, Oxford ; New York, 2000. ISBN 0198564767
  - Basically Brunelleschian
  - Piero's Perspective
- 'Canaletto's Camera' by Philip Steadman *In*: *Hockney's eye : the art and technology of depiction*. Paul Holberton Publishing Ltd., London, 2022. ISBN 1913645126 Download paper

References

- Antonio Criminisi, Martin Kemp, and Andrew Zisserman. Bringing pictorial space to life: Computer techniques for the analysis of paintings. pages 77–99, 2002
- Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

Updated: February 10, 2025

Week Three - The Gardner Museum

Thursday, 6 February 2024, 12:45 - 2:15 PM EST.
Isabella Stewart Gardner Museum

Figure 60: Isabella Stewart Gardner, 1888 painting by John Singer Sargent

Isabella Stewart Gardner (1840-1924) was a wealthy heiress who dedicated herself to promoting artists including John Singer Sargent (1856-1925) and collecting a world-class collection of art that would eventually be housed in a public museum after her death. She and her husband made several Grand Tours of Europe, during which she bought a number of masterpieces of the Italian Renaissance and 17th century Netherlands, including Vermeer's *The Concert* (1660s) Titian's *Rape of Europa* (1559-1562), Piermatteo de Amelia's *Annunciation* (1497) and Botticelli's *Story of Lucretia* (1496-1504). In 1990, the Vermeer was lost in the largest art theft in history (Fig. 61).

Figure 61: Vermeer's *The Concert*, stolen from the Isabella Stewart Gardner Museum. *NYTimes*, 3/18/1990

Boston Thieves Loot a Museum Of Masterpieces

By FOX BUTTERFIELD
Special to The New York Times

BOSTON, March 18 — Dressed as police officers, thieves broke into the Isabella Stewart Gardner Museum here early this morning and made off with 12 priceless artworks, including paintings by Rembrandt, Vermeer, Degas and Manet.

The daring theft, which the museum said was not discovered until the cleaning crew arrived this morning, is believed to be one of the largest in the world, said the Federal Bureau of Investigation and a museum spokesman.

Corey Cronin, a spokesman for the Gardner Museum, said it was very difficult to place an exact value on the stolen paintings because "they were acquired by Mrs. Gardner at the turn of the century" and have never been offered for sale since then. But an official of the Federal Bureau of Investigation in Boston said he heard estimates today that the paintings could be worth anywhere from $100 million to $200 million.

Updated: February 10, 2025

The Annunciation, Perspective, and Symbolic Form

The Annunciation was a frequent subject of Renaissance Christian Arts, depicting Gabriel announcing to Mary that she would conceive a child to be the Son of God. It depicts the story told in the Gospel of Luke.

> And in the sixth month the angel Gabriel was sent from God unto a city of Galilee, named Nazareth, to a virgin espoused to a man whose name was Joseph, of the house of David; and the virgin's name was Mary. And the angel came in unto her, and said, Hail, thou that art highly favoured, the Lord is with thee: blessed art thou among women. And when she saw him, she was troubled at his saying, and cast in her mind what manner of salutation this should be.
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> And the angel said unto her, Fear not, Mary: for thou hast found favour with God. And, behold, thou shalt conceive in thy womb, and bring forth a son, and shalt call his name Jesus. He shall be great, and shall be called the Son of the Highest: and the Lord God shall give unto him the throne of his father David: and he shall reign over the house of Jacob for ever; and of his kingdom there shall be no end.
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> Then said Mary unto the angel, How shall this be, seeing I know not a man? And the angel answered and said unto her, The Holy Ghost shall come upon thee, and the power of the Highest shall overshadow thee: therefore also that holy thing which shall be born of thee shall be called the Son of God. And, behold, thy cousin Elisabeth, she hath also conceived a son in her old age: and this is the sixth month with her, who was called barren. For with God nothing shall be impossible. And Mary said, Behold the handmaid of the Lord; be it unto me according to thy word. And the angel departed from her. -Luke 1:26–38, KJV

Figure 62: *The Annunciation* by Jan van Eyck, 1434-1436. Link to painting.

Jan Van Eyck's *Annunciation* is especially detailed with delicate and precise optical effects, light reflecting and refracting through windows and jewels. But Van Eyck also includes symbols that appear in thousands of paintings of this scene throughout the Renaissance, which would have been recognized any Christian worshipper. God's sight is indicated by a shower of light rays. The Holy Spirit is sent as a Dove. White lilies are a symbol of Mary's purity.

A religiously-devout painter, tasked with rendering a religious scene, might be religious about attending to every detail in their effort to do full justice to every earthly reality that begins as God's creation. But Van Eyck distorts one aspect of reality, linear perspective. He would not know about Brunelleschi's discovery of the laws of linear perspective, and so parallel lines in this and other paintings do not converge to common points.

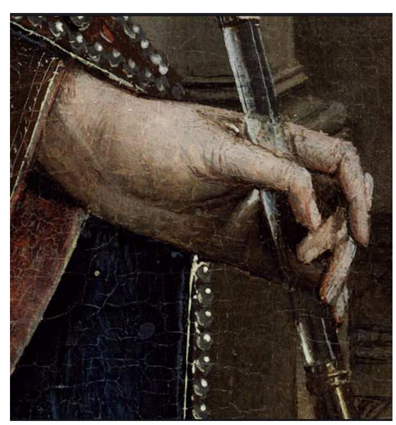

Figure 63: Cylindrical lensing in a close-up of Gabriel's hand.

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After Brunelleschi discovered linear perspective, artists began to use geometry to add symbolic form and narrative meaning. Martin Kemp made his switch from natural science to art history as an undergraduate at Cambridge University, when he saw a different rendition of the same holy moment, *The Annunciation* by Domenico Veneziano (1410–61), the small central panel of the St. Lucy Altarpiece (10" x 21"). Piero della Francesca, another master of linear perspective and geometry, was likely Veneziano's student.

Here, Veneziano uses linear perspective as a staging device that separates the scene into three. The left courtyard has the kneeling Gabriel and white lily. The central passage leads to a garden and closed door. The right *loggia* – room with open sides – has Mary in prayerful humility. The central vanishing point guides the eye to the closed door and trellis of roses without thorns – symbols of Mary's chastity. The painting has been trimmed on its left side, explaining the upset symmetry.

Figure 64: *Annunciation*, Domenico Veneziano, c.1442-48. Fitzwilliam Museum.

X-ray analysis reveals cuts in the white gesso priming that Veneziano used to create the geometry of the scene before he began painting, from the central vanishing point to the radiating lines that define the orthogonals within the three-dimensional space of the encounter between Mary and Gabriel.

David Hockney had his first encounter with Renaissance art as an eleven-year old in 1948, seeing a poster reproduction of Fra Angelico's *Annunciation.* (Fig. 65). Hockney still thinks about the construction of linear perspective in Fra Angelico's *Annunciation*. In 2017, he responded to Fra Angelico with his own *Annunciation* where the perspective is 'reversed', instead of lines of perspectives converging to a central vanishing point, the lines of perspective expand outward, more like how we experience a wide vista with our visual perceptions (Fig. 66). As an eleven-year old, Hockney had a turning point:

> At the age of eleven, I decided, in my mind, that I wanted to be an artist, but the meaning of the word "artist" to me then was very vague – the man who made Christmas cards was an artist, the man who painted posters was an artist, the man who did lettering for posters was an artist. Anyone was an artist who in his job had to pick up a brush and paint something... The idea of an artist just spending his time painting pictures, for himself, didn't really occur to me. Of course, I knew there were paintings you saw in books and in galleries, but I thought they were done in the evenings, when the artist had finished painting the signs or the Christmas cards or whatever they made their living from.

Figure 65: Fra Angelico, *The Annunciation*, 1440-1445, fresco, San Marco, Florence.

Figure 66: David Hockney, *The Annunciation*, 2017, acrylic on canvas, 121.9 cm x 243 cm.

THE THEOLOGICAL PROBLEM of representing the Gospel as realistically as possible led to the widespread use of linear perspective in painting the Annunciation. But another thorny theological problem was posed by the story itself, the problem of immaculate conception. How might the Son of God be created without physical contact? Optics provided one answer to artists as theologians – light creates vision without physical contact. The golden rays of light that shine from God to Mary in countless paintings of the *Annunciation* can be interpreted as an artistic representation of divine light leading to immaculate conception. This property of the painting introduces an interesting discourse on the science of vision as it was understood during this time period.

Figure 67: *The Annunciation*by Filippo Lippi, c.1449–1459, in the National Gallery, London is painted as a lunette that was likely placed above a door or bed.

LEO STEINBERG looked closely at *The Annunciation* by Fra Filippo Lippi (1406-1469), he found a surprise. On close inspection, the Dove/Holy Spirit sends golden rays towards Mary, just like many other paintings of the scene. But in this painting, Mary's womb *returns* golden light.

From antiquity to the Renaissance, there were two schools of thought about human vision. An *extramission* theory by Galen held that visual perception was triggered by beams emitted by the eye – consistent with divine light emanating from God in many paintings. The *intromission* theory, which we now know to be correct, is that vision happens when rays of light are reflected from objects onto the eye. Filippo Lippi, a friar, might have heard of a theory by by Roger Bacon (1219-1292), an English friar who intertwined Catholic faith with scientific thinking. Bacon suggested that both intromission and extramission were true – beams of light from the eye are reflected back – and this composite idea might have been put into paint by Filippo Lippi. Filippo Lippi *was* trying to capture reality. But reality is what you think it is.

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LEONARDO DA VINCI'S *Annunciation* is his earliest major work, painted when he was an apprentice in the studio of Verrocchio. Leonardo paints the architecture following the rules of linear perspective with a central vanishing point. Lines cut into the gesso underlayer reveal the method by which he effectively calculated the geometry. These cut lines radiate from the central vanishing point and a lateral vanishing point at the very right edge of the painting. Intersections between these two sets of radiating lines define the layout of the tiled floor under Mary.

Figure 68: *The Annunciation* by Leonardo da Vinci, c.1472–1476, in the Uffizi is his first complete narrative work (39 in x 85 in).

PIERMATTEO D'AMELIA (1445-1503), a contemporary of da Vinci in Florence, painted his *Annunciation* with the narrative form of linear perspective that guides the eye to a distant garden. Every painter of this biblical scene faced the challenge of finding a new way to tell the same story that under the strong constraints of religious tradition.

Figure 69: *The Annunciation* by Piermatteo d'Amelia (1483).

Scenes from Antiquity

SANDRO BOTTICELLI (1446-1510), another Florentine contemporary, often painted scenes from classical antiquity. Greek myth was a secular sources of inspiration in the Renaissance.

Botticelli's best known painting might be *The Birth of Venus*, a massive canvas with three narrative spaces. In the middle, the goddess emerges from the sea on a shell. On the left, wind-gods blow her to shore. On the right, a Nymph receives her with outspread cloak.

Botticelli achieves harmony and divides space without respect to linear perspective. The figures are laid out in the two-dimensional plane of the painting. The artist also takes liberties with human anatomy. Venus has an unnaturally long neck, left shoulder that falls too steeply, and left arm with an unusual hinge.

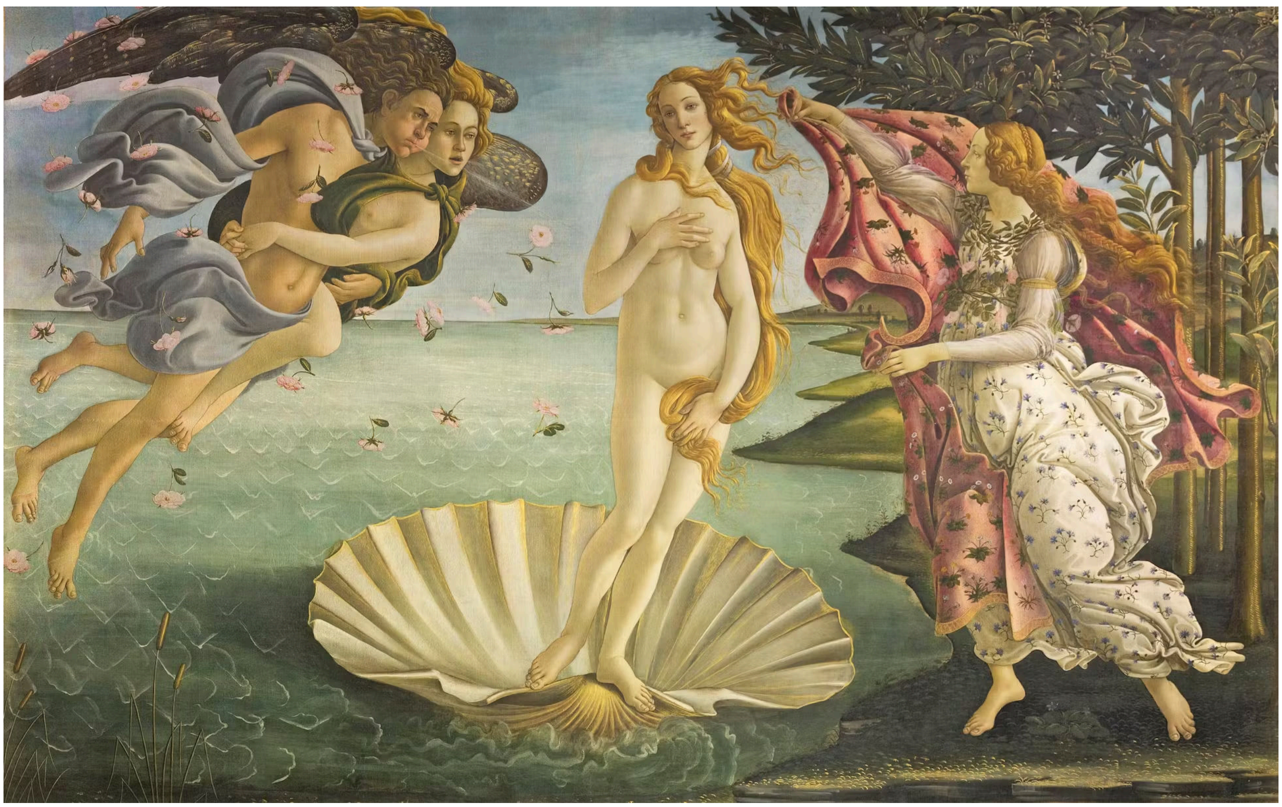

Figure 70: *The Birth of Venus* by Sandro Botticelli (1480s). 68 in x 110 in.

The Story of Lucretia traditionally marks the transition of Rome from monarchy to Republic. In 510 BC, Lucretia was a noblewoman who was raped by Sextus Tarquin, the son of the last king of Rome. Her subsequent suicide was the spark that led to the rebellion that brought down the Roman monarchy.

Botticelli tells the story in his *Story of Lucretia* at the Gardner, painted between 1496-1504. Here, Botticelli uses narrative space to create three separate scenes that tell the story in episodes. The scene in the left porch shows Tarquin threatening Lucretia with his sword when her husband is away. The scene on the right porch is her death, she had stabbed herself in front of her husband after telling her story. The scene in the middle is the legendary funeral oration. Lucius Junius Brutis stands over her body, raising a revolutionary army to overthrow the Tarquins. Botticelli mixes a revolutionary scene from the Old Testament into the narrative, putting a statue of David, with Goliath's head at his feet, on the central pedestal.

Figure 71: *The Story of Lucretia Venus* by Sandro Botticelli.

THE RAPE OF EUROPA tells another horrific story, a Greek myth from Ovid's *Metamorphoses.* After the generation of the giants in Florence – Michaelangelo, Raphael, and Leonardo da Vinci – Tiziano Vecellio (1488-1576) emerged in Venice as the most important painter of his time.

Titian (the commonly-used English translation of his name) was sought by patrons from across Europe.

The Rape of Europa, painted in 1560-1562, was one of three massive paintings that were commissioned by Philip II of Spain. In this story, Zeus assumed the form of a bull to lure Europa to Crete, where she would eventually become the first Queen of Crete. Titian depicts the abduction that foreshadows the violence.

Isabella Stewart Gardner considered this painting to be a jewel of her collection, spending hours looking at it, the brutal narrative notwithstanding.

Figure 72: *The Rape of Europa* by Titian, 70"x81".

Writing

Your third Essay will be due Thursday, Feb 27. 500-1000 words. While there was no special formula for making paintings of the Annunciation, many themes and symbols were used in different ways. Pick one such painting from the Renaissance, either from this reading or from your own search, and describe how the artist tells the story in their own unique way, along with the differences and commonalities with other contemporary portrayals. If relevant, relate thematic elements in your chosen painting to optics and/or linear perspective.

References

- Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6
- Erwin Panofsky. *Perspective as Symbolic Form*. Zone Books ; Distributed by the MIT Press, New York : Cambridge, Mass., 1st ed. edition, 1991. ISBN 0942299523

Figure 73: *The Rape of Europa*, a faithful copy by Rubens in 1628-1629, 72"x79".

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