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

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Renaissance artists began to create stunningly realistic representations of their world. Paintings started to resemble photographs, suggesting that artists had solved technical problems that escaped their forebears. Our brains effortlessly deduce three-dimensional scenes from two-dimensional images. But faithfully transferring spatial information to a flat canvas – a sense of depth, surface and shadow, geometrical accuracy – is hard to do. We will discuss how artists from van Eyck to Vermeer to Ingres to modern artists might have used science to make art. We will ask how devices like pinhole cameras, mirrors, and lenses might help artists see more deeply and create images more faithfully. We will perform science experiments with our own hands to appreciate how optical devices might be useful to artists. We will try to use devices to create our own artwork. We will meet artists and scientists who think about art and optics from different perspectives. Our seminar is a synthesis of art history, art making, and science. **Prerequisites:** No prior training in art or science. We will learn how to draw in our own workshop. We will learn the science of optics 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.

The visual arts and the sciences have progressed side-by-side for centuries, from the Renaissance to now. How have science and technology, particularly optics, affected Western art from van Eyck to da Vinci to Vermeer? The Dutch Golden Age, in particular, saw dialogues between science and art. At the same time that Christiaan Huygens (1629-1695) was developing the astronomical telescope and Antonie van Leeuwenhoek (1632-1723) was developing the microscope and discovering microorganisms, Dutch painters – including Vermeer (1632-1675), Carel Fabritius (1622-1654), and Saenredam (1597-1665) – were enriching paintings with optical qualities, incorporating reflection, refraction, light, shadow, and geometrical perspective with ever greater accuracy and freedom. In fact, Leeuwenhoek and Vermeer were born in the same year in the same small town of Delft. The artist and scientist likely knew each other. Leeuwenhoek might even be the young man in Vermeer's *Astronomer* and *Geographer* (Fig. 1). [1]

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

Updated: February 26, 2024

David Hockney, contemporary artist and provocateur, has long been inspired by optical qualities in picture-making across the centuries. His controversial 'Hockney Thesis' is that artists have not just been inspired by optics, but that artists have used optical tools like mirrors, lenses, and prisms to *make* paintings with more regularity than historical records or historians will admit. Hockney's suggestions are debated by some and dismissed by others. Did van Eyck really use a spherical mirror to make optical projections of scenes when painting? Did Ingres really use a camera lucida to rapidly and accurately draw portraits? Either way, a dialogue between optics, science, and Western art across centuries has occurred. We use this dialogue as a starting point to think about the history and practice of picture-making, starting with questions about technology but journeying further.

Figure 2: *The Arnolfini Portrait* by Jan van Eyck (1390-1441) in the National Gallery of London, and Link to all of van Eyck's Paintings.

In our photographic age, optics are everywhere. Our smartphones are extraordinary imaging-making devices that did not exist a few years ago. We take optics and picture-making for granted. Once upon a time, optical effects had to be discovered, understood, and codified before artists could incorporate them into paintings. Jan van Eyck (1390-1441) clearly reveled in the optical effects of reflection and refraction, portraying these complex plays of light with care and precision. The spherical mirror depicted on the back wall of his *Arnolfini Portrait* is so carefully painted that the room can be reconstructed from its curved reflections (Fig. 2).

Figure 3: 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.

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. 3). Playing with concave mirrors and projected images, Hockney became convinced of their effectiveness as drawing aids. 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. [2]

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

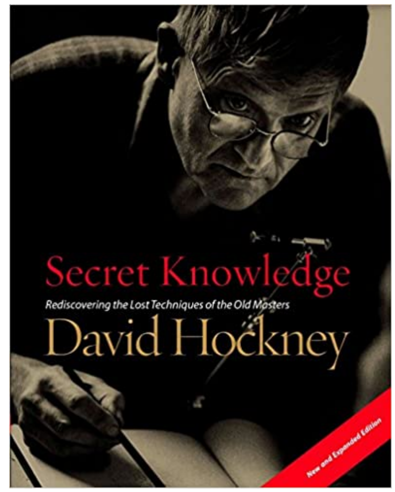

Figure 4: David Hockney using a camera lucida on the cover of his book.

OUR GOAL is not to settle debates. These debates will never end, not without hard evidence. Without hard evidence that Old Masters used tools – like concave mirrors or the camera obscura or the camera lucida – Hockney is free to speculate that they did. Hockney argues based on selected qualities of pictures themselves, the theme of his book *Secret Knowledge.* The absence of evidence is not evidence of absence. Nevertheless, historians of art and science are justifiably skeptical. It is dangerous to argue, like Hockney, that the absence of hard evidence that artists used optical tools is due to secretive hiding of evidence across centuries. Whatever happened in art history, Hockney's speculations have fed his creativity. The reflections on the rear and side walls of his *Ready-made with Skull and Mirrors* seem to reflect Hockney's thoughts about van Eyck, whether or not the historical van Eyck used mirrors.

Figure 5: *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.

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 what artists have made of our world across centuries. Artists have seen more deeply and worked more effectively with insights from science. Our goal is to enrich ourselves in the same way, with a journey across art and science from the Renaissance to now.

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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 at the SMFA and Abe Morell, a camera obscura artist – and artists who don't – Susan Lichtman, a figurative painter at Brandeis and Nard Kwast, a Dutch painter who incorporates 'Old Master' techniques (Fig. 6).
- **Science Experiments**. Appreciating the interplay between optics and art requires technical intuition. We will gain an understanding of optics, mirrors, lenses, reflection, and refraction by hands-on experimenting, not with equations (Fig. 7).
- **Field Trips**. We will visit local museums, especially the collections of the Harvard Art Museums and the MFA. We will visit the Boston Public Library to see their iconic murals by John Singer Sargent. We will study original artworks, evaluate their optical and aesthetic qualities, and think about the skill and technology that went into their making (Fig. 8).

Figure 6: 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.

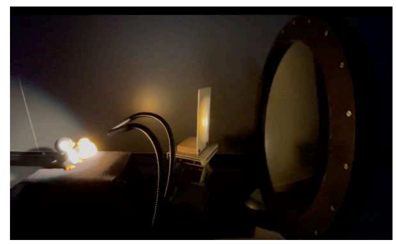

Figure 7: *The Arnolfini Ducky* by Daniel Davis. The image of a brightly illuminated object will be focused on a flat surface by a concave mirror at an appropriate distance and with an appropriate curvature.

We will usually meet in Harvard Art Museums 0600. Except when we take field trips when we will Uber to the MFA and Boston Public Library. We will occasionally use HAM's Art Study Center to look closely at works in Harvard's collection. We will also use HAM's M-Lab, its maker space, to perform experiments and make art. We meet Thursdays from 12:45–2:45 PM.

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 us to make our own pictures with paintbrush or pencil.

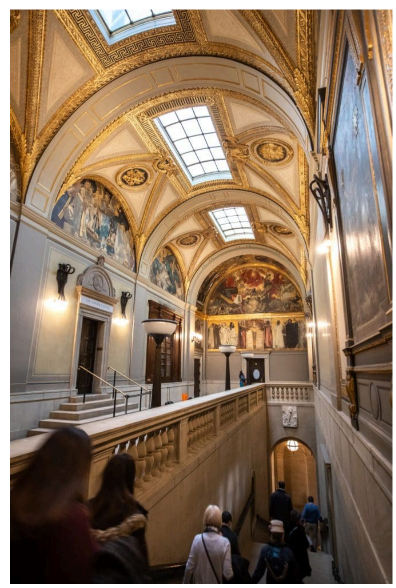

Figure 8: John Singer Sargent's mural cycle in the Boston Public Library, called the *Triumph of Religion*, was a central occupation of his life. We will visit the paintings and the extraordinary work that Sargent put into it.

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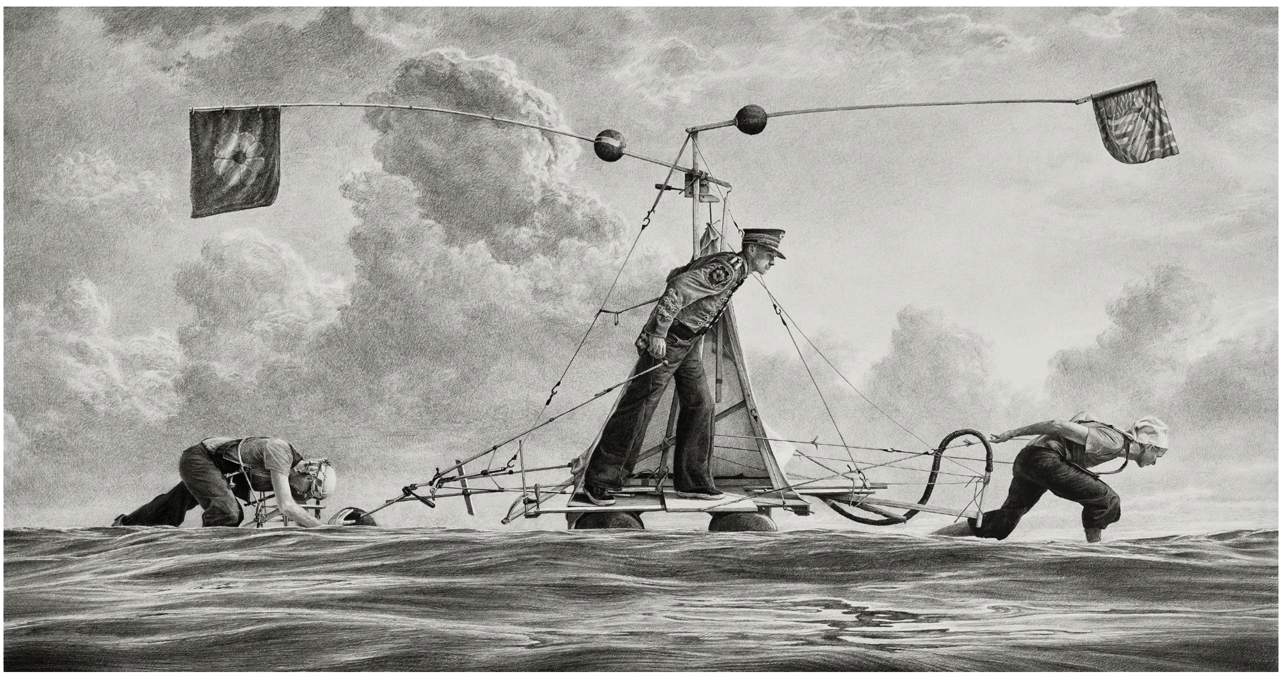

Figure 9: *For All Intents and Purposes* by Ethan Murrow. Graphite on Paper, 52" x 100".

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.

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.

Susan Lichtman is a figurative painter of domestic spaces. She is Professor of Painting at Brandeis. Susan'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.

Michelle Luo '14 studied computer science at Harvard. She has worked as a product manager at Google Arts and Culture where she created vision and strategy for Apps to find and view artwork.

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.

Kate Smith, Senior Conservator of Paintings at the Harvard Art Museums, played a major role in the restoration of the Sargent murals at the Boston Public Library.

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

Philip Steadman is the author of *Vermeer's Camera*, a deep exploration of how Vermeer might have used a camera obscura to render his domestic scenes.

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Link to Gallery of Student Art

Figure 10: *School Class with a Sleeping Schoolmaster* by Jan Steen, 1672

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Calendar

Class Meeting	Topic	Hands-on Projects
Week 1. Jan 25	Introduction	Drawing with mirrors
Week 2. Feb 1	Seeing color	Creating color with Susan Lichtman
Week 3. Feb 8	Silhouette and shadow	The physiognotrace with Penley Knipe
Week 4. Feb 15	Ingres and Hockney	Drawing with a camera lucida
Week 5. Feb 22	Perspective from Brunelleschi to Vermeer	The camera obscura and Philip Steadman
Week 6. Feb 29	Virtual Museums and Google Arts and Culture	Generative Imagery with Michelle Luo
Week 7. Mar 7	Field trip to the SMFA	Drawing with Ethan Murrow
Week 8. Mar 21	Painting in the Dutch Golden Age	Painting with Nard Kwast
Week 9. Mar 28	Field trip to the Boston Public Library	Painting restoration with Kate Smith
Week 10. Apr 4	The camera obscura	Photography with Abe Morell
Week 11. Apr 11	Bonnard, de Witte, de Hooch	Painting with Susan Lichtman
Week 12. Apr 18	Field trip to the MFA	Early Netherlandish painting with Chris Atkins

Figure 11: *The Baptistry in Florence* by Abe Morell, photograph taken with tent camera obscura.

Figure 12: *Family After a Meal* by Susan Lichtman.

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Reserve Reading in Lamont Library

- Ernst Gombrich. *Art and Illusion: A Study in the Psychology of Pictorial Representation*. Princeton University Press, 2000. ISBN 0691070008
- David Hockney. *Secret Knowledge*. Viking Studio, New York, 2006. ISBN 978-0-14-200512-5
- Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6
- Abelardo Morell. *Camera obscura*. Bulfinch Press, New York, NY, 1st ed. edition, 2004. ISBN 0821277510
- Asma Naeem. *Black Out: Silhouettes Then and Now*. Princeton University Press, Princeton, New Jersey, 2018. ISBN 069118058X
- Philip Steadman. *Vermeer's Camera*. Oxford University Press, 2001. ISBN 978-0-19-280302-3
- Arthur K Wheelock. *Vermeer & the art of painting*. Yale University Press, New Haven, 1995. ISBN 0300062397

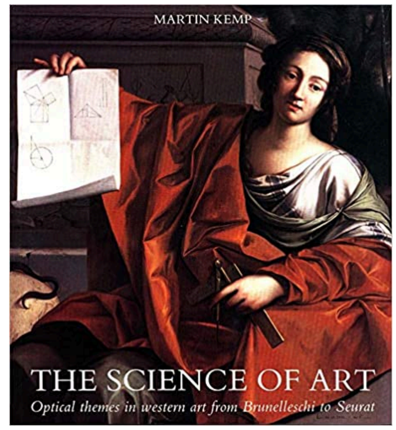
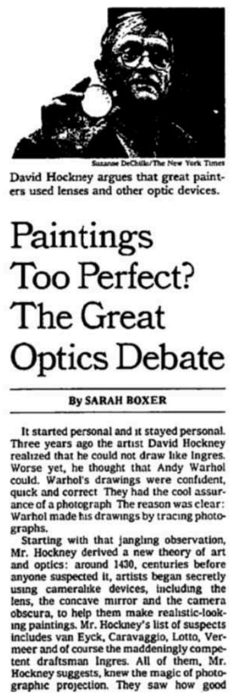


Figure 13: *Still Life with Books.* by Jan Lievens, c. 1627–1628.

Week One - Paintings too Perfect?

Thursday, 25 January 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums 0600

'Paintings too perfect?' is the *New York Times* article about the origin of 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 seemingly supernatural level of photographic perfection in his drawings and paintings (Fig. 14). Hockney knew why he did not draw as well as his friend Andy Warhol (Fig. 16). Warhol drew better than Hockney when he traced optical projections. Might Ingres also have gotten help from an optical device?



Suzanne DeChillo/The New York Times

David Hockney argues that great painters used lenses and other optic devices.

Paintings Too Perfect? The Great Optics Debate

By SARAH BOXER

It started personal and it stayed personal. Three years ago the artist David Hockney realized that he could not draw like Ingres. Worse yet, he thought that Andy Warhol could. Warhol's drawings were confident, quick and correct. They had the cool assurance of a photograph. The reason was clear: Warhol made his drawings by tracing photographs.

Starting with that jangling observation, Mr. Hockney derived a new theory of art and optics: around 1430, centuries before anyone suspected it, artists began secretly using cameralike devices, including the lens, the concave mirror and the camera obscura, to help them make realistic-looking paintings. Mr. Hockney's list of suspects includes van Eyck, Caravaggio, Lotto, Vermeer and of course the maddeningly competent draftsman Ingres. All of them, Mr. Hockney suggests, knew the magic of photographic projection. They saw how good

Hockney's evidence was the artwork itself. Ingres's drawings are photographic in parts and imperfect in other parts. Maybe the perfect parts had been traced and the other parts "eyeballed" (to use Hockney's word for it). As Hockney reviewed the progression of Western art from the Renaissance to now, he seemed to find a centuries-long conspiracy. Hockney thought the artwork pointed to the comprehensive use of optical aids to make naturalistic illusions, from van Eyck to Vermeer to Ingres. Historical records harbor little evidence that most artists owned or used devices – mirrors or lenses or prisms – as art-making tools. Artists who acknowledged optical tools were the exception, not the rule. Leonardo da Vinci knew how to project an image with a pinhole camera. Canaletto used a camera obscura to draw landscapes. The spotty historical record did not trouble Hockney. Hockney argued that jealous artists would guard the tools of their trade, hiding evidence from history. Hockney suggested that the use of optical tools in art-making was *Secret Knowledge*, the title of his book. [3]

Figure 14: *Portrait of Madame Charles Hayard and Her Daughter Caroline* by Ingres. Link to drawing at the Harvard Art Museums.

Figure 15: Hockney knew that Warhol traced these drawings using a projector, thus their confident, unerring lines.

Figure 16: *Drawing of Lancaster*, David Hockney. This drawing is 'eyeballed' without the use of any optical tool. Link to drawing at the Harvard Art Museums.

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

I DISCOVERED THE HOCKNEY THESIS in a *New Yorker* by Lawrence Weschler, an admirer of Hockney (see Reading). There is a compelling historical coincidence. When Ingres was drawing photograph-quality portraits, the physicist William Wollaston was championing the camera lucida for drawing. The camera lucida allows the user to see a superposition of subject and drawing, allowing accurate tracing. In fact, the camera lucida has been a favored tool in the natural sciences to make drawings, often preferred to photography. When Hockney used a camera lucida to make art (see the cover of *Secret Knowledge*), 'photographic' portraits indeed became easier (Fig. 17). The quantitative part – capturing the proper size and proportion of facial features – was done by the camera lucida. The 'art' was done by hand and eye.

Figure 17: *Camera lucida drawing of Martin Kemp* by David Hockney.

HOCKNEY ADMIRED PHOTOGRAPHIC NATURALISM in the paintings of Ingres and others. But he also insists that photography and photographic naturalism will never replace painting 'because it is not real enough.' Reality is not an optical match. Painting is an act of communication from the mind of the painter to the viewer. Visual truth does not necessarily demand photographic accuracy. Compare Figs. 18 and 19.

Figure 18: Self-portrait by Hockney wearing an "eyeballed" tweed suit. Hockney's clothing is certainly less 'photographic' than Madame Leblanc's dress, but is it any less real?

Figure 19: *Madame Jacques-Louis Leblanc* by Ingres and its Link at Google Arts and Culture. The folds and intricate pattern of the dress are an exquisite 'photographic' illusion. The dress is certainly more 'accurate' than Hockney's tweed jacket, but is it any more real?

Figure 20: A camera lucida in the Harvard Museum of Scientific Instruments.

Before the camera lucida, other optical devices would have been used. The convex mirror in the back of van Eyck's *Arnolfini Portrait* in 1434 might have been turned around to reveal a concave mirror that can, in principle, cast an optical projection. Hockney speculated that if Van Eyck could *paint* a spherical mirror, he could *use* a spherical mirror. Hockney experimented with modern concave mirrors, and convinced himself that they can also be helpful in drawing with photographic accuracy. We will repeat the experiment. It's tricky, but fun and instructive. Watch a video of the experiment, performed by Daniel Davis (see video).

Tim Jenison, an inventor who works in computer graphics, also wondered whether simple tools could help draw or paint with photographic realism. Tim had read Philip Steadman's book *Vermeer's Camera*, which suggested that Vermeer might have used a camera obscura to capture the linear perspective in his many paintings of interior Dutch scenes. The trouble with a camera obscura, as Tim discovered, is that it allows the tracing of outlines (sufficient for linear perspective) but not capturing tone and color. Vermeer masterfully captured the subtle effects of light and shadow in his paintings. Tim invented his table-top comparator mirror that facilitates drawing, using a front-surface mirror instead of a prism like a camera lucida. With a telescope made of a lens and curved mirror, Tim built a device that allowed him, with no painting experience, to paint a reasonable copy of Vermeer's *Music Lesson*. These adventures are recounted in the film *Tim's Vermeer*. We will repeat the experiment with the comparator mirror (Fig. 21).

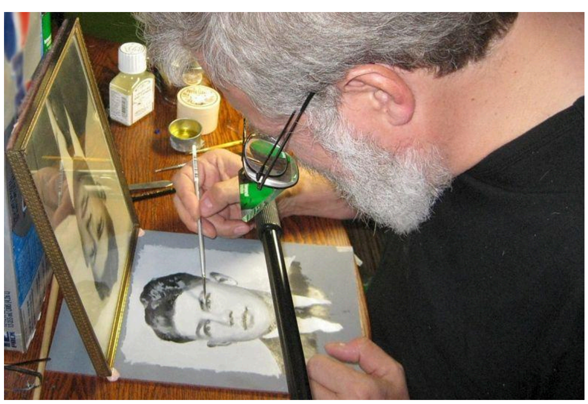
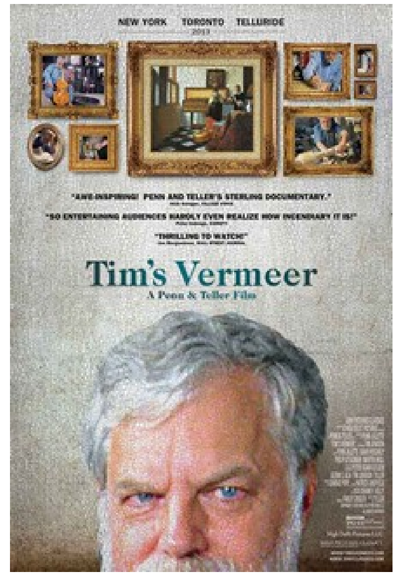


Figure 21: Tim using a comparator mirror system to copy an image onto paper.



DAVID STORK, a scientist and 'art analyst', doubts the historical reality of Hockney's thesis and *Tim's Vermeer*. The lack of historical evidence that optical tools were comprehensively used is troubling. Skilled artists, with sufficient training and hard work, can accomplish extraordinary things without help. Read Stork's arguments, and judge for yourself.

ARTHUR WHEELOCK, an art historian and former Curator of Northern Baroque Paintings at the National Gallery of Art in Washington D.C., also thinks deeply about 'opticality' in Vermeer. Wheelock's study leads him to a different perspective about why Vermeer so diligently sought to portray light, shadow, and geometry. Vermeer did not want to *become* the best camera he could be to capturing visual truth. Vermeer, a religious man in a religious time, wanted to capture the deeper truth of the illuminated world as divine creation. Read Wheelock for this biographical and historical context.

Reading

- Lawrence Weschler. The looking glass. *The New Yorker*, 31 Jan 2000 Download PDF
- Arthur K. Wheelock. Vermeer becoming Vermeer. *Artibus et historiae*, (84):307, 2021 Download PDF
- David G. Stork. Optics and realism in Renaissance art. *Scientific American*, 291(6):76–83, 2004 Download PDF
- David G Stork, Christopher W Tyler, and Sara J Schechner. Did Tim paint a Vermeer? *Journal of Imaging Science and Technology*, 64: 60403–1–60403–12, 2020 Download PDF

Looking

- *Tim's Vermeer* Link to Movie on course website
- Link to today's slides

Week Two - Color

Thursday, 1 February 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums 0600

We see with different photoreceptors cells for dim light (mediated by rod cells) and bright-light (mediated by cone cells). The human retina has ∼130 million rods and ∼7 million cones (Fig. 22). All rod cells have one peak wavelength sensitivity, whereas our three cone sub-types are tuned to long, medium, and short wavelengths. Thus, rod vision is monochromatic and cone vision is trichromatic. Trichromacy means that any color that we can see can be built from three different wavelengths of visible light such as red/green/blue or cyan/magenta/yellow. A stimulus space with only three dimensions gives rise to the staggeringly diverse range of colors and hues that we see and artists use.

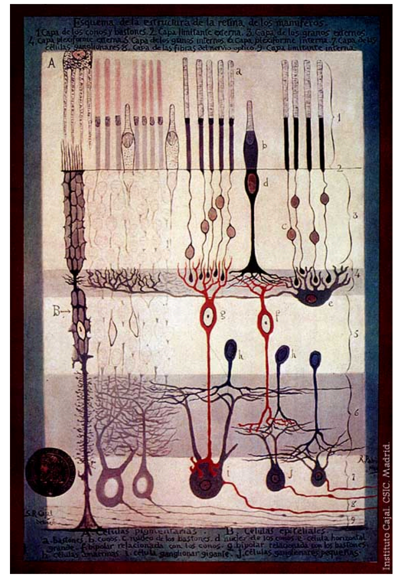


Figure 22: *Structure of the Mammalian Retina* c.1900 By Santiago Ramon y Cajal. a. Rods. b. Cones. c. Rod nucleus. d. Cone Nucleus. e. Large horizontal cell f. Cone-associated bipolar cell. g. Rod-associated bipolar cell. h. Amacrine cells. i. Giant ganglion cell. j. Small ganglion cells.

Using a prism, Newton discovered he could separate white daylight into a spectrum of different colors (Fig. 23). Using a second prism, he could recombine the spectrally-separated light back into white light. White light is the sum of all wavelengths from ∼400 nm to ∼700 nm delivered at equal intensity.

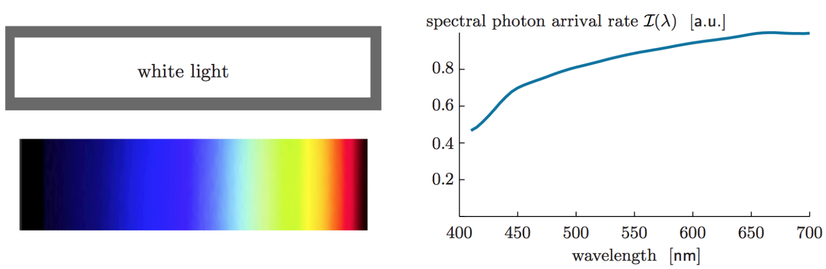


Figure 23: Sunlight consists of a broad spectrum of photon energies. When passed through a prism, it separates into a continuous distribution of colors. We can represent the spectrum by a photon arrival rate function that is nearly constant over the range of visible light. From Nelson (2017)

Vision does not need to be limited to a three-dimensional color space. Electromagnetic radiation at one wavelength can carry different information from radiation at another wavelength. This is how frequency-modulated (FM) radio transmission works: each station sends its radio signal in a different electromagnetic 'color'. When a signal is distributed on two different axes (e.g., when information is distributed across two different wavelengths), the space of all possible signals lives in 2-dimensions. One can imagine a visual system that more fully exploits the spectrum of visible light – from 400 nm (blue) to 700 nm (red) – by disentangling information that is carried on more than three wavelengths. But to read N-dimensional color in-

Figure 24: Drawing of a silhouette, from J.C. Lavater's *Physiognomische Fragmente*, 1797

formation, the retina would need at least N receptor types, each primarily tuned to a different wavelength. With only three cone types, human trichromatic vision projects all of the information carried by different wavelengths onto a three-dimensional space. Our retinas discard information by 'flattening' color information onto three axes. This is akin to the flattening and loss of information that occurs when you see the two-dimensional shadow of a three-dimensional object (Fig. 46) Most animals have fewer dimensions of color perception than we do (horses have two cone types and dichromatic vision) but some more (mantis shrimps have 16 cone types, and might have the best color discrimination on Earth).

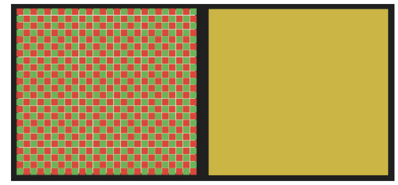


Figure 25: **Color illusion.** When viewed up close, the left box is seen to consist of small red and green squares. The image of each square on the back of the retina is larger than the size of photoreceptor cells. When viewed from afar, each photoreceptor receives light from both red and green squares, whose spectra merge. The perceived color becomes closer to the color in the right box than red or green. Red + Green ∼ Yellow.

Trichromatic vision is helpful to the painter, letting them create any visible color by mixing only a small number of pigments. The artist in Rembrandt's studio only appears to use seven pigments on his palette (Fig. 26). Leonardo da Vinci wrote that he only needed four different pigments – yellow, blue, green, and red – to create all colors. Yellow and blue make green. So da Vinci might have gotten away with three pigments. But there is also more to paint than color, as you will learn from talking to artist instead of a visual neuroscientist.

Figure 26: *A painter in his studio* Rembrandt Harmensz van Rijn (Anonymous pupil of) 1600-1700. Link to painting.

Color and context

Color perception is much more than the pixel-wise activity of cone cells. We perceive color by integrating the information across the visual field. Cajal's wiring diagram of the retina points directly to the spatial integration of visual information. The retina has two layers of cells – horizontal cells and amacrine cells – that make lateral connections, modulating the flow of information from the layer of photoreceptor cells to the layer of ganglion cells that send signals along the optic nerve to the brain. Many visual illusions about color are side effects of this spatial integration of visual information. [4]

[4] Dale Purves, R Beau Lotto, and Surajit Nundy. Why we see what we do. *American scientist*, 90(3):236–243, 2002

Figure 27: Spectrally identical patches can look differently colored when placed in spectrally different surrounds. The two central targets here are identical, as can be seen by masking out the surround.

One visual illusion is when two targets with the same spectral information are surrounded by backgrounds with different spectral information. If the pixel-wise spectral intensity determined color (like in a camera), the context provided by surrounding color would have no effect on target color. But in human vision, the color of the target will appear different, even though the cone cells that are receiving the light from the target are activated in exactly the same way (Fig. 27)! Another example is the Rubik's cube illusion (Fig. 28). Provide yellow or blue illumination to a Rubik's cube tiled with different colors. Tiles that are spectrally gray when viewed in isolation become blue when viewed with yellowish illumination. The same tiles become yellow when viewed with bluish illumination.

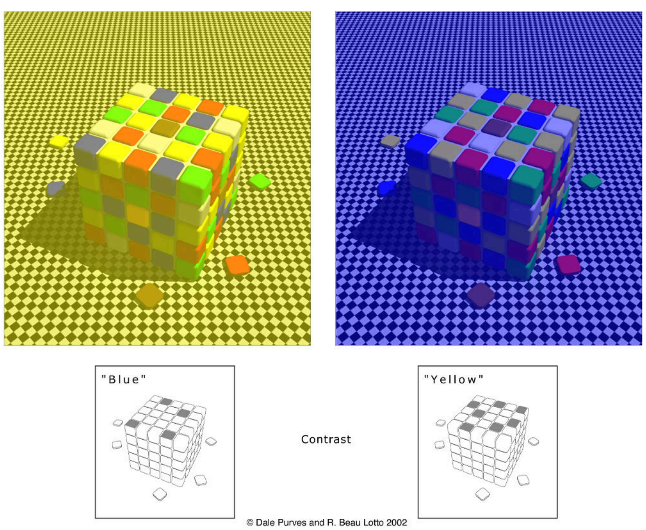


Figure 28: Upper images show the cubes as if in yellowish (top left) or bluish (top right) illumination. The lower images show specific tiles of interest in the absence of these contexts. The yellow-looking tiles depicted as if under blue light and blue-looking tiles depicted as if under yellow light are actually a gray on their own.

Trichromatic color vision is more than summing the activity of cone cells at each retinal 'pixel'. The color of each object depends on the context and color of surrounding objects.

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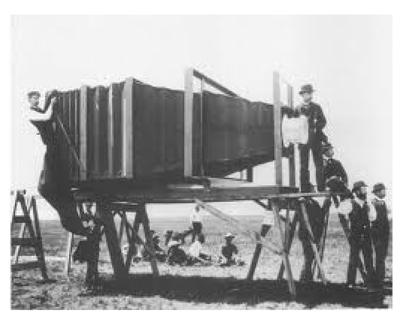
We discriminate the shape and positions of objects by spatial comparisons of luminosity. Unlike drawings with pencil or pen, objects in the real world are not bounded by 'lines'. We see the boundaries of objects by seeing differences in luminosity, or light intensity, at their edges. This is why black and white photography works. With no color information at all, we have no trouble distinguishing the shape and positions of objects in a black and white photograph. Each object has its own continuous field of luminosity, with sharp discontinuities at their edges.

Our retinas are wired to detect spatial differences in luminosity to identify object boundaries. When Cajal reconstructed the mammalian retina, he found rich networks of lateral wiring (the horizontal and amacrine cell layers in the retina, Fig. 22). One role for this lateral wiring is to make spatial comparisons of visual information at adjacent points in the visual field. By calculating spatial derivatives in luminosity, the retina heightens its sensitivity to edges and object boundaries, the basis of the Mach band illusion where the edges between isoluminous strips is enhanced, accentuating your perception of object boundaries without drawn lines.

Figure 29: Along the boundary between adjacent shades of grey in the Mach bands illusion, lateral inhibition makes the darker area falsely appear even darker and the lighter area falsely appear even lighter. From Wikipedia.

Figure 30: The shadows, reflections, landscape, sky, trees are easily recognized in this famous landscape photograph of Yosemite made by Carleton Watkins (1829-1916). Watkins was famous for landscape photography before Ansel Adams was born. He couldn't buy a simple film camera, and prepared his own film by hand in the field, pouring chemicals onto glass, exposing, and processing each unique photograph in the field. Watkins traveled with an extraordinary room-size camera to make his landscape photographs.



Impression, Sunrise by Monet, 1872

The name of the impressionist movement came from this painting of the port of Le Havre. The haziness and loose brush strokes were dramatic breaks from traditional landscape painting. Objects are hardly distinguishable, object boundaries vanish, subverting the normal visual processing that searches for object boundaries by differences in luminance. Even the sun appears to shimmer, without a clearly demarcated boundary in the cloudy sky. Margaret Livingstone pointed out that this is a visual illusion. When *Impression, Sunrise* is viewed in grayscale, the sun disappears. Not surrounded by an edge with a difference in luminosity, the brain has trouble identifying the boundary and position of the sun. Monet has discovered color mixes for sun and sky that are equally luminous, causing the sun to pulse and vibrate in the cloudy sky. A similar pulsing and vibration happens in the isoluminous regions of red and green in *Plus Reversed*, oil on canvas, by Richard Anuszkiewciz (1930-2020).

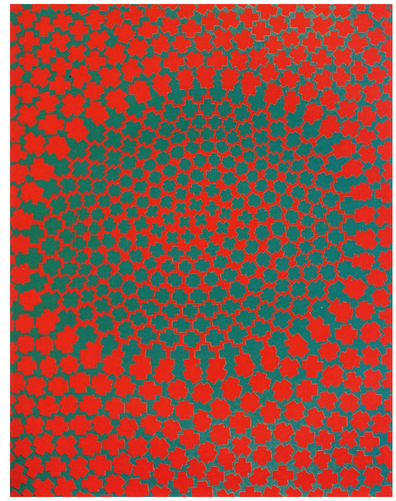


Figure 31: *Plus Reversed Sunrise* by Richard Anuszkiewciz, 1960. The equally luminous green and red fields shimmer and dance.

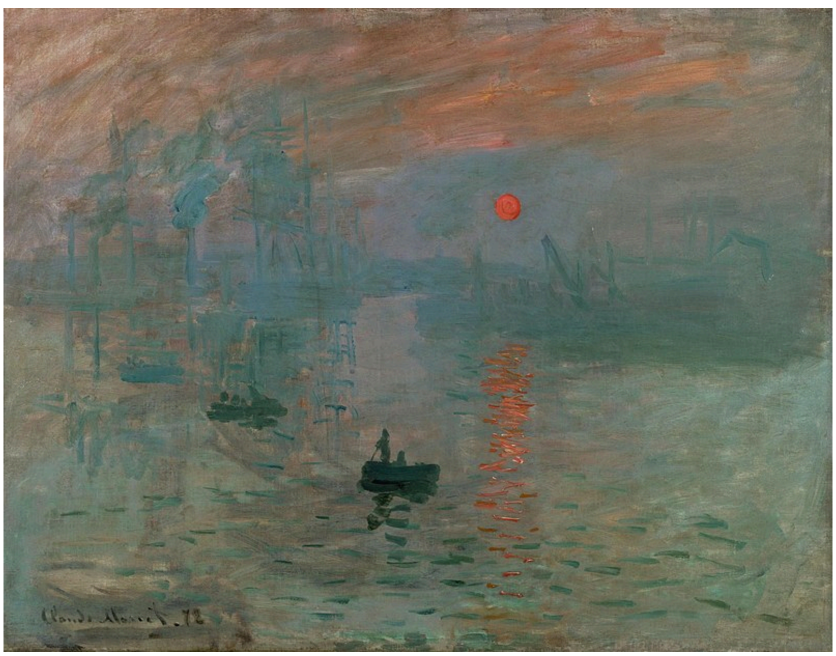
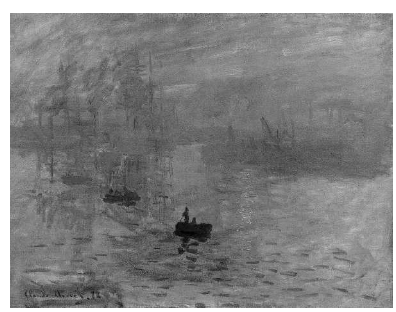


Figure 32: *Impression, Sunrise* by Claude Monet. Below, the same painting in grayscale. Almost all luminosity boundaries disappear, including between sun and the sky. By subverting your brain's ability to see object boundaries using luminance, the brain is confused.



Reading

- Dale Purves, R Beau Lotto, and Surajit Nundy. Why we see what we do. *American scientist*, 90(3):236–243, 2002 Download paper
- Bevil R Conway and Margaret S Livingstone. Perspectives on science and art. *Current Opinion in Neurobiology*, 17(4):476–482, 2007 Download paper

Looking

- Susan Lichtman's slides

Bibliography

- Philip Charles Nelson. *From photon to neuron : light, imaging, vision*. Princeton University Press, Princeton, New Jersey, 2017. ISBN 9780691175188
- Margaret Livingstone. *Vision and Art: The Biology of Seeing*. Harry N. Abrams, Inc., Publishers, New York, 2002. ISBN 0-8109-0406-3

Updated: February 26, 2024

Week Three - Shadow

Thursday, 8 February 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums 0600

Shadow and silhouette might represent the beginnings of Western Art. The earliest European Art are the Paleolithic paintings of the Caves of Altamira in Northern Spain. Applied 36,000 years, discovered in 1868, these charcoal and polychrome profiles of bison and other fauna mark the beginnings of visual representation. Side profiles captured in shadow and silhouette are just enough to convey meaning and identity. Although spare in detail, most Americans have little trouble recognizing George Washington in his portrait silhouette , But any silhouette viewed frontally becomes anonymous, a useful rendering for the familiar 'Missing Photo' icon.

Shadow might have been the first 'optical effect' that was mimicked and traced to become Western art. One poetic fancy is that portraiture was invented when Boutrades, a potter of Ancient Corinth, noticed a shadow made by lamplight, traced by his daughter of a boy she loved. Boutrades filled the outline with clay and so invented portrait sculpture. This story, written by Pliny the Elder (AD 23/24 - 79), was once a common subject for paintings about the origin of painting.

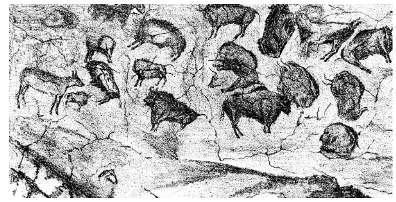


Figure 33: The Caves of Altamira

Figure 34: Hollow cut silhouette portrait of George Washington (ca. 1798), by Eleanor Custis, his adopted stepdaughter and granddaughter of Martha Washington. Link to Metropolitan Museum of Art.

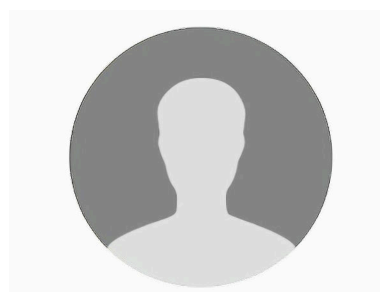


Figure 35: Anonymous

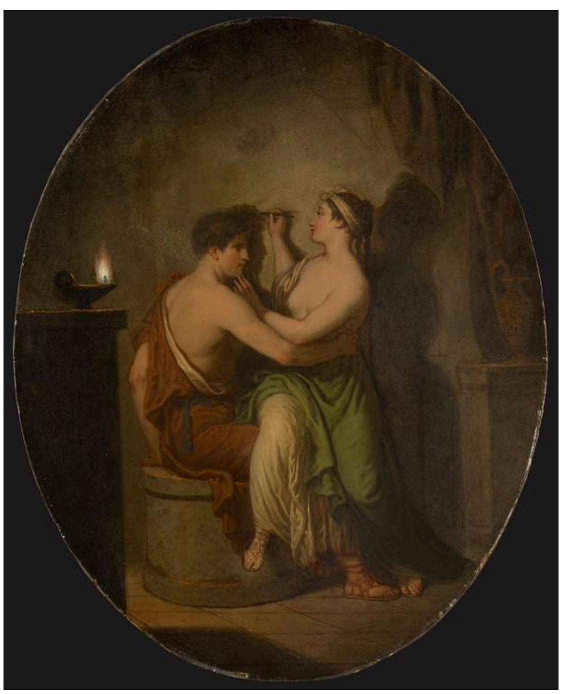


Figure 36: David Allan, *The Origin of Painting*, 1775. Link to painting.

SHADOW BECAME UBIQUITOUS in Western Art to attain naturalistic accuracy, both for traditional modeling in light and shade as well as cast shadows. Cezanne uses modeling and cast shadows to effectively create three-dimensionality for his apples and pears, while purposefully avoiding traditional geometrical means of creating three-dimensionality with fixed point perspective (Fig. 37). In the Italian Renaissance, the Mannerist painter (∼1520 - 1578) was more assiduous in capturing modeling and cast shadows with optical accuracy, witness the rounding of the column and cast shadows of the legs in (Fig. 38). Leonardo da Vinci thought carefully about the physics of shadows, as he described in 67 pages of his *Codex Urbinas*. But in his notes on painting, *Trattoto della Pittura*, he advocated leaving them out.

Figure 37: *Still Life with Apples and Pears,* Paul Cezanne, 1891. Link to Metropolitan Museum of Art

> Light too conspicuously cut off by shadows is exceedingly disapproved of by painters. Hence, to avoid such awkwardness when you depict bodies in open country, do not make your figures appear illuminated by the sun, but contrive a certain amount of mist or of transparent cloud to be placed between the object and the sun and thus, – since the object is not harshly illuminated by the sun – the outlines of the shadows will not clash with the outlines of the lights.

Figure 38: *Portrait of a Gentleman*, Giovanni Battista Moroni, 1556. Link to Google Arts and Culture

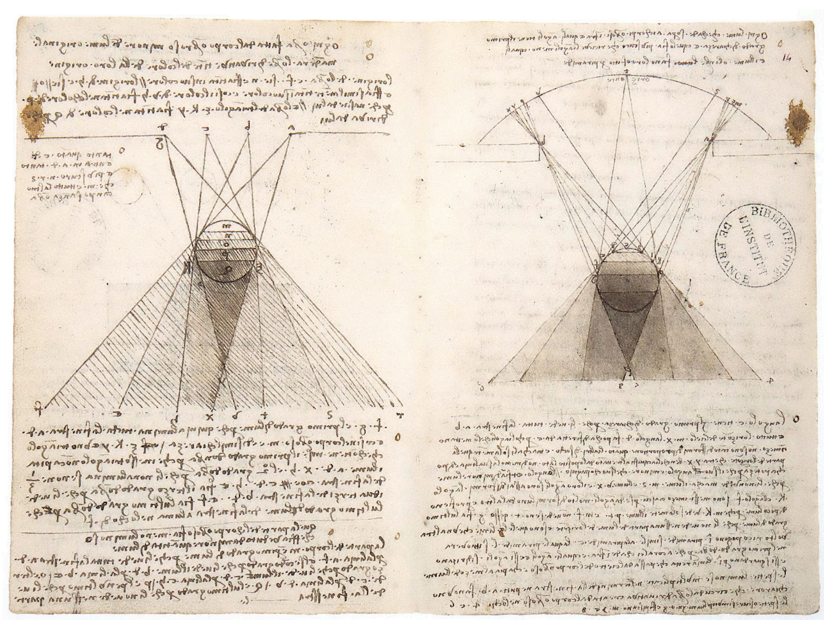


Figure 39: *Study of the Graduations of Shadows on Spheres from Leonardo's Codex Ashburnham*

LEONARDO FOLLOWED HIS OWN ADVICE by attenuating and confusing shadows and sources of light in the *Mona Lisa* and elsewhere.

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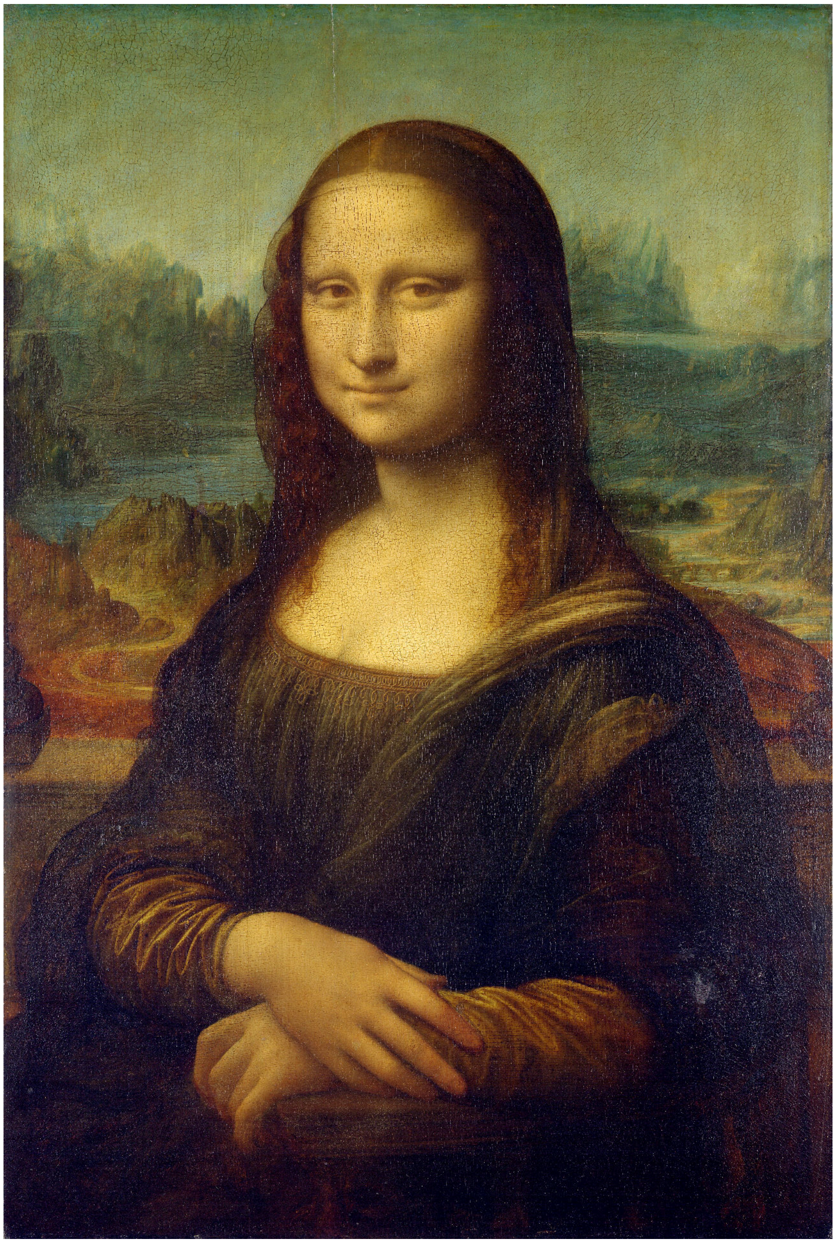

Figure 40: Portrait of Lisa Gherardini, wife of Francesco del Giocondo, Mona Lisa, 1503-1519, Leonardo da Vinci.

Chinese artists scarcely used shadows in painting, but knew about shadow in life. Shade but no shadow, modeling or cast, were needed by the 13th century monk Mu Chi'I to the Zen effects of *Six Persimmons*, what has been called the Chinese *Mona Lisa.*

Mu Ch'I's Persimmons By Gary Snyder

There is no remedy for satisfying hunger other than a painted rice cake.
—Dōgen, November, 1242.

On a back wall down the hall

lit by a side glass door

is the scroll of Mu Ch'i's great
sumi painting, "Persimmons"

The wind-weights hanging from the
axles hold it still.

The best in the world, I say,
of persimmons.

Perfect statement of emptiness
no other than form
the twig and the stalk still on,
the way they sell them in the
market even now.

The original's in Kyoto at a
lovely Rinzai temple where they
show it once a year

this one's a perfect copy from Benrido
I chose the mounting elements myself
with the advice of the mounter

I hang it every fall.

And now, to these overripe persimmons
from Mike and Barbara's orchard.
Napkin in hand,
I bend over the sink
suck the sweet orange goop
that's how I like it
gripping a little twig

those painted persimmons

sure cure hunger

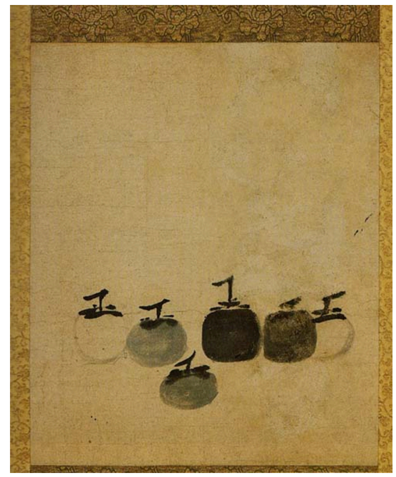

Figure 41: *Six Persimmons* by Mu Chi'I, 13th century. Link to Wikipedia

DA VINCI'S HANGUP about shadow and silhouette was discarded in the Western tradition. A follower of Rembrandt or his school used shadow to paint light streaming through a window with shadow slanting on a wall to anamorphic effect. The Surrealist de Chirico sharpens and heightens shadow and silhouette to create the eerie effect of a deserted city.

Figure 42: *The Enigma of a Day* by Giorgio de Chirico, 1914.

Figure 43: *Man Seated Reading at a Table in a Lofty Room.* by Follower of Rembrandt or his school, 1628/30. Link to painting at the National Gallery.

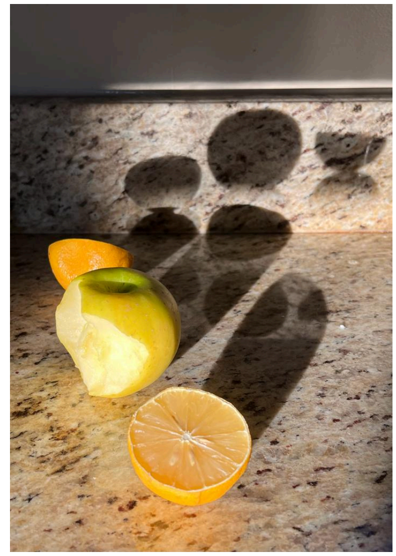

Figure 44: *Still Life with Oranges* by Francesca Bewer, 2024.

PIETER JANSSENS ELINGA (1623-1682), a Dutch Golden Age painter, was as fascinated by light and shadow as Vermeer. In his painting of a quiet interior, a lady sits at a table, a maid sweeps the floor, and a painter (Elinga himself?) stands in a back room. In this painting, shadows are made with both direct and reflected light off the marble floors, achieving a complex and natural realism in a painting that has other departures from reality. Elinga could not likely afford geometrically laid marble floors, rare in any Dutch household. Francesca Bewer achieved similarly complex shadows as Elinga in her photographic still life.

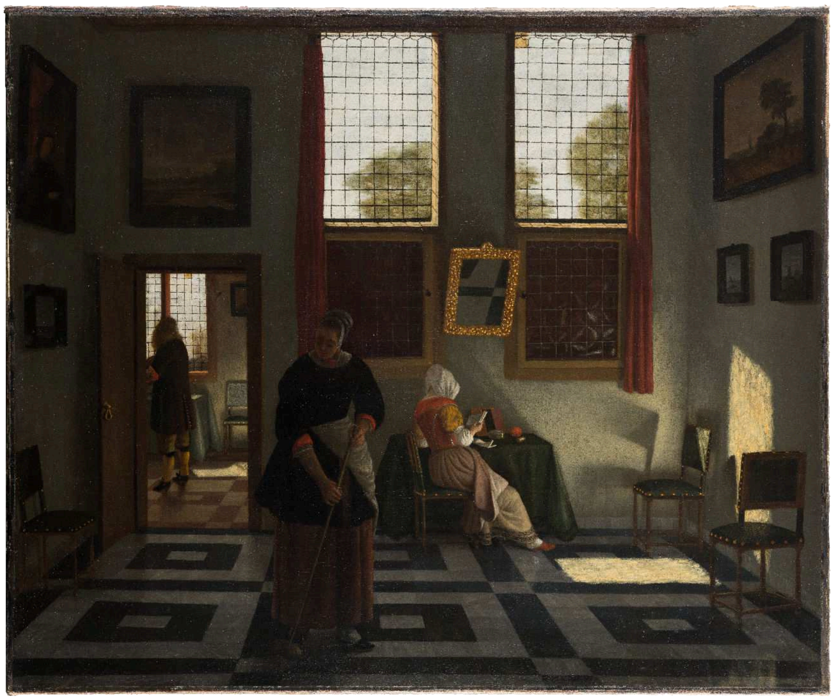

Figure 45: *Interior with Painter, Woman Reading and Maid Sweeping,* by Pieter Janssens Elinga, 1665-1670. Link to painting at the Staedel Museum, Frankfurt

Figure 46: Augustin Amant Constant Fidèle Edouart, French, *Album of Silhouettes*. Harvard Art Museums.

Silhouettes in history and modernity were the subject of an exhibit at the National Portrait Gallery and accompanying book. [5] Penley Knipe authored a chapter, focusing on silhouettes in American portraiture. She is our local expert on Harvard's substantial silhouette collection.

Silhouetted portraits played an important role in the history of American portraiture. A silhouette can be created with a pair of scissors and skilled hands. Surging interest in silhouettes led to technological inventiveness to speed production and accuracy (Fig. 47) Chemical photography ended the heyday of the American portrait silhouette, which nonetheless remains as a cut-and-dried example of tools in art-making. The flattening of an image in black and white abolishes photographic realism and linear perspective, but distinctly preserves its own naturalness and likeness.

[5] Asma Naeem. *Black Out: Silhouettes Then and Now*. Princeton University Press, Princeton, New Jersey, 2018. ISBN 069118058X

Figure 47: A Sure and Convenient Machine for Drawing Silhouettes by Thomas Holloway ca. 1788.

Chris Stokes re-engineered the original physiognotrace invented by John Hawkins to mass-produce silhouettes, so we can experiment with it.

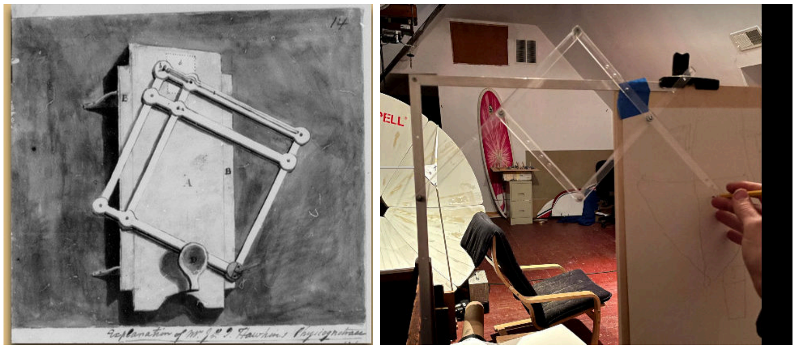

Figure 48: Left: Drawing of John Hawkin's physiognotrace device from *Black Out:Silhouettes Then and Now*. Right: Pantograph made by Chris Stokes.

Modern artists have reinterpreted the silhouette as an art form. Kara Walker (1969-) manipulates the history of the silhouette in her disturbing and striking social commentaries (Fig. 49). Kumi Yamashita (1968-) plays with the dimensionality of the silhouette by shaping paper objects that create silhouettes as shadows when properly illuminated (Fig. 50). Yamashita's works are anamophoric shadows.

Figure 49: *Auntie Walkers Wall Sampler for Savages* by Kara Walker. Kara Walker, a contemporary artist, uses mural-scale silhouettes to enact the cruelty of antebellum plantation life. In contrast to polite portraiture, what the silhouette largely was in the 19^{th} century, Walker evokes exploitation and dark fantasy in 19^{th} century life with her modern use of the art form of their era.

Updated: February 26, 2024

Reading

- "Shades of Black and White" by Penley Knipe. From Asma Naeem. *Black Out: Silhouettes Then and Now*. Princeton University Press, Princeton, New Jersey, 2018. ISBN 069118058X. Download paper

Looking

- Look at Harvard Art Museums collection of silhouettes including Augustin Amant Constant Fidèle Edouart's *Album of Silhouettes*.

Bibliography

- E. H. (Ernst Hans) Gombrich. *Shadows : the depiction of cast shadows in western art*. Yale University Press, New Haven, new edition. edition, 2014. ISBN 9780300210040

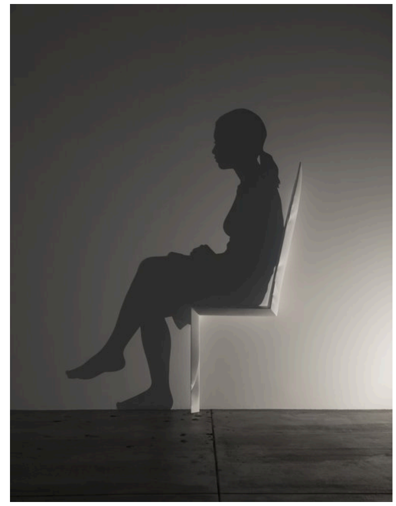

Figure 50: *Chair*, by Kumi Yamashita, 2014. Carved wood, single light source, shadow.

Figure 51: *Fragments*, by Kumi Yamashita, 2009.

Updated: February 26, 2024

Week Four - Ingres

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

Jean-Auguste-Dominique Ingres (1780-1867) studied in the French neoclassical school with Jacques-Louis David (1748-1825), the preeminent painter of gand history and narrative works. But Ingres was also one of the best draftsmen with graphite and paper of any era. The Hockney thesis was born in 1999, when Hockney happened to visit a major exhibition of Ingres's portraits at the National Gallery in London, both drawings and paintings, assembled from international loans [6]. Hockney marveled at the drawings, seeing photographic precision with unerring lines in some parts and loose sketching in other parts. His hunch was that the assured and definite lines had been traced. Hockney guessed that Ingres sometimes used a tool like a camera lucida and sometimes drew freehand with "eyeball". At Harvard, we can study many of these drawings up close with the largest Ingres collection outside France.

In 1811, Ingres was crushed when his *Jupiter and Thetis*, submitted for a final student project to the French Academy, was poorly received. Why *Jupiter and Thetis* was ridiculed whereas David's *Oath of the Horatii* was revered is beyond our scope (Figs. 53, 54). For us, this marked a turning point for Ingres. Ingres did not return to France until 1824. He staying in Italy to lick his wounds, indulging in the self-pity of misunderstood artist who had to suffer. To support himself, he turned to portraits. "Cursed portraits! They always keep me from undertaking important things." Portraits *were* the important things.

Figure 52: *Self-Portrait* by Ingres (1859). Link to painting at Harvard

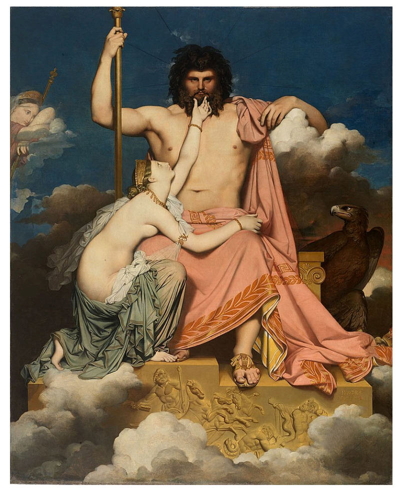

Figure 53: *Jupiter and Thetis* by Ingres (1811), Link to painting at Google Arts and Culture

Figure 54: *Oath of the Horatii* by David (1784), Link to painting at Wikipedia

[6] *Portraits by Ingres : image of an epoch*. Metropolitan Museum of Art : Distributed by Harry N. Abrams, New York, 1999. ISBN 0870998900

In French-occupied Italy, Ingres was able to support himself with commissions, thanks to tourists who wanted pencil portraits. In these 'starving artist' years, Ingres estimated he made three hundred portrait drawings, earning about $32,000 in today's dollars. Before photography, if you wanted a fully-realized likeness of yourself beyond the contours of a silhouette, a pencil portrait by a draftsman as good as Ingres was the quickest and cheapest way to get an photo-realistic image. Sitters reported that Ingres would deliver a drawing within days. Sometimes he drew sitters alone (Figs. 55, 56). Sometimes he drew families (Fig. 57). Many drawings exhibited exquisitely drawn faces amid loosely drawn backgrounds. A tourist seeking a pencil portraits perhaps sought a form of visual "non-fiction" that they could take home, analogous to a modern photobooth, as opposed to seeking a self-transformation of their visage into high art.

Figure 55: *Portrait of Count Adolphe de Colombet de Landos* by Ingres, 1812 Link to drawing

Figure 56: *Portrait of Madame Charles Hayard* by Ingres, 1812 Link to drawing

Figure 57: *Portrait of Mrs. George Vesey and Her Daughter Elizabeth Vesey* by Ingres, 1816. Link to drawing

When in Rome, Ingres also executed a new painting that is now in Harvard's collection, *Raphael and the Fornarina* (Fig. 61). Near the end of his life, Ingres would rank this painting as his fourth most imaginative work (after three grand history paintings). Harvard has the first version of the painting, which Ingres would repeat and revise in several other versions. Ingres did not paint a woman sitting in his studio, but copied the woman in Raphael's *La Fornarina*. This Fornarina (Italian for baker) was thought to be Raphael's mistress (and the cause of his death through excessive love-making according to Vasari, his first biographer). La Fornarina is also thought to be the subject for the Virgin in his *Madonna of the Chair* that leans on the back wall in Ingres's depiction. Ingres's Raphael resembles the Raphael of his self-portrait (Fig. 60).

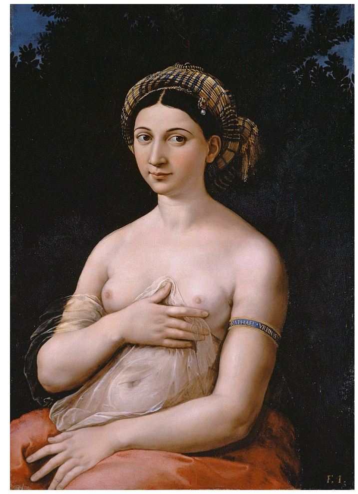

Figure 58: *La Fornarina* by Raphael, 1518/1519 Link to painting

Figure 59: *Madonna della Seggiola* by Raphael, 1513/1514 Link to painting

Figure 60: *Self-Portrait* by Raphael, 1504/1506 Link to painting

Figure 61: *Raphael and La Fornarina* by Ingres, 1814 Link to painting

The characters in Raphael and the Fornarina are fictional, and presumably not drawn with an optical tool. Interestingly, the study for the painting in the Harvard Art Museums is the drawn visage of the Fornarina that has the same qualities that convinced Hockney that Ingres used a camera lucida tool to draw real sitters (Fig. 64). Ingres self-drawn self-portrait also has these very same qualities of photographic quality and unerring lines (Fig. 63). It is hard to see how Ingres could have used a camera lucida to draw himself. Ingres drawing of his wife is also photographic in quality. A husband would perhaps be unwise to draw his wife with every blemish captured with photographic accuracy. If Ingres used a camera lucida, he did so selectively, not for every picture and not for every detail.

Figure 62: *Delphine Ingres* by Ingres, 1855 Link to painting

Figure 63: *Self-portrait* by Ingres, 1822 Link to drawing

Figure 64: *Study for La Fornarina* by Ingres Link to drawing

Figure 65: *Madame Jacques-Louis Leblanc* by Ingres, 1823 Link to painting

Hockney also marveled at Ingres portrait paintings. Leonardo da Vinci's *Mona Lisa*, seen by the public in the Louvre after 1797, would inspire a cult following. High-society women subscribed to the mythology of the subject transformed into a timeless work of art. In his paintings of these women who sought Ingres to effect their transformation, Ingres would lavish as much attention on their expensive clothing and accessories as the subjects themselves. Hockney could not believe that the complexity of the folds and crumples of intricately patterned fabric could be captured without help from an optical device. Hockney, an extraordinarily prolific and busy artist, would expect any artist would take shortcuts, if they could.

Ingres's portrait painting was as much fantasy as reality. The seated portrait of Madame Paul-Sigisbert Moitessier is an apotheosis of his subject – whom he didn't originally want to paint until he met her and saw what she looked like – giving her the posture of the Arcadian goddess in a fresco in Naples and an impassive regal gaze (Figs. 66, 67). Was Ingres in a hurry? Ingres spent 12 years on this painting that underwent multiple revisions including erasing her daughter and changing her dress to keep up with trending fashion.

Figure 66: *Madame Moitessier* by Ingres, 1844-1856 Link to painting

Figure 67: Fresco depicting Hercules finding his son Telephus in Arcadia, from Basilica of Ercolano, Naples province, Italy

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PICASSO ADMIRED INGRES. In his painting of Marie-Thérèse Walter, he mimics the pose of Madame Moitessier – head on hand, fan not book, and mirror reflecting her face from the side.

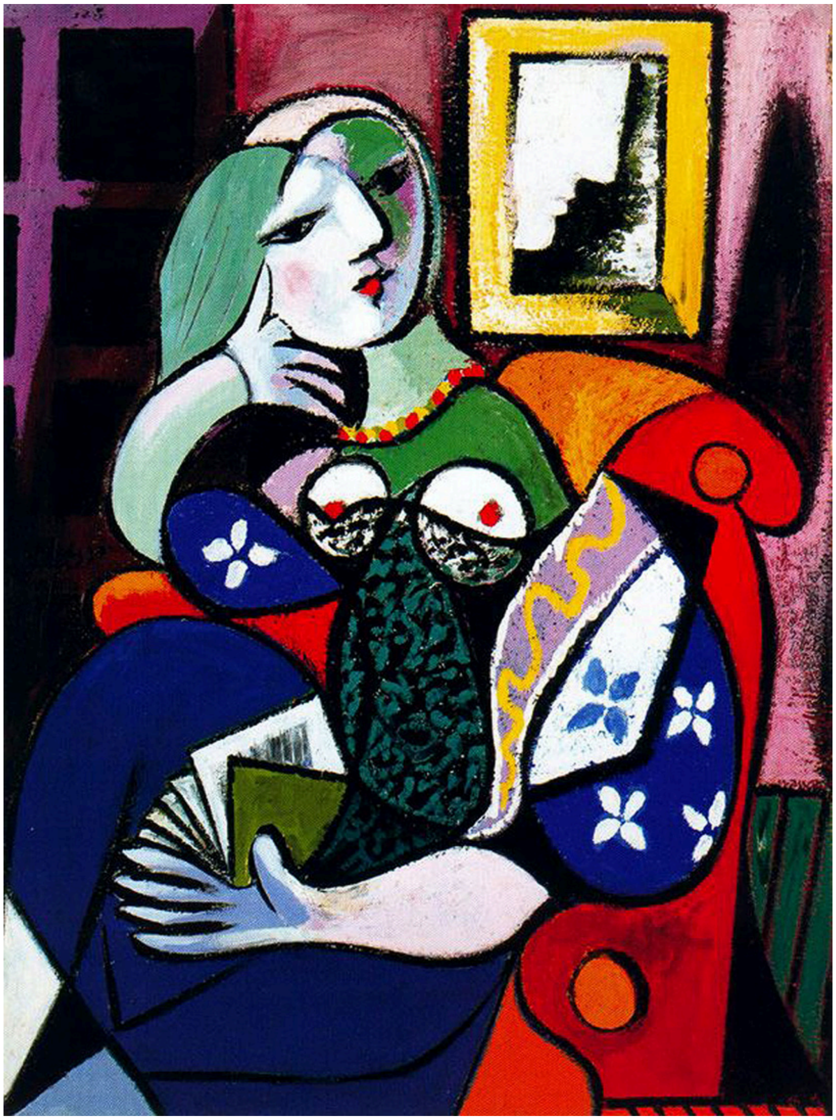

Figure 68: *Woman with a Book* by Picasso, 1932. Link to Painting

Hockney did master the use of the camera lucida, and used it to draw hundreds of pictures of his friends. In Hockney's own portrait exhibition at the National Gallery in London he responded to Ingres with a esries of portrait drawings of the gallery guards, a visual pun, drawing the men and women who watch the men and women who look at the drawings. The uniformity of the uniformed guards allows the viewer to focus on their differences, the keenly observed differences in posture, body language, and human nature that makes these images truer than photographs.

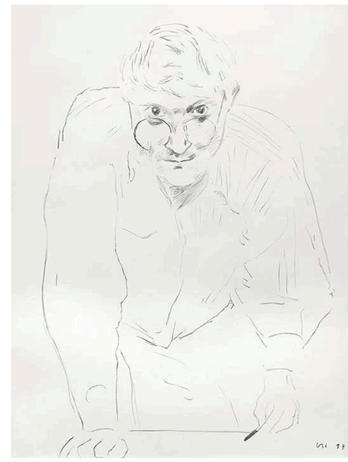
Figure 69: *Self Portrait* by Hockney, 1983

When Hockney realized he could achieve the same effects as Ingres when drawing others, he became convinced that Ingres also wielded a tool like a camera lucida, easily achieving a scientific precision that would have taken more time and effort to achieve without the device. Hockney was not the first person to observe "scientific" disinterest in Ingres's drawings. Charles Blanc, the first professor of art history at the College de France, also marveled at the lifelike quality of Ingres's portrait drawings, writing "art is, when it wants to be, more exact than science, more precise than mathematics... more sensitive than collodion, more subtle than chloride, more clear-sighted than light... truer, at last, than truth itself." The prism of the artist's mind is more revealing than the prism of the camera lucida.

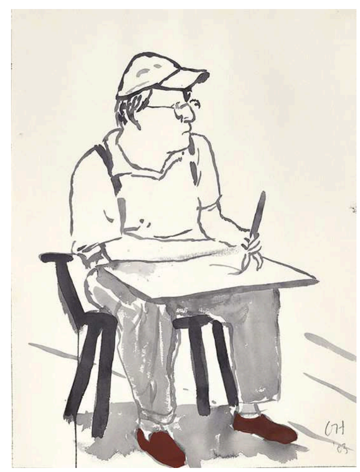
Figure 70: *Self Portrait Using Three Mirrors* by Hockney, 2003

In the end, Hockney is an artist, not a mechanic. This is revealed in his own process when using a camera lucida, from a letter to Martin Kemp.

> Los Angeles, 1999
>
> Dear Martin,
>
> As I keep repeating, the use of optics does not necessarily mean that fantastic clear images (like a projected slide) are needed. We are talking about imaginative clever artists, just as I used the camera lucida for two minutes (you can't really trace a living face) and then worked hard for two hours, so with others. A good artist doesn't need that much help from them and would know how to use the deficiencies, they have imagination after all....
>
> As ever,
>
> DH

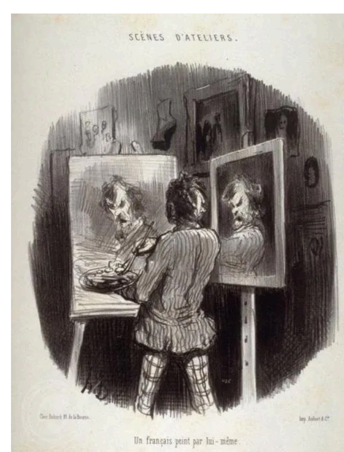

Figure 71: *A French Painter Paints Himself* by Daumier, 1823

Notably, when Hockney drew himself, he used a mirror, not a camera lucida – like the artist in Honoré Daumier's *A French Painter Paints Himself* – and he would need more than one mirror to see himself from the side.

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Figure 72: *Twelve Portraits after Ingres in a Uniform Style* by Hockney, 1999

DOES A WORK OF ART cease to be a work of art if a tool was deceptively used in its execution? Immanuel Kant thought about this.

> "But it is the indispensable requisite of the interest which we here take in beauty, that the beauty should be that of nature, and it vanishes completely as soon as we are conscious of having been deceived, and that it is only the work of art – so completely that even taste can then no longer find in it anything beautiful nor sight anything attractive. What do poets set more store on than the nightingale's bewitching and beautiful note, in a lonely thicket on a still summer evening by the soft light of the moon? And yet we have instances of how, where no such songster was to be found, a jovial host has played a trick on the guests with him on a visit to enjoy the country air, and has done so to their huge satisfaction, by biding in a thicket a rogue of a youth who (with a reed or rush in his mouth) knew how to reproduce this note so as to hit off nature to perfection. But the instant one realizes that it is all a fraud no one will long endure listening to this song that before was regarded as so attractive."
>
> Immanuel Kant, *The Critique of Judgment*

Figure 73: *The Church Porch, East Bergholt* by John Constable Link to painting at the Tate

John Constable, the British landscape artist, considered himself a scientist. [7]

> "Painting is a science," Constable said, "and should be pursued as an inquiry into the laws of nature. Why, then, may not landscape painting be considered as a branch of natural philosophy, of which pictures are but the experiments?"

Figure 74: *Drawing of the Church Porch, East Bergholt* by John Constable.

[7] Ernst Gombrich. *Art and Illusion: A Study in the Psychology of Pictorial Representation*. Princeton University Press, 2000. ISBN 0691070008

HARVARD HAS A DRAWING BY CONSTABLE that we know was made using a transparent plane. Leonard da Vinci's sketchbooks describe the use of a transparent plane to sketch a scene: fix viewpoint; sketch the scene before you onto an intervening transparent plane; copy sketch onto paper. This is what Constable did, a study of perspective for architecture in a painting *Church Porch, East Bergholt* (Figs. 73, 74).

HARVARD HAS OTHER DRAWINGS that were made with optical tools. Cornelius Varley invented a patent graphic telescope, the most sophisticated drawing aid of his time, described in his *Treatise on Optical Drawing Instruments* in 1845 [8] (Fig. 76). The Graphic Telescope, a combination of a telescope and camera obscura, allows the artist to simultaneously look forward at the subject and down on the drawing surface, so that drawn image can be matched to seen image. We can directly compare these drawings, known to have been made with optical tools, to drawings whose methods we can only speculate about.

[8] Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

Figure 75: *At Parton Hall, Staffordshire, 1820* by Cornelius Varley. Made with graphic telescope.

Reading

- Martin Kemp. Lucid Looking:David Hockney's drawings using the camera lucida. *Nature*, 400:524, 1999 Download paper
- 'Ingres's Portraits and their Muses' by Robert Rosenblum *In*: *Portraits by Ingres : image of an epoch*. Metropolitan Museum of Art : Distributed by Harry N. Abrams, New York, 1999. ISBN 0870998900 Download paper

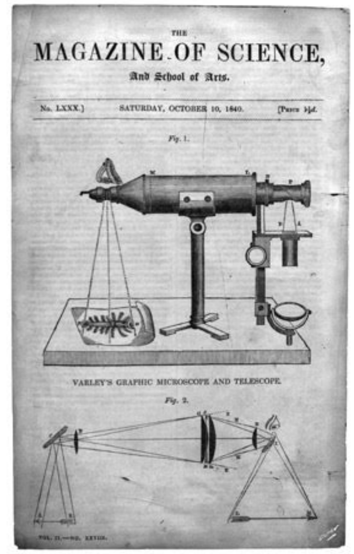

Figure 76: Illustration of the graphic telescope and its optical principles. From the Magazine of Science, and School of Arts, 1840.

Looking

The Harvard Art Museums have the largest Ingres collection outside France including:

- Augustine-Modeste-Hortense Reiset
- Odalisque, Slave, and Eunuch
- Self-Portrait
- Profile Portrait of a Man
- Portrait of Count Adolphe de Colombet de Landos
- View of the Villa Medici, Rome
- Portrait of Mrs. George Vesey and Her Daughter Elizabeth Vesey, later Lady Colthurst
- Portrait of Mme Delphine Ingres
- Portrait of Etienne-Jean Delecluze
- The Martyrdom of Saint Symphorien
- Portrait of the Architect Francois-Desire Girard de Bury
- Roger Freeing Angelica

Updated: February 26, 2024

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- *Hockney's eye : the art and technology of depiction*. Paul Holberton Publishing Ltd., London, 2022. ISBN 1913645126
- Ernst Gombrich. *Art and Illusion: A Study in the Psychology of Pictorial Representation*. Princeton University Press, 2000. ISBN 0691070008
- Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

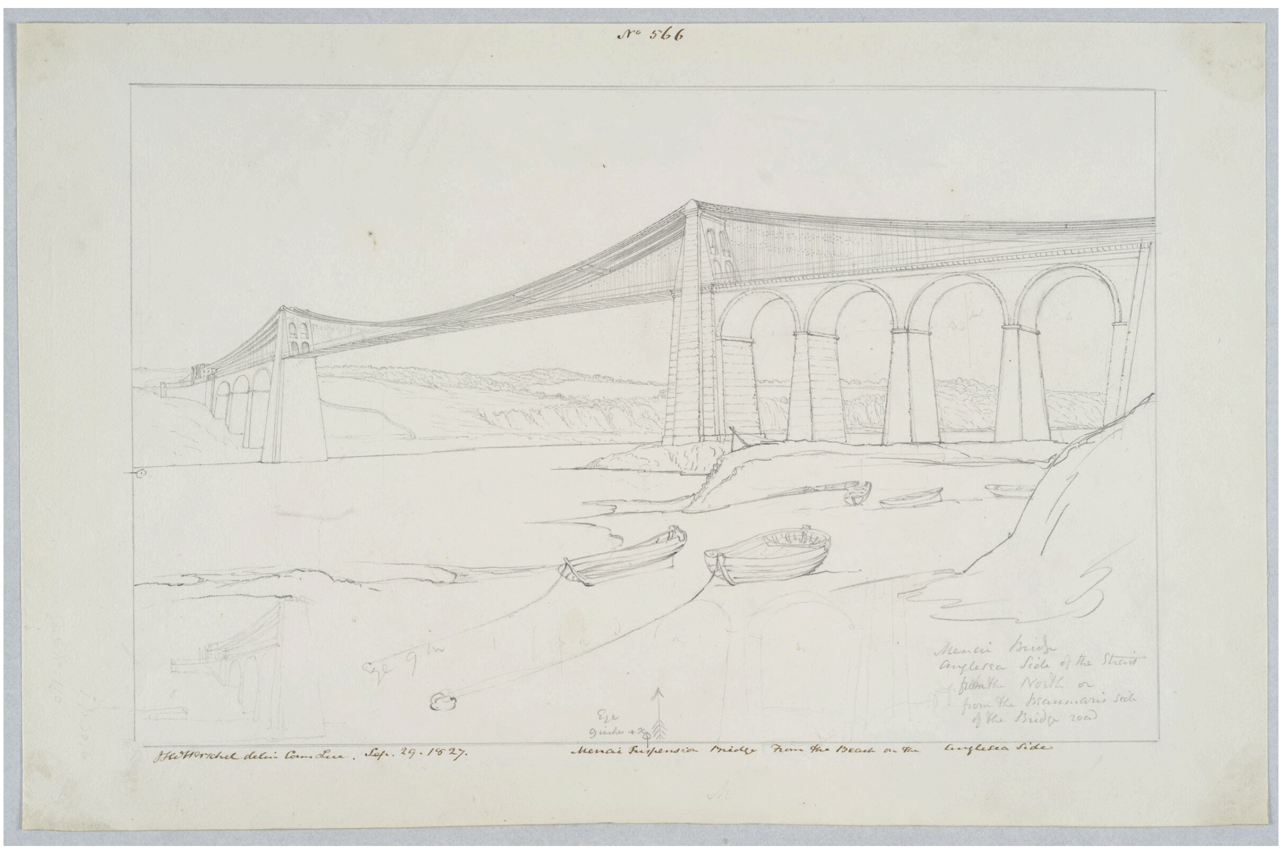

Figure 77: *Menai Suspension Bridge From the Beach on the Anglesea Side* by John Herschel, 1827. Made with camera lucida.

Updated: February 26, 2024

Week Five - Perspective from Brunelleschi to Vermeer to Canaletto

Thursday, 22 February 2024, 12:45 - 2:15 PM EST.
Harvard Art Museums, 600

We see in three dimensions using information that has been flattened onto our two-dimensional retinas. Retinal information has to be un-flattened by the brain to see depth. How is three-dimensional information beyond a plane (like a glass window) accurately represented by two-dimensional information on the plane (like a drawing or painting)? Effectively, one must transform the plane, from a window to the view beyond, into an illustration of the same view. Geometrical laws of 'linear perspective' are the set of mathematical relationships, drawn from Euclidean geometry, that precisely map the shape, orientation, and positions of solid objects in 3D space onto 2D images (see Appendix I).

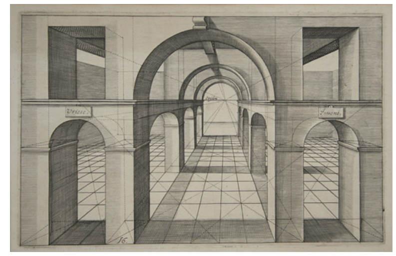

Figure 78: An engraving from *The Book of Perspective* by Hans Vredeman de Vries. De Vries wrote and illustrated a guidebook on perspective that artists of the day, including Vermeer, owned and consulted.

These laws had to be discovered – by Filippo Brunelleschi (1377-1446), a Florentine architect – and codified – by Leon Battista Alberti (1404-1472), a Genoan scholar – before exploding across Western art. Brunelleschi discovered that parallel lines that are orthogonal to the viewing plane in the real world (lines that will never meet in 3D space) will converge to one vanishing point in a flat 2D image (Fig. 78). Other sets of parallel lines in 3D space will converge to other unique points on the 2D image. The transparent plane that has become an illustration of the view beyond is sometimes called 'Alberti's window'.

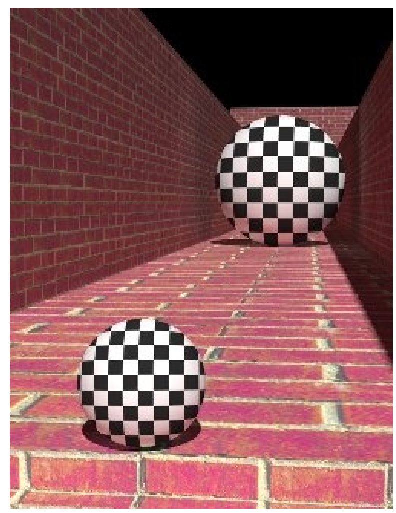

Figure 79: The two balls are exactly the same size, yet the upper ball appears larger. The brain uses multiple cues when assigning the relative sizes of the balls, not just the size of their retinal projections. 123opticalillusions.com

One reason for the difficulty in discovering these laws of projective geometry is that the human brain does not rely on geometry to perceive depth. The brain integrates many different cues in addition to geometry – perspective, shading, motion, stereopsis – to create our internal representation of our three-dimensional surroundings. Conflict between different cues can lead to interesting visual illusions (Fig. 79).

Linear perspective, strictly speaking, demands that the painter and the 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 skew and anamorphosis. In reality, we rarely notice such aberrations. Our brains are so good at dealing with 3D information, we unconsciously and effortlessly erase geometrical 'problems' from our images that we look at from different angles and at different distances. Brunelleschi had to suppress the unconscious workings of his own brain to become conscious of linear perspective. Later, both da Vinci and Dürer described tools that helped with accurate drawing with linear perspective, mechanics over mind, all variations on Alberti's window.

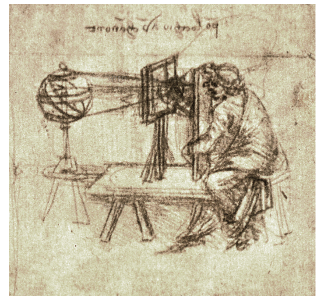

Figure 80: Leonardo's *Draughtsman using a Transparent Plane to Draw an Armillary Sphere*

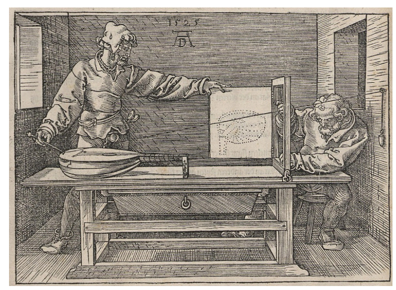

Figure 81: Albrecht Dürer. 1525. *Artist Drawing a Lute.*

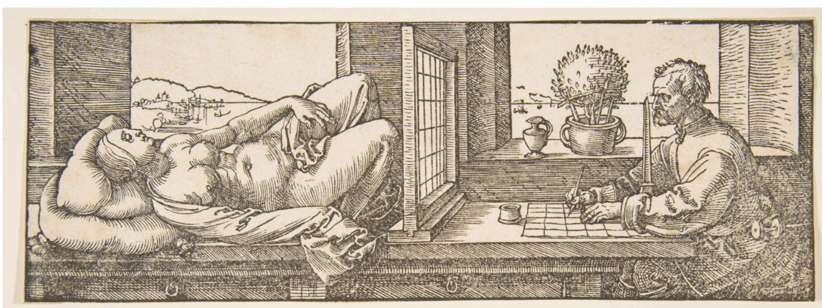

Figure 83: Albrecht Dürer. 1525. *Artist Drawing a Nude with Perspective Device.*

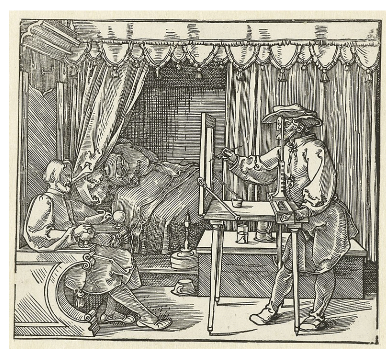

Figure 82: Albrecht Dürer. 1525. *Artist Painting a Portrait.*

Figure 84: Albrecht Dürer. 1525. *Artist Drawing a Vase.*

Architecture requires knowing what large three-dimensional geometrical object will look like. It might not surprise that it was an architect not a painter – Filippo Brunelleschi – who discovered the mathematical laws of linear perspective. As an architect, Brunelleschi is best known for designing and building the iconic dome of the cathedral of Florence, the Santa Maria del Fiore, which is still the largest brick dome that has ever been constructed, towering 375 feet. Construction of the cathedral had begun in 1296, but nobody knew how to build the dome. Brunelleschi worked out the design, scaffolding, and construction methods that would finish the dome in 1436.

Figure 85: The Duomo of the Santa Maria del Fiore, viewed from the Michelangelo Hill.

Brunelleschi would have been well-versed in Euclidean geometry and adept with surveying tools. His discovery of linear perspective was documented by a contemporary who described certain 'demonstration panels' made by Brunelleschi, essentially a type of 'peepshow'. He made two demonstration panels, one of the Baptistery in Florence, an octagonal building with many sets of parallel lines to contemplate (Fig. **??**) and one of the Palazzo de' Signori (Fig. 86). 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. The effectiveness of the panel was confirmed by the viewer by raising or lowering the mirror and comparing the real and painted images. Brunelleschi's panels have now been lost but were reported to be stunningly accurate.

Figure 86: *View of the Piazza della Signoria,* Giuseppe Carocci, 19th century, lithograph.

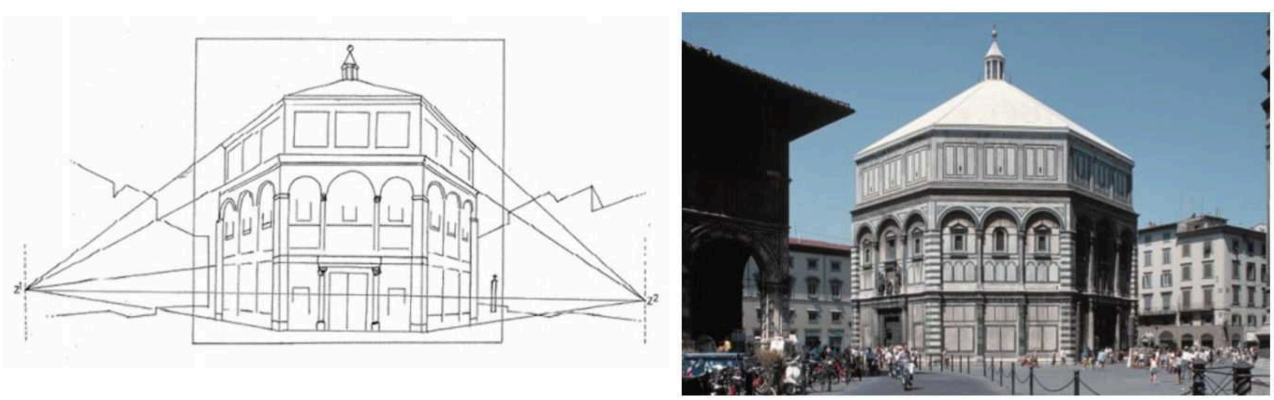

Figure 87: Brunelleschi's first demonstration of linear perspective used the Baptistery of the Florence Cathedral.

How Brunelleschi made the demonstration panels is not known. Philip Steadman thinks that these panels might have been made by painting directly onto a mirror. Steadman performed the experiment himself, fixing his eye and directly painting the image of the Florentine Baptistery onto its reflection. In *Secret Knowledge*, David Hockney did a different experiment, using a concave mirror to project an image of the Florentine Baptistery onto paper, tracing the geometry of linear perspective with pencil. Brunelleschi would also have been familiar with surveying tools – tools that would be familiar to a practicing architect. If Brunelleschi 'discovered' geometrical principles with surveying tools, he would have measured and transcribed the images of the Baptistery and Palazzo onto his demonstration panels, as described by Martin Kemp. [9].

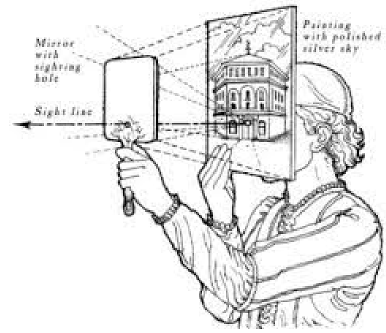

Figure 88: Schematic of Brunelleschi's demonstration panels.

Figure 89: BBC documentary, *Secret Knowledge*

[9] Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

Renaissance painters rapidly took up the concepts of Brunelleschi's perspective. Masaccio, a younger friend of Brunelleschi, rigorously adopted the precepts of linear perspective in his construction of *The Holy Trinity*. This painting, a fresco in the Santa Maria Novella in Florence, is the first where all orthogonals converge to a single point. The artist did not transcribe a visual scene, what Brunelleschi did with the Baptistery. Masaccio executed a remarkable act of mathematical and artistic imagination. Masaccio imagined a three-dimensional tableau and predicted the two-dimensional visual image that would be produced on 'Alberti's window'. Brunelleschi might have been a consultant in Masaccio's pioneering work. The mathematical rigor and geometrical sophistication of Masaccio's *Trinity* has allowed a computer-based reconstruction of the space that first existed in Masaccio's imagination (Fig. 91). [10].

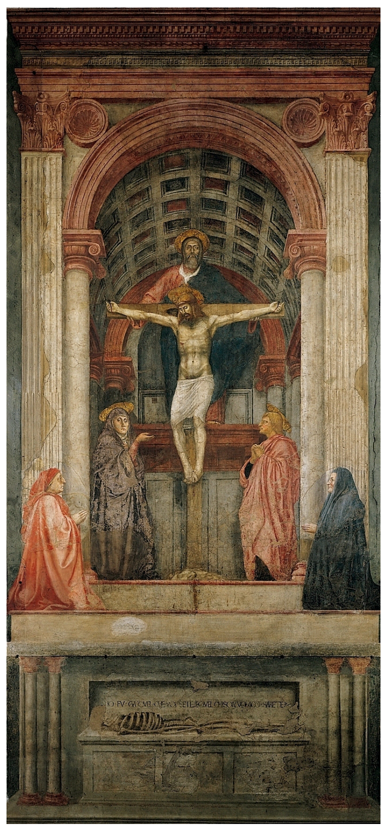

Figure 90: *The Holy Trinity* by Masaccio. [Link to artist at Google Arts and Culture].

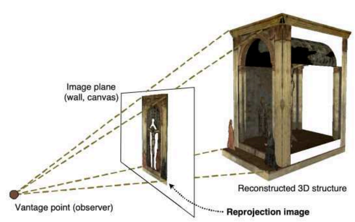

Figure 91: Reprojection image created by projecting the computer three-dimensional reconstruction onto the plane of a painting.

[10] Antonio Criminisi, Martin Kemp, and Andrew Zisserman. Bringing pictorial space to life: Computer techniques for the analysis of paintings. pages 77–99, 2002

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SLAVISH APPLICATION OF THE LAWS OF LINEAR PERSPECTIVE was hard analytical work with limited aesthetic benefit. Few painters tried to implement linear perspective without compromise. Even Masaccio's *Trinity* includes several subtle compromises away from the unforgiving requirements of linear perspective, favoring other artistic purposes. These compromises are probably not accidents or errors, but rather deliberate choices. [11].

[11] Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

We need to talk about the most virtuosic display of linear perspective in the Italian Renaissance, a dazzling two-dimensional projection of an elaborately complex three-dimensional tableau, the *Flagellation* by Piero della Francesca. 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 no simple checkerboard, but a complex pattern of triangles, squares, rectangles, and parallelograms. This floor required meticulous analysis to create its fully accurate anamorphic projection.

Why go through the trouble? The three-dimensional configuration and shadowing with illumination from the left is hyper-realistic and consistent throughput the painting, except for the bright light surrounding Christ and the column to which he is bound. Christ is emphasized by illumination of a uniquely bright light from the right that only he sees. The entire three-dimensional study in Earth-bound perspective and shadowing is a vehicle to emphasize and celebrate a divine, God-given source of light.

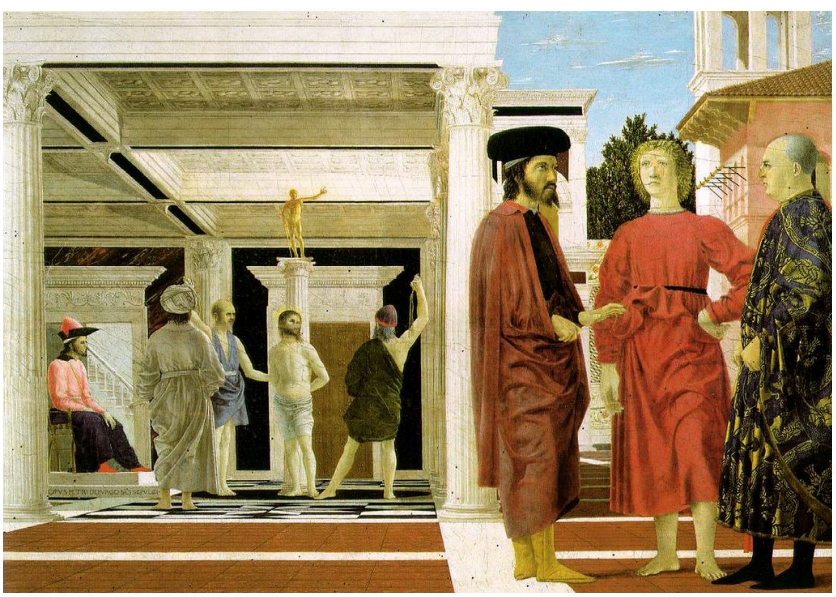

Figure 92: *The Flagellation* by Piero della Francesco (1468-1470). Link to Wikipedia.

Once discovered, linear perspective became an important tool in the Renaissance arsenal.

> "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

But the paintings tell us that da Vinci was not slaved to the demands of geometrical perspective. Aesthetics and other practicality could win over perspectival accuracy. Leonardo's *Last Supper* depicts his best known imaginary three-dimensional tableau. Perpendicular lines to the plane of the painting convergence to a central point at Christ's head. If you get close enough to the actual painting, you will find a small nail hole at this vanishing point, suggesting that Leonardo pulled a taut string from a nail to make other perfectly radiating lines along the coffers of the ceiling and wall tapestries.

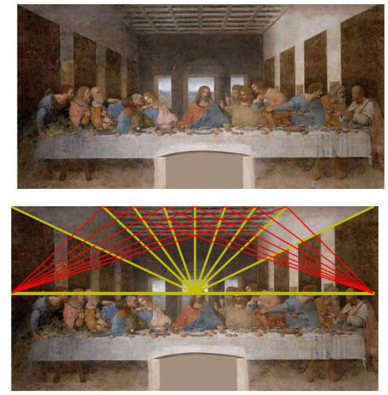

Figure 93: Analysis of *The Last Supper*. The vanishing point at Christ's head can be inferred from the coffered ceiling. Red lines indicate the focus of diagonals two coffers deep. If the coffers are rectangular, twice as wide as long, these foci convey the distance between viewer and image. Kemp (1990).

But the fresco is too high on the wall for any viewer to put their eyes on the perpendicular to the vanishing point. The painting would never be viewed from a single ideal point. The laws of perspective would have to be compromised.

Geometry and measurement 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 calculating 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 these 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. 94) [12]. Leonardo traded geometrical harmony for musical harmony, making little difference to the casual viewer but having some aesthetic meaning to him.

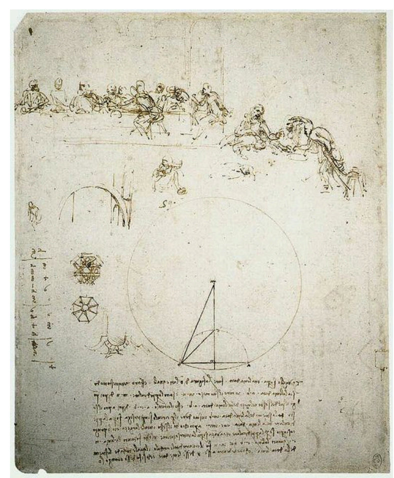

Figure 94: *Study for The Last Supper, with Method of Constructing an Octagon and Arithmetical Calculation*. Leonardo da Vinci.

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

The Last Supper is an act of *fantasia*, a gesture towards the rules of perspective, making it seem like looking through Alberti's window into a hallowed space, but with conscious departures toward narrative purpose.

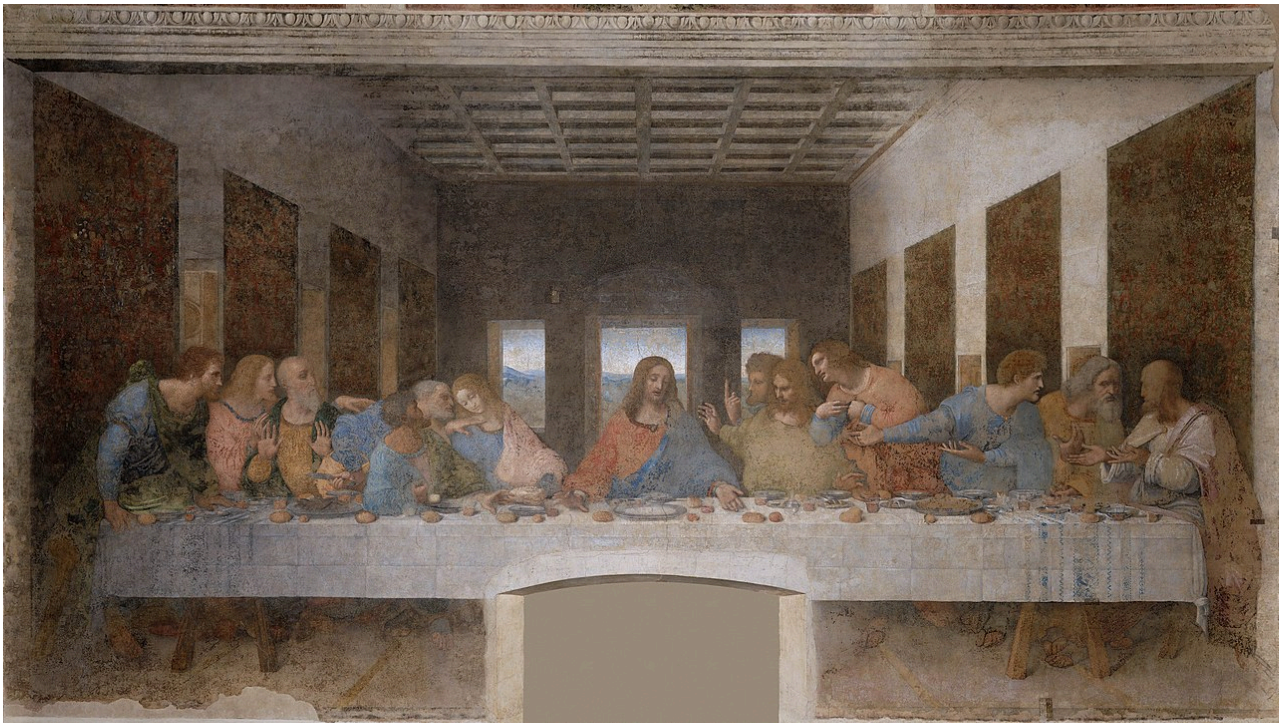

Figure 95: *Last Supper* by Leonardo da Vinci (1495-1498). Link to official site.

THE CAMERA OBSCURA, or ‘dark room’, is a dark chamber where one wall has a small aperture to the illuminated outside world. Leonardo da Vinci admired the camera lucida for its clues about the nature of visible light and the visual world:

> “O marvellous necessity... O might process. Here the figures, here the colours, here all the images of the parts of the universe are reduced to a point... Forms already lost, can be regenerated and reconstituted.” [13]

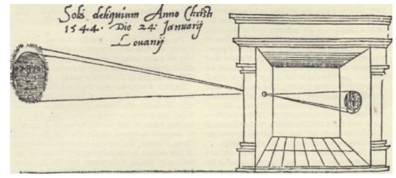

Figure 96: Camera obscura illustrated by the Dutch mathematician Gemma Frisius in 1545.

Figure 97: Vermeer (Colin Firth) and Griet (Scarlett Johannssen) looking through a *camera obscura* in the film *Girl with a Pearl Earring*.

Rays of light pass through the aperture. The rays cross, re-emerge, and diverge. When the diverging rays are captured on a flat screen, they form a reversed and inverted image. This image is dim, because only a small fraction of photons reflected from objects in the outside world will travel through the aperture. The aperture needs to be small to produce a sharp image. The smaller the aperture, the sharper and dimmer the image. Dimness can be helpful, for example, in early astronomical observations of the sun (Fig. 96). To see a solar eclipse, we still make ‘pinhole cameras’ out of cardboard boxes based on the same principles.

A CONVEX LENS will collect more light than a pinhole, and produce a brighter image at its focal distance. The lens-augmented camera obscura became a startling way to capture visual truth, a form of ‘natural magic’. In 1622, Constantijn Huygens (father of Christiaan, the renowned Dutch physicist and optical scientist) wrote of the camera obscura:

[13] Martin Kemp. *The Science of Art*. Yale University Press, New Haven, Connecticut, 1990. ISBN 0-300-04337-6

> “It is impossible to express its beauty in words. The art of painting is dead, for this is life itself, or something higher, if we could find a word for it.” [14]

[14] Svetlana Alpers. *The Art of Describing*. University of Chicago Press, 1983. ISBN 978-0-226-01513-2

These were provocative words in the Dutch Golden Age, the era of Rembrandt and Vermeer. But the Dutch Renaissance was also a Golden Age in optical science led by physicists like Christiaan Huygens and microscopists like Antonie von Leeuwenhoek. Dutch scientists and artists knew and admired their respective and extraordinary achievements, and a camera obscura made its way into the film *Girl with a Pearl Earring*, based on the book, a historical fiction, of the same name.

Figure 98: A portable *camera obscura* circa 1765 from Harvard’s Collection of Scientific Instruments.

HARVARD’S COLLECTION OF SCIENTIFIC INSTRUMENTS has a working portable *camera obscura* from the 19th century (Figure 98).

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Figure 99: *The Lacemaker* by Johannes Vermeer. Link to painting at Google Arts and Culture

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