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DOUBLE TAKE

Chinese Optics and their Media in Postglobal Perspective

ABSTRACT

In order to complicate the notion of a visual world universally constituted by light, this article undertakes an archaeology of light as a medium in China, where the discoveries of the polymath Mo Di 墨翟 (ca. 470–ca. 391 BCE) established different epistemological foundations for the study of light roughly a century before the *Optica* (*Optics*) of the Greek mathematician Euclid (mid-4th–mid-3rd century BCE). Indeed, many traditions of optical media, including but not limited to that of China, have been subsumed into or allegedly superseded by—and thus rendered invisible within—contemporary “global” practices, which are simply those of the Euclidean tradition propagated broadly. Yet it would be difficult to sketch a “global” history of optical media in a single book, let alone a single article. Consequently, this article examines the development of light as a medium in China in order to understand how the Mohist epistemology of light and its media can be understood in contrast, connection, and comparison to the Euclidean framework of early optics and its subsequent developments, now presumed to be normative. This article thus seeks to expose the limitations of such paradigms, and moreover, to provoke revision of other narratives of light and its media before and beyond the Euclidean tradition, while attending to the methodology of “postglobal” art history.

If Chinese optics never equalled the highest level attained by the Islamic students of light such as Ibn al-Haitham [sic], who benefitted by the accessibility of Greek geometry, it nevertheless began at least as early as the optics of the Greeks. It has proved so easy to find traces of optical thought and experimentation in Chinese literature that an extended investigation would be likely to find much more, though a great deal (even apart from the Mohist material) is likely to be irretrievably lost.¹

However, optical devices did not catalyze scientific inquiry in China until the nineteenth century when, after circulating widely for about two centuries, they inspired the first Chinese treatise on optics, Zheng Fuguang's (1780–c.1853) Crazy about Lenses for Sale [sic] (Jingjing ling chi, 1846).²

The globality of the present information age is broadcast predominantly in the medium of light. Specifically, information transmitted on the internet reaches its viewers and readers by means of display devices that convert digital data into electrical impulses; these generate

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the light that forms words and images. Digital images transmitted via the internet create instantaneous communication, including the sharing of visual imagery. Such instantaneous communication thus makes possible a more homogeneous world culture. While the homogenizing potential of instantaneous communication is distributed as widely as the information itself, however, that potential is rarely realized in ways that are truly universal, unedited, and global. Moreover, when the potential of instantaneous communication to homogenization is redirected towards individual, selective, and local interventions against such homogenizing global culture, that phenomenon is often mistaken for that which it seeks to problematize, if not work against.

To complicate the notion of a visual world universally constituted by light, this article undertakes an archaeology of light as a medium in China, where the discoveries of the polymath Mo Di 墨翟 (ca. 470–ca. 391 BCE) established different epistemological foundations for the study of light roughly a century before the *Optica* (*Optics*) of the Greek mathematician Euclid (mid-4th–mid-3rd century BCE).³ Indeed, many traditions of optical media, including but not limited to that of China, have been subsumed into or allegedly superseded by—and thus rendered invisible within—contemporary “global” practices that are simply those of the Euclidean tradition and its successors propagated broadly. Yet it would be difficult to sketch a “global” history of optical media in a single book, let alone a single article. Consequently, this article examines the development of light as a medium in China in order to understand how the Mohist epistemology of light and its media can be understood in contrast, connection, and comparison to the Euclidean framework of early optics and its subsequent developments, now presumed to be normative. This article thus seeks to expose the limitations of such paradigms, and moreover, to provoke revision of other narratives of light and its media before and beyond the Euclidean tradition.

The “Postglobal”: A Methodological Preamble

Within the discipline of art history, practitioners from “emerging art histories” have begun to question the validity of “global” approaches to the discipline, approaches that address “the rest” on terms dictated by “the West,” often at moments of contact between “the West” and “the rest,” and all too frequently and unavoidably through pre-existing structures of knowledge formed in and by “the West.”⁴ In the case of optical media, for example, such practices might be understood to be exemplified by the two epigraphs at the beginning of this article. The first, drawn from the classic study of Chinese optics, finds Chinese optics wanting thanks to its lack of knowledge of Euclid, despite the fact that it is the absence of Euclidean geometry that facilitates the development of Chinese optical media. The second, drawn from a recent work of art-historical scholarship, implies that China had no optics until imported Western optical devices had circulated there for two centuries, where they promoted (again implicitly Western) “scientific inquiry” well after the import of Chinese optical media to Europe transformed European spectacular experience. These perspectives sit against those of scholars who work on “the West,” who may have no knowledge that China had a discrete history of the study of optics and of optical media.

It is in the face of scholarship of this type that scholars from and working in “emerging art histories”—the histories of art of cultures that, while producing art in their indigenous media, have not framed it in the terms afforded by the implicitly “Western” discipline of art history—have begun to propose “postglobal” approaches.⁵ “Postglobal” approaches seek to examine histories of art outside those of established traditions: they address this art firstly

in its own terms, and only then by identifying its similarities to, and differences from, the established paradigms that shape the epistemological structures and language of established art histories. The goal of such inquiry is to consider art made outside “the West” literally in its own terms, emphasizing nomenclature as a means by which to consider the resemblance, correspondence, and incommensurability of “non-Western” cultures with those of “Western” art history in order to restore the primacy of “non-Western” art and to undercut the dominance of “Western” art history.

The goal of these approaches is to articulate, productively, the epistemic differences and/or convergences of emerging and established art histories, the latter often implicitly or explicitly “Western.”⁶ The scope and language of this endeavor, however, remain unsatisfying. So pervasive, insidious, and polymorphous is “the West”—encompassing variably Europe (from the ancient Near Eastern sites invoked tacitly and unremarkably as pre-Greek progenitors of the Judeo-Christian tradition, the long geography of which also encompasses Egypt, also tacitly and unremarkably, given its place in texts of this tradition), its colonies and/or former colonies (on a case-by-case basis, not including indigenous practices that pre- and postdate the colonial project), and its cultural forms propagated through global flows of capital (mutating through local adaptation)—that limiting its metastasizing reach in order to create the possibility for other narratives of art history is itself a problem.

As a nascent method in art history, a comparativist, “postglobal” approach has no fixed practice, nor does the term “postglobal” have a fixed definition. To work in this new and experimental methodological space is to seek to understand phenomena outside the terms of a single, universal or “global” narrative that implies cultural connection or cohesion, the approach of “the West” to “the rest.”⁷ Rather, this method rejects the reaching out of “the West” to “the rest”; it upholds the primacy of “the rest” (or rather of a discrete culture or cultures within “the rest”). It therefore privileges the recovery of indigenous, “non-Western” knowledge from the specific culture or cultures in which such knowledge originates, what might be called a “preglobal” moment (even if that knowledge has become embedded, at least to some extent, in “Western” structures of knowledge). Subsequently, this approach problematizes the moment when indigenous, non-Western and imported, Western knowledge—the latter often perceived to be universal and/or normative—mingle in the formation of a “global” narrative, one in which “the West” makes contact with, catalogues, and perhaps assimilates “non-Western” knowledge. Finally, this method attempts to elucidate indigenous, “non-Western,” “preglobal” knowledge in dialogue with, but not circumscribed by, implicitly “Western,” “global” knowledge, to create a “postglobal” episteme that allows the indigenous, “non-Western” phenomenon to be understood on its own terms, freed as much as possible from any prior “Western” constraints placed upon it, while seeking sufficient comparative context as to make indigenous terms intelligible to those familiar with a universalizing, implicitly “Western” narrative of art history.⁸

To be clear: “preglobal,” “global,” and “postglobal” are not chronological categories, but epistemic ones used for analytical purposes. These categories are no more “true” in historical terms than many studies of “globalization” are “global.”⁹ Across the span of human history, things and ideas have moved broadly. The art historian, however, requires tools of fixity that, no matter how artificially, stop or segment moments in artistic mobility and knowledge transfer in order to understand their implications. It is as tools that interrupt and/or pause what are in practice continuous historical phenomena that the terms “preglobal,” “global,” and “postglobal” function in this article.¹⁰

Light: A Universal Medium?

In our globalized world, contemporary works of art naturalize divergent histories and cultures of optical media. When viewers see any number of works, they see images constituted, in seemingly similar ways, by light; examples might include works by the contemporary Canadian artists Jeff Wall (b. 1946) and Michael Snow (b. 1929), and by the contemporary Chinese artists Song Dong 宋冬 (b. 1966) and Xu Bing 徐冰 (b. 1955).¹¹ Two contemporary works of art, Jeff Wall's *A Sudden Gust of Wind (After Hokusai)* of 1993 (fig. 1) and Xu Bing's *Background Story 4* of 2004 (fig. 2), each engage a place-specific historical work of art, in Wall's case the print *Ejiri in Suruga Province (A Sudden Gust of Wind)* (*Suruga Ejiri* 駿州江尻) of 1831, by Katsushika Hokusai 葛飾北斎 (1760–1849), from his *Thirty-six Views of Mount Fuji* (*Fugaku sanjurokkei* 富嶽三十六景; fig. 3); and in Xu's case *Dwelling in the Fuchun Mountains* (*Fuchun shanju tu* 富春山居圖) of 1350, by Huang Gongwang 黃公望 (1269–1354; fig. 4).¹² Although luminous, when viewed from the front (as they typically are), the way in which they are lit internally cannot be seen. Viewing the physical relation of light source to image in these works, however,

FIGURE 1. Jeff Wall (b. 1946), *A Sudden Gust of Wind (After Hokusai)*, Canada, 1993. Transparency on lightbox, 250 × 397 × 34 cm. Tate Museum, London. Photograph courtesy of Jeff Wall, © Jeff Wall

FIGURE 2. Xu Bing (b. 1955), *Background Story 4*, China, 2008. Mixed media installation, trash and natural debris attached to frosted glass panel. Installation view (front) at Xiangshan Campus, China Academy of Art, Hangzhou, China, 2008. Photograph courtesy of Xu Bing Studio, © Xu Bing Studio

FIGURE 3. Katsushika Hokusai (1760–1849), *Suruga Ejiri* (Eijiri in Suruga Province), from *Fugaku sanjurokkei* (Thirty-six Views of Mount Fuji), Japan, 1831. Polychrome woodblock print, ink and color on paper; 25.4 × 37.1 cm. The Metropolitan Museum of Art, New York

FIGURE 4. Huang Gongwang (1269–1354), *Fuchun shanju tu* (Dwelling in the Fuchun Mountains; detail), China, 1350. Ink on paper, H. 33 cm. National Palace Museum, Taipei

makes clear how optical media constitute them, for example, in the case of works by Jeff Wall (fig. 5) and of Xu Bing's *Background Story 4* (fig. 6). Whereas Wall's light boxes, constructed on the wall with their oversized photographic transparencies, conceal the very light source that makes their static images visible, Xu's installation reveals its light sources and its capacity to project even the potential motion of its free elements onto a shadow screen.

In contrast, works by Michael Snow and Song Dong use and manipulate optical media. In *WVLNT* (or *Wavelength for Those Who Don't Have the Time*) of 2003 (fig. 7), Michael Snow cut his well-known, forty-five-minute film *Wavelength* of 1966–67 into three equal lengths and superimposed them in a film of fifteen minutes. In *Father and Son at Tai Miao* [*the Imperial Ancestral Temple*] (*Fuzi Tai Miao* 父子太廟) of 1998 (fig. 8), Song Dong projected three images: one of his face (shown right), one of his father's face (shown left), and one constituted by the superimposed projection of both faces (shown center). Whereas Snow digitally remasters an optical, time-based medium by exploiting the properties of light and transparency to establish a new sequence and temporality of viewing, Song manipulates the properties of

FIGURE 5. Jeff Wall,
Lightbox interior, as
seen during installation
process at the Louisiana
Museum of Modern Art,
Humblebæk, Denmark,
2015. Detail of screenshot
after <http://channel.louisiana.dk/video/jeff-wall-pictures-poems>

FIGURE 6. Xu Bing, *Background Story 4*
(fig. 2), verso. Installation view (back) at
Xiangshan Campus, China Academy of Art,
Hangzhou, China, 2008. Photograph courtesy
of Xu Bing Studio, © Xu Bing Studio

FIGURE 7. Michael Snow (b. 1928), *WVLNT (or Wavelength for Those Who Don't Have the Time)*, Canada, 2003. Digital media after scanned film. Detail of screenshot after <http://www.youtube.com/watch?v=AQ0row2iTfU>

FIGURE 8. Song Dong (b. 1966), *Fuzi Tai Miao* (Father and Son at Tai Miao [the Imperial Ancestral Temple]), China, 1998. Transparent slides projected onto painted wood. Photograph courtesy of Song Dong, © Song Dong

light and transparency inherent in projected images to create a new image through optical superimposition.

All four works appear grounded in a shared, “universal” knowledge of light and optical media, including the possibilities of diffused and lens-focused light sources, transparency and bodilessness, and temporality. Such a contemporary, universal understanding of light as a medium presumes a single, unified, and tacitly “Western” discourse of optical media. Indeed, “Western” discourses of optical media presume that devices for the movement and projection of

images originate only within the “Western” tradition.¹³ This notion of light is propagated—and underscored—by access to these works and their Anglophone internet criticism, works and criticism transmitted to their audiences through the ubiquitous optical medium of the LED screen. This article takes these works not as objects of study but as pretexts for a larger argument about the histories of optics and their media that such works obscure.

These works presume a universal and undifferentiated contemporary sense of light-based media that inherently equates and compares works made in different cultural contexts. This is to some extent a result of the fact that, when the “Western” discipline of art history has turned its attention to matters of light and optics, and to the allied fields of catoptrics, perspective, and dioptrics, it has tended to look only within its own tradition (although that tradition is broadly conceived as encompassing ancient Near Eastern and Egyptian antiquity).¹⁴ Even when scholars working outside the “Western” tradition have attended to such matters, they have taken the “Western” tradition as normative, and thus have been unable to understand “non-Western” traditions on their own terms.¹⁵ To remedy this state of the field, contemporary works executed in optical media might be understood more precisely with respect to a strongly revisionist, albeit schematic, “postglobal” history of optics.

The essay that follows proposes to rethink the historical and epistemological foundations of contemporary works of optical media by placing them in the context of a schematic history of optics segmented into three epistemic phases. First, it examines the discrete, “preglobal” origins of optics and optical media in China and in “the West,” here exemplified by Greece and the optics of Euclid; this account makes clear that Chinese scholars beginning with Mo Di—and not scholars in the “Western” tradition—first established the properties of light, and did so outside Euclidian conventions of optics symbiotically (and thus inextricably) linked to Euclidean geometry.¹⁶ Second, it sketches one moment in the connective, “global” development of the science of optics, during which “Western” optical knowledge, exemplified by that of Europe, circulated to China, and Chinese optical knowledge circulated to “the West” (specifically to Europe), as exemplified by documentation of the contact of ideas and devices transmitted between them. Third, it seeks comparative, “postglobal” epistemologies of optical media that retain and/or restore knowledge of the local, indigenous histories of ideas and devices that inform work made in what might otherwise appear to be a “universal” language of light and the visual images constituted by it. By presenting an outline history of optical media in China—one in which China “invents” optical media based on an optics unburdened by Euclidean geometry, shares its knowledge with “the West,” and subsequently devalues this indigenous knowledge—this essay concludes by revisiting the works of Snow, Song, Wall, and Xu to probe how a “postglobal” history of optical media creates preconditions for understanding light, the universal medium, in historically, geographically, and culturally specific terms within and beyond the foundations laid by Euclid.

The “Preglobal” Moment of Chinese Optical Media: A “Postglobal” Perspective

Chinese optical media began with the origin of optics in China and developed along two axes: its relation to optics and its devices, and its relation to human vision. The study of optics in China originated with Mo Di, also known as Mozi 墨子, in the fifth through fourth centuries BCE. Likely an artisan and certainly a polymath, Mo Di excelled in making unusual devices.¹⁷ He was the first student of light to theorize it in ways that we today understand to be “accurate,” his text completed roughly a century before the *Optics* of the Greek mathematician Euclid, dated circa 300 BCE. Some texts provide suggestive but inconclusive evidence of the possible

existence of glass lenses in China; however, no examples of early Chinese transparent lenses survive.¹⁸ Given the development of bronze technology in China before the Common Era, the principal instrument for the investigation of the properties of light in China was the mirror (fig. 9). What is significant in comparing the histories of optics in China and Greece is firstly that Mo Di preceded Euclid by roughly a century, and secondly that, for Mo Di, optics was not lens-based, as was the case in “the West,” where polished crystal lenses appeared as early as 750 to 710 BCE, as exemplified by the “Nimrud/Layard Lens” (fig. 10), with analogues in Greek antiquity.¹⁹

Mo Di coherently explained multiple optical phenomena. These include shadow (the term used in the original text is *ying* 景, the precursor to the modern term *ying* 影), in some cases best translated as “reflection” or “image”; umbra and penumbra (literally “doubling,” *zhong* 重); refraction (literally “appearance,” *xian* 見, described with respect to the appearance of a thing submerged); pinholes (*ku* 庫), definition of focal point (*duan* 端), and inversion of images (*jingdao* 景到, literally “the image inverted”); and plane (*zhengjian* 正鑒), concave (*jianwei* 鑒位, literally “the mirror [that is] concave”), and convex bronze mirrors (*jiantuan* 鑒團, literally “the mirror [that is] convex”).²⁰ Significantly, in comparative histories of optics, the properties of light articulated by Mo Di are fundamentally the same as those later articulated by Euclid. Yet Euclid framed his understanding of light in terms of fifty-eight theorems dependent on four definitions that are remarkably similar to the theorems and definitions of his *Geometry*, whereas Mo Di grounded his optics in experimental practice, namely the observation of light and its movement.²¹ It is for this reason that Euclidean optics has a symbiotic relation to Euclidean geometry, the principles of which condition its relation to optical devices, vision, and spatial representation in “the West.”

FIGURE 9. Mirror with three dragons, China, 2nd half of 4th–1st half of 3rd century BCE. Cast bronze, Diam. 15.3 cm. Reportedly from Jincun, Luoyang, Henan Province. Bishop William C. White Collection, The Royal Ontario Museum, Toronto. Photograph courtesy of The Royal Ontario Museum, Toronto, © The Royal Ontario Museum, Toronto

FIGURE 10. Nimrud Lens (a.k.a. Layard Lens), Iraq, 750–710 BCE. Rock crystal, Diam. 3.8 cm. Excavated from Nimrud, Iraq. The British Museum, London. Photograph courtesy of The British Museum, London, © The British Museum

Mohist optics facilitated the development of optical media. Defined as those media that use light to create images (often by illumination or projection), optical media also frequently move images constituted by light.²² No later than the Former Han dynasty (206 BCE–8 CE), simple optical media feature in Chinese texts. Both the *Records of the Historian* (*Shi ji* 史記, completed ca. 94 BCE) and the *History of the Han Dynasty* (*Han shu* 漢書, completed 111 CE) indicate that, during this period, shadow puppetry applied optical knowledge to image-making, notably in the creation of moving human figural images (fig. 11).²³

Furthermore, Mohist optics supported optical media that were generated in more complex ways. Another account of the Former Han dynasty, from the *Miscellaneous Records of the Western Capital* (*Xijing zaji* 西京雜記, ca. 4th–6th century), indicates the existence of a lamp capable of making a dragon writhe when lit.²⁴ Almost certainly this is an account of an early form of zoetropic lantern, or *lanterne tournante*, capable of rotating and projecting illuminated images using vanes and convection currents.²⁵ Also noted in the *Miscellaneous Records of the Western Capital* is a carved jade tube, a “Pipe for Summoning Illusions/Fantasies” (*zhaohua zhi guan* 昭華之琯); powered by a small windmill or turbine, the tube projected moving images onto a screen.²⁶ No evidence exists in “the West” of the contemporaneous development of simple or complex optical media.²⁷

Even as early conjurers applied knowledge of Mohist optics to the production of optical media, later Chinese scholars followed Mo Di to describe the projection of an image by a pinhole, a pin-sized hole in an opaque support that allows for the transmission of a small beam of light through the hole. Although the transmission of light by pinholes was not instrumentalized—as *camerae obscurae*—in China (as later became the case in both China and “the West”), the ninth-century scholar Duan Chengshi 段成式 (d. 863) described this phenomenon in his *Miscellaneous Morsels from Youyang* (*Youyang zazu* 酉陽雜俎); Duan, however, misunderstood its cause.²⁸ Joseph Needham has suggested that anecdotes detailing the re-animation of lost loves in optical media, such as those of Gao Yanxiu 高彥休 (fl. 874–79) in “Tang Memorabilia” (*Tang que shi* 唐闕史) and of Sun Guangxian 孫光憲 (d. 968) in “Northern Dreams and Trifling Talk” (*Bei meng suo yan* 北夢瑣言), may record images generated by a pinhole, in this case one larger than a pin-head, fitted with a transparent, plano-convex lens.²⁹ Ultimately, the eleventh-century polymath Shen Kuo 沈括 (1031–1095) corrected Duan’s misinterpretation of the workings of the pinhole based on the Mohist optics current in his lifetime, indicating

FIGURE 11. *Monkey King Fighting*, China, March 28, 2007. Video of shadow puppets projected on backlit screen. Dongzha Village, Wuzhen. Detail of screenshot after <https://www.youtube.com/watch?v=lazfPhHS1dcShadowPuppet>

how the image of a pagoda was formed upside down when projected through a pinhole.³⁰ Shen Kuo thus explained the optical properties of a *camera obscura*, and indicated its potential for image-making.³¹ In discrete histories of Chinese and Greek optics, both Mo Di and Euclid (and later Aristotle) understood the function of the pinhole.³² These histories diverged when, beginning in the mid-ninth century, the projection of light-based images using a pinhole began to circulate in China, knowledge that appeared in Europe centuries later, perhaps through contact with knowledge of optics imported from the Islamic world.³³

Foundational to Mohist optics is an accurate description of how light appears and is received, either by the eye or by a mirror. One passage within Mo Di's text describes this phenomenon with respect to the pinhole (*ku*): "As for the image, an illuminated person shines as though shooting [forth rays of light] (*ying*: *guang zhi ren xu ruo she* 景: 光之人、煦若射)."³⁴ A subsequent passage on the transmission of light by plane mirrors (*zhengjian*) states, "The target [for the rays of light] of that which is mirrored is in the mirror (*jianzhe zhi nie yu jian* 鑒者之臬於鑒); [it] lacks that [which is] not mirrored (*wu suo bu jian* 無所不鑒)."³⁵ Together the passages indicate that the object, the image of which is projected through a pinhole or captured in a mirror, emits light that is mediated by either the pinhole or the mirror. These passages thus make clear that, for Mo Di, the eye saw light emitted by objects.³⁶

Whereas in Mohist optics light was understood to be given off or reflected from objects and received by a mirror (or an eye), and not emitted from the eye, in "the West" the source of light and the process by which the eye perceives light and objects were debated for centuries. Euclid posited that visual rays extend outward from the eye to illuminate the object, a theory of vision known as "extramission," which the Greek philosopher Plato (ca. 424–ca. 348 BCE) shared but his student Aristotle (384–322 BCE) rejected.³⁷ Aristotle instead argued for "intromission," in which the eye receives rays emanating from objects, a model compatible with Mo Di's theories on the transmission of light.³⁸ Tensions between intromission and extramission persisted for centuries in "the West." In his *Kitāb al-Manāẓir* كتاب المناظر (Book of Optics), translated into Latin circa 1200 as *De aspectibus*, the Arab polymath Abū 'Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham أبو علي، الحسن بن الحسن بن الهيثم (ca. 965–ca. 1040), a native of Basra active in Cairo also known simply as Ibn al-Haytham or Alhacen, countered Euclid's notion of extramission and proposed an opposing theory of intromission that denied the existence of visual rays, ascribing the sense of sight to the eye itself.³⁹ The European reception of Ibn al-Haytham's theory of the relation of vision and optics, based on his engagement with Euclid, laid the groundwork for a series of scholars, including Leonardo da Vinci (1452–1519), to understand ocular vision with increasing accuracy.⁴⁰ This process culminated in 1604, when the German mathematician and astronomer Johannes Kepler (1571–1630) hypothesized, correctly, how the retinal image worked.⁴¹

It is clear that, by the time of the eleventh-century polymath Shen Kuo (noted above), the basic function of the eye was known in China, and binocular vision was taken to be normative. Whereas Mohist optics and knowledge of the pinhole provided a paradigm for understanding the movement of light into a single eye, early Chinese texts such as the *I Ching*, also known as the *Changes of Zhou* (*Zhou yi* 周易), and its commentaries, compiled between the tenth and fourth centuries BCE, address vision and sightedness incidentally, noting the anomaly of one-eyed vision through use of the term *miao* 眇, which (among multiple definitions) can mean "to see with a single eye."⁴² Such concerns continued to be articulated in Shen Kuo's time, as by his contemporary, the scholar and poet Chao Buzhi 晁補之 (1053–1110).⁴³ Medical and physiognomic texts current during Shen Kuo's lifetime also attended to the appearance and function of the human eye, as well as those of animals.⁴⁴

Texts from the Song dynasty (960–1279) repeat earlier formulations about the workings of the eye and sightedness. Specifically, commentaries on the *I Ching* elaborate on these earlier articulations, enhanced by greater knowledge of the function of the eye. Shen Gai 沈該 (fl. 1131–62), for example, reproduces text that he ascribes to the *Jing shi yi zhuan* 京氏易傳 (Commentary to the *Yijing*) by Jing Fang 京房 (77–37 BCE), indicating the mechanical function of the eye: “As for sheep, sheep’s eyes [that is, their pupils] enlarge when they see. Unilluminated, [they] take in light [that] resides in them. [Even] a single eye (*miao*) is able to see an image” (*Dui wei yang, yang mu da er shi. Bu jing ming, yi yang ju zhi. Miao neng shi zhi xiang ye* 兌為羊, 羊目大而視. 不精明、以陽居之; 眇能視之象也).⁴⁵ Like this example from Shen Gai, other Song texts also express the possibility of monocularity, sustained through use of the term *miao*.⁴⁶ Yet these texts persist in indicating the normativity of binocularity, principally denoted by the term “two-eyed” (*liangmu* 兩目).⁴⁷

During the Song dynasty, mathematical treatises underscored the implications of binocularity. Specifically, problems involving dual lines of site and the Pythagorean Theorem to calculate distance had been included in “Right Angles” (*Gougu* 勾股), the final chapter of *The Nine Chapters on the Art of Mathematics* (*Jiu zhang suan shu* 九章算術), the text of which was compiled corporately between the tenth and second centuries BCE, and assumed its present form in the second century CE; these problems also had appeared in the supplemental *Sea Island Mathematical Treatise* (*Haidao suan jing* 海島算經), the text of which was compiled by Liu Hui 劉徽 (ca. 225–ca. 295 CE). Both texts were republished repeatedly, including during the Song dynasty in 1084 and 1213.⁴⁸ These mathematics problems make clear, by extension, that Chinese of the period had the mathematical foundation to understand parallax, its relation to the estimation of space, and its dependence on binocularity and/or a mobile eye. Indeed, the Pythagorean Theorem, attributed to Pythagoras of Samos (ca. 570–ca. 495 BCE) but likely known in ancient Greece well before his time, was integral to Euclidean geometry; for whatever reason, however, its implications for binocular vision appear not to have been considered.

In China, knowledge of optics, vision, and mathematics facilitated the development of schema for the representation of space that accommodated the lack of fixity presupposed by dynamic processes of human sight. Unlike the Euclidean tradition, the Chinese tradition does not posit a one-to-one correspondence of optical and spatial knowledge. In recording the notions of painting held by the eleventh-century Chinese painter Guo Xi 郭熙 (ca. 1020–ca. 1090) in *Lofty Treatise on Forests and Springs* (*Linquan gaozhi* 林泉高致), his son Guo Si 郭思 (fl. ca. 1070–after 1123) included his father’s notion of the “Three Distances” (*sanyuan* 三遠).⁴⁹ As the text indicates, these distances are predicated on the existence of a mobile, binocular gaze that scans the picture plane.⁵⁰ Specifically, “high distance” (*gaoyuan* 高遠) is the pictorial space as scanned from the bottom to the top of the picture plane (and vice-versa), allowing the viewer to take in the height of the landscape depicted. In contrast, “deep distance” (*shenyuan* 深遠) is the space experienced by looking through the represented landscape, from front to back and vice-versa. Finally, “level distance” (*pingyuan* 平遠) is pictorial space as scanned horizontally (right to left and vice-versa), which permits a level gaze across a painted landscape.⁵¹

In practical terms the “Three Distances” are simply nomenclature for the three axes of three-dimensional space: height (i.e., “high distance”), depth (i.e., “deep distance”), and width (i.e., “level distance”). It is the ability to gaze into the distance (*wang* 望) along each axis from at least two points that permits the calculation of distance and, by extension, of spatial relation and proportionality.⁵² Height, depth, and width are visible in Guo Xi’s *Early Spring* (*Zao chun tu*

早春圖) of 1072 (fig. 12), and differently so in his *Old Trees, Level Distance* (*Shu se ping yuan tu juan* 樹色平遠圖卷; fig. 13), the title of which emphasizes its width. The ability to calculate these values in empirical terms is described in the *Sea Island Mathematical Treatise*, which contains commonly known problems for calculating height (*gao* 高), depth (*shen* 深), and width (*guang* 廣) in landscape settings.⁵³ These include problems that solve, via two viewing points, the height of the eponymous Sea Island (*dao gao* 島高), of a pine tree on a hill (*song sheng shan shang* 松生山上), and of a building as viewed from a hill (*deng shan wang lou* 登山望樓); the depth of a deep valley (*shen gu* 深谷) and of a clear pool (*qing yuan* 清淵); and the width of a river mouth (*bo kou* 波口) and of a river-ford viewed from a mountain (*deng*

FIGURE 12. Guo Xi (ca. 1020–ca. 1090), *Zao chun tu* (Early Spring), China, 1072. Ink on silk, 158.3 × 108.1 cm. National Palace Museum, Taipei

FIGURE 13. Guo Xi, *Shu se ping yuan tu juan* (Old Trees, Level Distance), China, ca. 1080. Ink on silk, 35.6 × 104.4 cm. The Metropolitan Museum of Art, New York

shan wang jin 登山望津).⁵⁴ Because calculations of spatial relations result from the ability to see from two locations, the mobility of the eye of the viewer is integral to the viewership of a landscape painting from the Song dynasty. In the Mohist tradition, the resonance of optical media with the pictorial representation of three-dimensional space arises because the fugitive images of optical media move the eye to create an image in three-dimensional space just as the eye moves in scanning an image to estimate its proportions, and thus its three-dimensionality. In this way, the algebraic space of the Mohist tradition diverges from the geometric space of the Euclidean tradition.⁵⁵

What is significant in comparative histories of spatial representation linked to underlying notions of the function of the eye, monocular and/or binocular seeing, and optics is that, at least in theory, the eyes of the viewer must wander to at least two fixed points in each dimension in order to estimate the dimensions of the space in the case of a landscape painting from the Song dynasty.⁵⁶ In contrast, a painting of the European high Renaissance such as *The Last Supper* (fig. 14), begun circa 1495–96 by Leonardo da Vinci (one of the great students of optics, the eye, and spatial representation), makes entirely different demands on the viewer. Here, the viewer must look at the painting with a single, stationary eye to see the dimensions of the space generated by Leonardo's knowledge and application of linear perspective. The rules

FIGURE 14. Leonardo da Vinci (1452–1519), *The Last Supper*, Italy, begun ca. 1495–96. Tempera and oil on plaster, 460 × 880 cm. Santa Maria delle Grazie, Milan

and formulae for such linear perspective were articulated by Leon Battista Alberti (1404–1472), for example, in “On Painting” (*De Pictura*) of 1435, and firmly grounded in Euclid’s *Elements*, specifically its description of similar triangles.⁵⁷

It is a common misconception in the field of Chinese painting history that the Japanese scholar of Chinese painting Ogawa Hiromitsu demonstrated “the existence of a horizon and vanishing point” in Guo Xi’s *Early Spring*. Rather, in an article reliant on the concept of an “origin” (Jp. *genten* 原點), the mathematical term for the point at which x-, y-, and z-axes intersect in a three-dimensional Cartesian coordinate system (fig. 15), Ogawa argues that, in *Early Spring*, Guo Xi invented proportional space centuries before the Italian Renaissance.⁵⁸ While Ogawa describes the proportional relationships of pictorial elements in the painting, the underlying mathematics that he uses—Euclidean geometry mapped via a Cartesian coordinate system—was unknown in China in Guo Xi’s time. Ogawa’s article is analogous to describing the proportional relationships within *The Last Supper* without understanding the relationship of that painting to Euclidean geometry, and its application to the representation of pictorial space by Alberti and his successors.

Whereas binocularity and trigonometry were integral to thinking about vision and space in China, in Europe knowledge of the pinhole, which provides a functional example of a single ray of light moving in a straight line, furnished the epistemic model for monocular vision grounded in mathematical geometry. The conceptual groundwork for the European epistemic model begins with Euclid’s treatment of light in his *Optica*, which is distinct from his *Catoptrica* (*Catoptrics*), his study of light and mirrors.⁵⁹ The fifty-eight theorems of the *Optica*, based on four definitions similar to those of his *Elementa*, model Euclid’s study of light on his study of geometry, with larger epistemological implications for the correspondence of optics and the representation of three-dimensional space in two dimensions.⁶⁰ Euclid’s statements on the properties of single rays of light, which move in space like the lines of his *Elements*, offer no model for the binocularity of vision.

Despite the limitations of the pinhole as a model for understanding vision in “the West,” the pinhole-based *camera obscura* nonetheless may have served as a device for rethinking received Greek notions of light and vision inherited from antiquity. In the “Western” tradition, experimentation with pinholes and the invention of the *camera obscura* often are ascribed to

FIGURE 15. Cartesian coordinate system.
Illustration by the author

Ibn al-Haytham, a misleading oversimplification of the history of optics in the Islamic world.⁶¹ Moreover, this “work” of Ibn al-Haytham often is perceived to underpin the work of Leonardo da Vinci on optics.⁶² The situation is more complicated than this: on the one hand, ancient Greek writers knew the pinhole and its properties, as noted above; on the other, extant copies of *De aesepectibus*, the Latin translation of Ibn al-Haytham’s Arabic-language *Kitāb al-Manāẓir*, do not include those passages of the original text that address the *camera obscura*, nor did Ibn al-Haytham take the *camera obscura* to be a proxy for the human eye.⁶³

The limitations of the *camera obscura* notwithstanding, beginning with Leonardo da Vinci, its use as a proxy for the human eye served as a foundation for the development of “Western” systems of representation, including perspective.⁶⁴ In his *Codex Atlanticus*, Leonardo illustrated the working of the *camera obscura* (fig. 16), and attempted to link the eye and *camera obscura* for the first time, following suggestive illustrations of 1492 (fig. 17).⁶⁵ Leonardo’s ideas about the mechanistic nature of the eye also are articulated in his Manuscript D of 1508, in which he describes how the passage of light through the pupil inverts the object (fig. 18), which is also the case for the *camera obscura*.⁶⁶ More importantly, in Manuscript D Leonardo specifically

FIGURE 16. Leonardo da Vinci, Pinhole projection of light/*camera obscura*, from *Codex Atlanticus*, Italy, 1519. Drawing, ink on parchment, paper; 64.5 × 43.5 cm. Biblioteca Ambrosiana, Milan

FIGURE 17. Leonardo da Vinci, Similitude of eye and *camera obscura*, from *Codex Atlanticus*, Italy, 1519. Drawing, ink on parchment, paper; 64.5 × 43.5 cm. Biblioteca Ambrosiana, Milan

FIGURE 18. Leonardo da Vinci, How the passage of light through the pupil inverts the image, from Manuscript D, Italy, 1508. Drawing and text, pencil on parchment; 22.3 × 15.9 cm. Bibliothèque de l'Institut de France, Paris. Photograph © RMN-Grand Palais/ Art Resource, NY

relates the eye to the *camera obscura*, even as he demonstrates an understanding of the binocularly of human vision.⁶⁷ René Descartes (1596–1650) and the English philosopher John Locke (1632–1704), among others, furthered the idea of the similitude of the human eye and the *camera obscura*.⁶⁸

The *camera obscura* played a significant role in the development of misleading monocular models of vision in Europe during the early modern period. Indeed, the aperture of the *camera obscura* reinforced the idea of the transmission of light through an aperture and, by extension, through lenses, for which significant, ancient precursors existed in “the West.” Following the practices of “Western” antiquity, European devices worked to focus light in single streams through man-made lenses. The man-made lens thus served as a monocular surrogate, prosthesis, and experimental model for the anatomical lens of a single human eye.

Ultimately in China, where a single, light-transmitting aperture such as a pinhole could be understood as a model for a single eye but not for monocular vision, modes of transmitting light optimized for mobile, binocular viewing manifested as optical media. As noted above, the Song-dynasty polymath Shen Kuo wrote about the projection of an image through a pinhole, a phenomenon that focuses light in the way that a lens does.⁶⁹ But Chinese scholars who studied light and its transmission also clearly understood the focusing of light and the possibilities that focus afforded for projecting images. Specifically, mirrors were used to move and project light-based images.⁷⁰ In addition to the specular projections of “light-penetrating mirrors” (*touguang jian* 透光鑑), significantly Shen Kuo, following Mo Di, noted the production of concave mirrors, devices capable of projecting images.⁷¹ While the technology to make such a mirror—that is, a concave mirror with a sufficient focal length to project an image—did not exist in Europe until

perhaps the seventeenth century, such technology did exist in China.⁷² One Chinese record of a mirror viewed in 1588 notes that the back face of the mirror inverted the shadow/reflection of the person (i.e., turned the shadow/reflection upside down), a defining property of a concave mirror.⁷³

Prior to their contact with each other, knowledge of optics, vision, and spatial representation in China and in Europe came to define radically different epistemic structures, including those that led to the development of optical media in China. It is not the case that China failed to develop an optics. Rather, subsequent to the development of peerless bronze casting technology in China by 1500 BCE (including the making of highly sophisticated bronze mirrors of multiple types), during the fifth through fourth centuries BCE Mo Di articulated the fundamental properties of light. In China, the alliance of metallurgy and optics served as a foundation for the development of optical media that projected and moved images. Moreover, optical media and their devices relied on an understanding of human vision as mobile and binocular, an understanding articulated in ancient Chinese commentaries on the Classics, later amplified in texts (like that of Guo Si) that describe indigenous Chinese means for constructing pictorial space. Chinese optics thus had very little in common with its “Western” counterpart dominated by transparent lenses (glass and its precursors), monocular vision, and notions of spatial representation linked to the study of geometry and predicated on these phenomena.

The Connections of Optical Media in China: The “Global” Perspective

In Europe and China, two very different histories of optics—and thus two very different epistemologies of optics in relation to human vision, two-dimensional constructions of three-dimensional space, and optical media (or its corresponding absence in “the West”)—existed parallel to each other until their collision during the sixteenth and seventeenth centuries. At a time when the Jesuits circulated knowledge between the many parts of the world in which they were active, the German Jesuit priest and astronomer Johann Adam Schall von Bell (1592–1666), in his treatise *Yuanjing shuo* 遠鏡說 (Speaking of the Telescope) of 1626, explained and illustrated the properties of different types and configurations of glass lenses to Chinese audiences more familiar with the comparable properties of bronze mirrors.⁷⁴ Schall also described the *camera obscura*, translating European knowledge of this device back into Chinese, a language in which the principles of the device already had been known for centuries—longer, in fact, than in Europe, as noted above.⁷⁵ Indeed it is Schall, in his treatise on the telescope, who made clear the applicability of monocular devices to image-making.⁷⁶ Knowledge of the telescope and its glass lenses, as well as of the *camera obscura* fitted with a glass lens or mirror (the Chinese term *jing* 鏡 is ambiguous), circulated in Chinese in the work of the literatus and philosopher Fang Yizhi 方以智 (1611–1671) from the mid-seventeenth century.⁷⁷

Just as optical devices embodied an imported monocularity in seventeenth-century China, European religious prints not only provided models for Chinese narrative woodcut images intended for a single, immobile eye but also served as templates for picturing the vision of such an eye.⁷⁸ Four texts propagated by the Jesuits in China functioned in this way. These are *Evangelicae Historiae Imagines* (Images from the New Testament) of 1593, by the Spanish priest Geronimo Nadal (1507–1580); *Práctica de rezar o rosário* of 1619, also known as *Song Nianzhu guicheng* 誦念珠規程 (Method of Saying the Rosary), by the Portuguese João da Rocha 羅儒望 (1587–1639), which imaged the mysteries of the rosary; *Tianzhu jiangsheng chuxiang jingjie* 天主降生出像經解 (Illustrated Explanation of the Incarnation of the Lord of Heaven) of 1637,

by the Italian missionary Giulio Aleni 艾儒略 (1582–1649); and Schall's *Jincheng shuxiang* 進呈書像 (Images [from a] Book Presented to the Emperor) of 1640.⁷⁹

A spectrum of representational possibilities, albeit those in which the pictorial space is delimited and constructed to be viewed by a fixed monocular gaze, circulated in seventeenth-century China.⁸⁰ Each Jesuit text named above includes an illustration of “The Annunciation,” the moment when the angel Gabriel appears to the Virgin Mary to inform her that she would conceive and become the Mother of God.⁸¹ Nadal's *Annunciatio* (“The Annunciation,” fig. 19), a European engraved image, uses the frame of the picture to limit the viewer's field of vision.⁸² Da Rocha's Annunciation (fig. 20), a copy woodblock-printed in China that translates Nadal's image into a Chinese pictorial idiom (including turning the very basic architectonic setting

FIGURE 19. Geronimo Nadal (1507–1580), *Annunciatio* (The Annunciation), from *Evangelicæ Historiæ Imagines* (Images from the New Testament), page 1r, The Netherlands, 1593. Monochrome engraving, ink on paper; H. 29 cm. Thomas Fisher Rare Book Library, University of Toronto

FIGURE 20. João da Rocha (1587–1639), *Anruo Jiabi'eer, Shengmu bao shuo Tianzhu xuan ta wei mu* (The Angel Gabriel Announced to the Holy Mother that the Lord Had Chosen Her to Be the Mother [of His Son]), from *Práctica de rezar o rosário/Song Nianzhu guicheng* (Method of Saying the Rosary), page 3b, China, 1619. Monochrome woodblock print, ink on paper; H. 26 cm. Getty Research Institute, Los Angeles

into an elite house), is similarly limited.⁸³ Aleni's image of The Annunciation, *Shengmu ling shangzhu jiangyun zhi bao* 聖母領上主降孕之報 ("The Holy Mother Receives the News [that She] Will Fall Pregnant by the Lord"; fig. 21), is an alternate presentation in Chinese of Nadal's work, retaining in the new style the composition (including the architectural form) of Nadal's original.⁸⁴ Schall's *Tianshen baozhi gujin diyi: Shengde tongnü wei tianzhu jiangsheng zhi mu xiang* 天神報知古今第一聖德童女為天主降生之母像 ("Image of the Angel Announcing to the Most Holy and Virtuous Virgin of All Ages that She Will Become the Mother of the Lord of Heaven's Incarnation," i.e., The Annunciation; fig. 22) translates the engraved work of Raphaël Sadeler II (1584–1627/1632), after Hans Rottenhammer (1564–1625), into a Chinese woodblock-printed idiom, adding detail not found in the original to the upper third of the picture plane, but retaining the spatial compression of the original as underscored by its framing.⁸⁵

FIGURE 21. Giulio Aleni (1582–1649), *Shengmu ling shangzhu jiangyun zhi bao* (The Holy Mother Receives the News [that She] Will Fall Pregnant by the Lord), from *Tianzhu jiangsheng chuxiang jingjie* (Illustrated Explanation of the Incarnation of the Lord of Heaven), page 6a, China, 1637. Monochrome woodblock print, ink on paper; 16.83 × 13.81 cm. Bayerische Staatsbibliothek, Munich

FIGURE 22. Adam Schall von Bell (1591–1666), *Tianshen baozhi gujin diyi: Shengde tongnü wei tianzhu jiangsheng zhi mu xiang* (Image of the Angel Announcing to the Most Holy and Virtuous Virgin of All Ages that She Will Become the Mother of the Lord of Heaven's Incarnation), from *Jincheng shuxiang* (Images [from a] Book Presented to the Emperor), page 5b, China, 1640. Monochrome woodblock print, ink on paper; 15.3 × 11.1 cm. Österreichische Nationalbibliothek, Vienna

Beyond using spatial compression and framing to limit the mobility of the eye, woodblock prints made by Jesuits in China reveal assorted attempts at rendering single-point perspective in simple terms. Each of the books named above includes multiple attempts to do this. *Circvnsisio Christi* ("The Circumcision of Christ"; fig. 23) from Nadal's *Evangelicae Historiae Imagines* depicts the left and right edges of the raised platform on which Christ is to be circumcised, and the leading edges of the stairs that flank them, to have these lines converge in a vanishing point where the chandelier joins the chain from which it hangs.⁸⁶ Lacking an image of the Circumcision, da Rocha's *Song Nianzhu guicheng* contains an image of the Purification (fig. 24); in the foreground, lines define the left and right edges of the steps up to the platform to converge in a vanishing point at the base of the chandelier.⁸⁷ Based on an image of the same subject from

FIGURE 23. Geronimo Nadal, *Circvnsisio Christi* (The Circumcision of Christ), from *Evangelicae Historiae Imagines*, page 5r, The Netherlands, 1593. Monochrome engraving, ink on paper; H. 29 cm. Thomas Fisher Rare Book Library, University of Toronto

FIGURE 24. João da Rocha, *Shengdan hou sishi ri, Shengmu song Yesu yu tianzhu* (Forty Days After the Birth of Our Lord the Holy Mother Presented Jesus to the Lord), from *Práctica de rezar o rosário/Song Nianzhu guicheng*, page 9b, China, 1619. Monochrome woodblock print, ink on paper; H. 26 cm. Getty Research Institute, Los Angeles

Nadal's *Evangelicae Historiae Imagines* (*Purification*; fig. 25), this image is similar compositionally to Nadal's *Circumsio Christi* (see fig. 23).⁸⁸

Jesuit books printed in China also contain complex articulations of single-point perspective. In Aleni's *Tianzhu jiangsheng chuxiang jingjie*, the influence of single-point perspective is visible in *Saint John, Forerunner [of] the Lord, To Be Conceived* (*Sheng Ruohan xian tianzhu er yun* 聖若翰先天主而孕; fig. 26).⁸⁹ In this image, the lines of the external walls of the Temple of Jerusalem, pictured as though a Chinese courtyard house, converge in a vanishing point equidistant between the characters 先 and 天 in the heading. Although the linear pattern of the floor tiles falls outside the perspectival rendering in this scene, floor tiles are a site at which perspectival renderings are attempted repeatedly in Schall's *Jincheng shuxiang*. The most straightforward example of this is *Image of Lord Jesus Preaching in his Youth* (*Tianzhu Yesu huanling jiang dao xiang* 天主耶穌幼齡講道像; fig. 27), in which single-point perspective is rendered nearly (but not quite) perfectly in the floor tiles.⁹⁰ In its imperfection, this rendering simultaneously embodies both the Chinese understanding of this imported system of spatial representation and the Baroque decay of that system in Europe, the site of its origin.⁹¹

These illustrations were not isolated phenomena. Rather, they embodied new ways of thinking about the representation of space made possible by the translation of Euclid's geometry, with its implications for the representation of space, into Chinese. Specifically, Paul Xu

FIGURE 25. Geronimo Nadal, *Purificatio* (The Purification), from *Evangelicae Historiae Imagines*, page 8r, The Netherlands, 1593. Monochrome engraving, ink on paper; H. 29 cm. Thomas Fisher Rare Book Library, University of Toronto

FIGURE 26. Giulio Aleni, *Sheng Ruohan xian tianzhu er yun* (Saint John, Forerunner [of] the Lord, To Be Conceived), from *Tianzhu jiangsheng chuxiang jingjie*, page 5b, China, 1637. Monochrome woodblock print, ink on paper; 16.83 × 13.81 cm. Bayerische Staatsbibliothek, Munich

FIGURE 27. Adam Schall von Bell, *Tianzhu Yesu huanling jiang dao xiang* (Image of Lord Jesus Preaching in his Youth), from *Jincheng shuxiang*, page 11b, China, 1640. Monochrome woodblock print, ink on paper; 15.3 × 11.1 cm. Österreichische Nationalbibliothek, Vienna

Guangqi 徐光啟 (1562–1633), a prominent Chinese literatus baptized into the Catholic faith by João de Rocha in 1603, worked together with the Italian Jesuit priest Matteo Ricci 利瑪竇 (1552–1610) to translate the first six books of Euclid’s *Elementa* into Chinese, published in 1607 as *Ji he yuan ben* 幾何原本 (literally “The Original Text on Geometry”).⁹² The *Elements* is not a perspective treatise, but Renaissance perspective treatises such as Alberti’s *De Pictura* of 1435 were grounded in Euclidean geometry.⁹³ Knowledge of Euclidean geometry thus was necessary, if not sufficient, for the appropriation of single-point perspective in China.⁹⁴ Moreover, the Jesuit Missions in China possessed contemporaneous perspective treatises, the earliest editions dating to the sixteenth century.⁹⁵

Devices of monocularity and knowledge of single-point perspective circulated in China during the seventeenth century, but did not overtake indigenous notions of optics and visuality. Certainly some illustrations in Jesuit books printed in China depict space as viewed by a fixed monocular gaze.⁹⁶ Unable to prevent the reproduction of Chinese modalities of spatial representation, however, illustrated Jesuit texts printed in China during the seventeenth century also

present images for active, binocular vision, notably landscape images antithetical to European perspectivalism even in their European context, as Nadal's *Orat Christus in Horto* (literally "Christ Prays in the Garden," commonly known as "The Agony in the Garden"; fig. 28) makes clear.⁹⁷ Indeed, in his *The Compelling Image*, James Cahill notes the affinities of seventeenth-century, non-perspectival European landscape prints and Chinese landscape painting.⁹⁸ Whereas Nadal's 1593 image offers, in the place of single-point perspective, an integrated, continuous ground-plane suited to a fixed eye but open to a mobile one, da Rocha's 1619 adaptation of that image (fig. 29) features the disjunctive, spatially ambiguous groundplane of contemporaneous literati painting.⁹⁹ An example of the latter, which demands an active binocular gaze, may be seen in

FIGURE 28. Geronimo Nadal, *Orat Christus in Horto* (Christ Prays in the Garden), from *Evangelicae Historiae Imagines*, page 107a, The Netherlands, 1593. Monochrome engraving, ink on paper; H. 29 cm. Thomas Fisher Rare Book Library, University of Toronto

FIGURE 29. João da Rocha, *Yesu shounan qian yi xi, zai Aliwa shanyuan zhong daogao, Tianzhu ba de le sanci* (The Night Before Jesus Was Crucified, [while] Praying in the Garden at the Mount of Olives, the Lord Renounces Temptation Three Times), from *Práctica de rezar o rosário/Song Nianzhu guicheng*, page 13b, China, 1619. Monochrome woodblock print, ink on paper; H. 26 cm. Getty Research Institute, Los Angeles

FIGURE 30. Dong Qichang (1555–1636), *Jingxi zhao yin tu juan* (Invitation to Reclusion at Jingxi), China, 1611. Ink on paper, 26 × 92.6 cm. The Metropolitan Museum of Art, New York

FIGURE 31. Min Qiji (1580–after 1661), Illustration for Act 10 (Oriole Reads Scholar Zhang’s Love Letter), from *Xixiang ji* (The Romance of the Western Chamber), China, 1640. Polychrome woodblock print, ink and color on paper; 25.5 × 32.2 cm. Museum für Ostasiatische Kunst, Cologne

FIGURE 32. Min Qiji, Illustration for Act 14 (Madame Cui Scolds Crimson), from *Xixiang ji*, China, 1640. Polychrome woodblock print, ink and color on paper; 25.5 × 32.2 cm. Museum für Ostasiatische Kunst, Cologne

Invitation to Reclusion at Jingxi (*Jingxi zhao yin tu juan* 荆谿招隱圖卷; fig. 30) by Dong Qichang 董其昌 (1555–1636), dated 1611.¹⁰⁰

Around 1640, some Chinese printed illustrations resolutely rejected the external challenge of single-point perspective to render moments of vision predicated upon Chinese epistemologies of optics, vision, and spatial representation. Building upon foundational models for illustrating the Chinese play *The Romance of the Western Chamber* (*Xixiang ji* 西廂記) in ways that represent binocular vision and multipoint perspective, a new multi-block, color-printed edition of illustrations by the publisher Min Qiji 閔齊伋 (1580–after 1661) pictures indigenous ways of seeing.¹⁰¹ Specifically, Min’s illustration for Act 10 (fig. 31), “Oriole Reads Scholar Zhang’s Love Letter,” renders an image captured on the shiny surface of a mirror, which embodies the mirror-based optics of Mozi.¹⁰² His illustration for Act 14 (fig. 32), “Madame Cui Scolds Crimson,” represents images projected by lantern light, thus visualizing a practical derivation from Mohist optics and precursor devices based upon it.¹⁰³

During the extended moment in which the *camera obscura* was “re-introduced” to China from Europe, and the Jesuits sought to impose single-point perspective on select printed

illustrations prepared for their use in China, Chinese optical devices were introduced to Europe. The Dutch astronomer and mathematician Christiaan Huygens (1629–1695) is credited with the invention, not later than 1659, of the earliest extant European device for projecting images painted on glass.¹⁰⁴ Yet the Brabantian Jesuit mathematician André Tacquet (1612–1660) debuted lantern slides in Europe in illustrated lectures given at Leiden in 1653, and at Louvain in 1654, on the subject of the journey of the Italian Jesuit mathematician and astronomer Martino Martini 衛匡國 (1614–1661) from China to the Netherlands.¹⁰⁵ Both Tacquet and Huygens likely derived their knowledge of such devices from their contact with China. Tacquet knew Martini, who worked in the Catholic missions on the southeast coast of China across the transition from the Ming (1368–1644) to the Qing (1644–1911) dynasty.¹⁰⁶ Huygens’ familiarity with China likely came through his father, Constantijn Huygens (1596–1687), a diplomat who was influential around 1644 when the collapse of the Ming dynasty and the implications of this event for Dutch interests in China were a pressing subject; and through his brother, Constantijn Huygens, Jr. (1628–1697), who was known for his work on scientific instruments.¹⁰⁷

Alternative ways of seeing and conceptualizing images, including those likely derived from Chinese prototypes, coexisted in seventeenth-century Europe, even beyond spheres of Jesuit activity. *The Mysteries of Nature and Art, Contained in 4 Severall Treatises* of 1634, by the Englishman John Bate (fl. mid-17th century), illustrates multiple modes of seeing. By way of explaining convection currents, the first book of this compendium, on waterworks, illustrates moving images generated by devices that are similar to Chinese zoetropic lanterns (figs. 33, 34), the internal mechanisms of which are invisible when the lantern is in use (fig. 35); two mobile eyes are required to track fully the movement of such a device.¹⁰⁸ While the second book addresses the production of fireworks, illustrating the moving and illuminated images—including a “dolphin” (fig. 36)—created by them, the third book, “Of Drawing, Limning, Colouring, Painting, and Graving,” addresses the use of the monocular Albertian grid to render both a previously made image (fig. 37) and an urban landscape (fig. 38).¹⁰⁹ In Bate’s work, unrelated ways of seeing thus coincide.

In Europe, moreover, Chinese devices of non-monocular vision bred new devices from hybrid Chinese and European practices and technologies of vision. The German Jesuit polymath Athanasius Kircher (1602–1680), whose interest in China culminated in his *China monumentis illustrata* of 1667, also took an interest in the study of optics and optical media.¹¹⁰ In the 1646 edition of his *Ars magna lucis et umbra* (Great Arts of Light and Shade), Kircher noted a device he called the “text-projecting lantern” (*lucernam artificiorum construe, qua in remota distantia scripta legenda exhibeat*, literally “an artificially constructed lamp that displays [i.e., projects] written text in remote distance”), which he pictured in its simple form (fig. 39).¹¹¹ The subsequent edition of 1671 pictured both simple and elaborate forms of a “magic lantern” (*lucerna magicae*; fig. 40).¹¹² Whether Kircher invented the magic lantern himself or used his extensive but indirect contact with China to appropriate this device is unknown.¹¹³

The Postglobal Divergence of Optical Media

Across the seventeenth century, multiple milestones mark the beginnings of the globalization of optical media, a phenomenon that included the transfer of Chinese optical media to Europe and vice-versa. The most durable evidence of this transfer is found in the publication of multiple texts, including Xu and Ricci’s translation of Euclid’s *Elements* in 1607; Schall’s Chinese-language text “Speaking of the Telescope” in 1626; a suite of Sinophone, Jesuit illustrated books between 1619 and 1640 (including the aforementioned examples by da Rocha, Aleni, and

water it is become heuier then the weight, it will draw it up, and so open the said gates or little doores.

Experiments of motions by rarifying ayre by fire.

Let there be a round vessell of glasse, or horn, and on the top of it a vessell of bras, and in the midst a hollow pipe spreading it selfe into foure seuerall branches at the bottom: the ends of two of the branches must turn up, the ends also of two must turn down; upon these foure branches fasten a light cord, with seuerall images set upon it. Rarifie the ayre the by laying a red-hot

of the bras or tin vessell, and it will turn the wheele about, so that you would think the images to bee living creatures.

Another way.

First prepare a round peece of wood, hauing a bras box in the midst, such as they make to hang the mariners compasse with, but a good deale bigger, round about this peece of wood fasten diuers shreds of thin latten,

E 2

standing

standing obliquely or ascew, as the figure doth represent; round about these fasten a coffin of thin pastbord, cut into seuerall formes of fishes, birds, beasts, or what you please. Prepare a lantern with oyled parchment, sufficient to containe it, in the midst of whose bottom must be erected a spindle with a narrow point, to hang the pastbord cut into formes upon: upon each side let there be a socket for to set a candle in, also let there bee made a doore in the bottom to put the candles in at, and after to be shut, and it is done. If you set two candles in the sockets, the heat of them will turne the whole pastbord of formes round.

Amongst all the experiments pneumaticall, there is none more excellent than this of the Weather-glasse: wherefore I haue laboured to describe the making thereof as plainly as it possibly might be.

What the Weather-glasse is.

A Weather-glasse is a structure of, at the least, two glasses, sometimes of three, foure, or more, as occasion serueth, inclosing a quantity of water, and a portion of ayre proportionable, by whose condensation or rarification the included water is subject unto a continuall motion, either upward or downward; by which motion of the water is commonly foreshewn the state, change, and alteration of the weather. For I speak no more than what mine experience hath made me bold to affirme;

you

FIGURE 33. John Bate (fl. mid-17th century), "Experiments of Motion [...]," first illustration, from *The Mysteries of Natvre and Art, Contained in 4 Seuerall Tretises*, page 27, England, 1634. Monochrome woodblock print, ink on paper; H. 19 cm. Library of Congress, Washington, DC

FIGURE 34. John Bate, "Experiments of Motion [...]," second illustration, from *The Mysteries of Natvre and Art, Contained in 4 Seuerall Tretises*, page 28, England, 1634. Monochrome woodblock print, ink on paper; H. 19 cm. Library of Congress, Washington, DC

FIGURE 35. Artist unknown, *Shang yuan dengcai tu* (Colorful Lanterns at Shangyuan; detail), China, ca. 1572–1627. Ink and color on silk, detail approx. 4.5 × 5.2 cm. Mr. Jeff Xu collection, Taipei

FIGURE 36. John Bate, "How to make a Dolphin," from *The Mysteries of Natvre and Art, Contained in 4 Severall Tretises*, page 98, England, 1634. Monochrome woodblock print, ink on paper; H. 19 cm. Library of Congress, Washington, DC

FIGURE 37. John Bate, "How to take the perfect draught of any printed, or painted, picture," from *The Mysteries of Natvre and Art, Contained in 4 Severall Tretises*, page 107, England, 1634. Monochrome woodblock print, ink on paper; H. 19 cm. Library of Congress, Washington, DC

FIGURE 38. John Bate, "A very easy way to describe a towne, or a castle [. . .]," from *The Mysteries of Natvre and Art, Contained in 4 Severall Tretises*, page 110, England, 1634. Monochrome woodblock print, ink on paper; H. 19 cm. Library of Congress, Washington, DC

FIGURE 39. Athanasius Kircher (1602–1680), Script-projecting lantern, from *Ars magna lucis et umbra* (Great Arts of Light and Shade), page 887, Italy, 1646. Monochrome print, ink on paper; 30.6 × 20.2 cm. The Wellcome Library, London

FIGURE 40. Athanasius Kircher, Magic lantern, from *Ars magna lucis et umbra*, page 769, The Netherlands, 1671. Monochrome print, ink on paper; 40 × 26 cm. New York Public Library

Schall); Min Qiji's illustration for *The Romance of The Western Chamber* in 1640; Kircher's *Ars magna lucis et umbra* in 1664 and 1671, and *China monumentis illustrata* in 1667; and *Jing shi* 鏡史 (A History of Lenses), by Sun Yunqiu 孫雲球 (1650–after 1681), in 1681.¹¹⁴ During this century, knowledge of single-point perspective and transparent lenses, both rock crystal and especially ground glass, widened in China.¹¹⁵ Simultaneously, devices for the movement and projection of images proliferated in Europe, both challenging and serving as a foundation for alternatives to monocularity and single-point perspective.¹¹⁶

The impact of this seventeenth-century globalization of optical knowledge and optical media on the period from the eighteenth to the early twentieth century was uneven, marked by, for example, the European reintroduction of principles of Mohist optics to China. In China, building on Schall's reintroduction of optical concepts already known to Mozi, vision became a subject for study. Most notably, in 1729 the official Nian Xiyao 年希堯 (1671–1738) compiled an illustrated work on perspective, *Shixue jingyun* 視學精蘊 (Essence of Vision and its Principles), revised and published as *Shi xue* 視學 (The Study of Vision) in 1735; this work transformed abstract mathematical knowledge into a practical tool of visual composition, thereby facilitating its expanded use.¹¹⁷ Just as Schall reintroduced principles known in Mohist optics, Jesuits active at the Qing court used convex lenses and the *camera obscura*, devices with a

longer and perhaps more playful history in China than in Europe, together with novelties such as cylindrical and pyramidal mirrors to cast shadows and project images as *divertissements* for entertaining the Chinese, unaware of the irony of this situation.¹¹⁸

While devices of “pre-cinema”—partially or wholly based on those imported from the Jesuits and others active in China—proliferated in Europe, in China, concomitantly, an enlarged vocabulary for, and discussion of, optical phenomena emerged.¹¹⁹ This discussion included an enhanced discourse on shadows and specular images.¹²⁰ Furthermore, the representation of ephemeral optical phenomena (such as fireworks) and the introduction of plate glass as a medium transformed notions of visibility in quotidian life.¹²¹ At the same time, indigenous optical media reliant on a mobile gaze and binocular vision (for example, zoetropic lanterns and magic mirrors) continued to circulate in China, coincident with devices such as peepboxes that instead were dependent on the Chinese assimilation of imported notions of fixed gaze and monocular vision.¹²²

Whereas in China optical media, linked to traditional optics and modes of vision, became a marker of China’s backwardness, in Europe, due in part to changing epistemologies of vision grounded in advances in scientific knowledge of the function of the eye and brain, and strategies of representation that accounted more accurately for the binocularity of vision, these same media served as markers of modernity.¹²³ In China, for example, “light-penetrating mirrors” or “light-transmitting mirrors”—mirrors of unequal curvature (fig. 41)—continued to circulate but were no longer remarkable, while contemporaneously in Europe they were considered significant.¹²⁴ The divergent vectors of the science of optics and of optical media in China and Europe are evident, for example, in the fact that Zheng Fuguang 鄭復光 (1780–ca.1853) completed his *Jingjing ling chi* 鏡鏡鈴疑 (A Folly for Hawking Mirrors and Lenses), an illustrated treatise on optics that differentiated the functions of mirrors and lenses, thus bridging the fundamental divide between Chinese

FIGURE 41. Light projected through a Western Han magic mirror, China, 2016. Video. Detail of screenshot after <https://www.ntdtv.com/xtr/b5/2016/06/06/a1269906>

and European optics, in 1835, the year before the “invention” of the zoetrope in 1836 in the United States, a device indebted to the optical possibilities of Chinese “pacing-horse lanterns.”¹²⁵

During the nineteenth century, when European painting was no longer dependent on single-point perspective (its representational schema able to accommodate more sophisticated knowledge of the function of the eye), photography—the process of fixing optical phenomena in durable media—illustrated the disjunction of European and Chinese optics despite the increasing parity between European and Chinese knowledge of this field.¹²⁶ In this context, the value of optical media diverged: denigrated in China, the site of its origin; and celebrated in Europe, where it was novel and foundational to the development of photography.¹²⁷ In China, from the time of Mozi, the ephemerality of the light-based image was unproblematic, if not desirable; thus the *camera obscura* persisted, without the impulse to transform its images into artifacts. In contrast, in Europe in the early nineteenth century, the desire to fix light-based images, specifically those of the *camera obscura*, facilitated the emergence of photography.¹²⁸ Later Chinese intellectuals were left to ascribe the impetus to fixity—and thus the global origin of photography—retrospectively to the Chinese scholar Zou Boqi 鄒伯奇 (1819–1869).¹²⁹

Despite the globalization of optical media across the seventeenth through nineteenth centuries, the European desire for monocularity and fixity never fully encroached upon Chinese notions of binocularity and mobility. This left Chinese artists free to experiment with photography in ways that replicated indigenous ways of seeing.¹³⁰ Such a tendency perhaps was underscored by the 1805 Chinese ban on the transfer of Western scientific knowledge.¹³¹ Similarly, the early practice of photography in Europe brought this technology of image-making into pre-existing discourses on print-making and painting.¹³² In China and Europe, local optical epistemologies prevailed, the circulation of Euclidean/post-Euclidean and Mohist/post-Mohist optics notwithstanding.

Light as Postglobal Medium

In China and in the European tradition, discrete sciences of optics, with divergent epistemological frameworks, existed in parallel to each other from the fifth century BCE through the fifteenth century CE. Beginning in the sixteenth century, and culminating in the seventeenth, the mutual transmission of these two discrete systems of optics—notably in devices that mediated light and/or embodied an understanding of light and its transmission, their relation to human vision, and the implications of this relation for the representation of space in two dimensions—pushed each system of optics in new directions. Schematically speaking, this phenomenon, together with the assimilation (or erasure) of any number of optical knowledges, resulted in a universal understanding of light and its principles, an understanding that, even today, grounds universal narratives of optical media.

Each of the four artists with whose work this article began might be understood to represent a different position on a spectrum of possible positions between indigenous and universal knowledge of optical media. On one end of that spectrum, Michael Snow, consummately aware of the “Western” epistemological foundations of lens-based media (as exemplified by his experimental film, *La region centrale*, of 1971), potently refigures that understanding in the superimposition of the segments of *Wavelength*—itself a meditation on the use of the camera—in *WVLNT* (see fig. 7). On the other end of the spectrum lies Xu Bing’s *Background Story 4* (see figs. 2, 6), a work defined by the backlit screen medium of traditional Chinese shadow puppetry (see fig. 11) conjoined with the imagery of a traditional Chinese painting by way of materials suited to the traditional Chinese art of *penjing* 盆景, or “tray landscapes.” This use of a traditional form of Chinese optical media comes as no surprise, as Xu Bing has been

more self-reflexively attentive to traditional Chinese media than perhaps any other contemporary artist from China, as evident in works such as *Book from the Sky* (*Tian shu* 天書) of 1989, which engages the traditional medium of printing; and *Ghosts Pounding the Wall* (*Gui da qiang* 鬼打牆) of 1990, which is reliant on the traditional medium of ink-rubbing.

Other positions on this spectrum speak to divergent and circulating knowledge of optical media. Jeff Wall's *A Sudden Gust of Wind* (see fig. 1) suggests the global transfer of knowledge of backlit, shadow puppet screen lighting technology and, significantly, its integration with commercial variations on the lightbox, the Orientalism of his medium underscored by his reference to Hokusai. If Wall might be understood as a Canadian artist looking to an optical medium with a Chinese origin, in contrast, Song Dong's *Father and Son at Tai Miao* (see fig. 8) speaks to the use of globalized optical media—the transparent photographic image and the electric projector—by a contemporary Chinese artist: here a Chinese contemporary artist simply uses those media available to him without explicit reference to any tradition of optics.

If, following Marshall McLuhan, the medium—light, without which there is no optical vision, and thus no visibility—is the message, how, as a universal phenomenon, does light establish meaning in a postglobal world seeking alternatives to cultural homogeneity, yet shaped by the instant transfer of information via LED screen?¹³³ The works of Snow, Song, Wall, and Xu can be placed in a connected, global narrative of optical media, a narrative in which the universality of the medium—light—appears self-evident, and in which each artist produces work in a global, connected present. But in postglobal, comparative analysis, the medium of light as well as the works created by it, universal though they may be, also might be understood to defy that apparent universality, their contemporary incarnations underpinned by the parallel histories of the medium symbiotically related to discrete, culturally contingent sciences of optics. In the case of optical media, formal similitude—the “looks like” factor—should not occlude divergent histories and epistemologies of the medium. Nor should the visual resemblance of contemporary works be used as a means of retrospectively and erroneously positing a universal history of light as an image-making medium.

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Notes

Based on a paper presented at the Thirty-fourth International Congress of the History of Art (CIHA), this article is a sketch of a book-length project on Chinese optics and optical media. As a conference paper, it was intended to provoke responses to the problem of how light, the universal medium, is presently understood in ways that obscure knowledge of how it was perceived and understood in other times and places; it was also intended to be an experiment in writing about the methodology of a comparativist, “postglobal” art history, an idea much discussed, but about which almost

nothing has been written. Conceived as a set of talking points for a conference presentation on the topic of art and its media in global context, this article was never conceptualized as something that would be published in its current form; solicited for publication, however, its context needs to be specified. Please note: some material presented here was published previously in Jennifer Purtle, "Scopic Frames: Devices for Seeing China c. 1640," *Art History* 33.1 (2010): 54–73. Furthermore, Chinese characters in this article follow original usage: premodern names and texts appear in traditional characters, while the names of PRC scholars and titles of modern texts first published in the PRC remain in the simplified characters that are their native idiom.

Many thanks to Rick Asher, Eugene Wang, Yudong Wang, David Roxborough, Stephen Nelson, Nancy Micklewright, Cassie Mansfield, Giancarla Periti, Evie Gu, Jordan Bear, Kajri Jain, Ryan Whyte, and the two anonymous peer reviewers for their engaged responses, helpful suggestions, and as-yet unanswerable questions that will almost surely shape the next iteration of this project. Despite the generosity of these colleagues, all errors and lapses are my own.

1 Joseph Needham, *Science and Civilization in China*, vol. 4.1 (Cambridge: Cambridge University Press, 1954–), 78.

2 Kristina Kleutghen, "Peepboxes, Society, and Visuality in Early Modern China," *Art History* 38.4 (September 2015): 764.

3 The classic study of Chinese optics, used by Needham as a foundation for his work, is Tan Jiefu 譚戒甫 (1887–1974), *Mojing yijie* 墨經易解 (Analysis of the Mohist canon) (Shanghai: Commercial Press for Wuhan University, 1935).

4 This issue is among those explored in the application for the Getty Connecting Art Histories Project "Global and Postglobal Perspectives on Medieval Art and Art History," of which I was the principal author. I would be happy to share selections of this text upon request.

5 The statement above rather polemically restates unpublished material that I have presented elsewhere: "Recent fascination for 'the global' in more-developed art histories often springs from a desire to engage emerging (often non-Western) art histories by connecting them to Western traditions. In emerging art histories, the idea of 'the postglobal' constitutes an important new paradigm for writing art histories in ways conversant with, but not beholden to, the art historiography and current scholarship of established art histories that address materials from their cultures." See Jennifer Purtle, "Global and Postglobal Perspectives on Medieval Art and Art History," unpublished application document, 7.

6 The language of "the West" and "the rest," or of "Western" and "non-Western," is, of course, crude. Absent greater knowledge of art produced outside the Western tradition, however, it is often the case that a counter-narrative must rest on a case study of material outside the Western tradition serving as a placeholder for the larger mosaic of cultural forms outside the Western tradition.

7 Purtle, "Global and Postglobal Perspectives," 7.

8 This notion draws on material that I have written previously: "To be committed . . . to a more evenly developed practice of art history worldwide is to take seriously the critical terms by which emerging art histories seek to redress imbalances of art-historical power. There may be a lack of consensus about definitions of global and postglobal art histories and of their merits. But rather than dismiss these critical terms because they lack fixity and perhaps gravitas," a preferable path may be to "redirect disciplinary debates staged in whatever critical terms are current as the practice of art history becomes more evenly developed worldwide." Purtle, "Global and Postglobal Perspectives," 7.

9 Many attempts at formulating the idea of global art history attend in various ways to the impossibility of a truly global art history. These include, but are not limited to, John Onians, "World Art Studies and the Need for a New Natural History of Art," *The Art Bulletin* 78.2 (1996): 206–8; John Onians, *Atlas of World Art* (London: Laurence King, 2004); Kitty Zijlmans and Wilfried van Damme, eds., *World Art Studies: Exploring Concepts and Approaches* (Amsterdam: Valiz, 2008); David Summers, *Real Spaces: World Art History and the Rise of Western Modernism* (New York: Phaidon Press, 2003); Hans Belting et al., eds., *Global Studies: Mapping Contemporary Art and Culture* (Ostfildern: Hatje Cantz, 2011); and perhaps most significantly, James Elkins, ed., *Is Art History Global?* (New York: Routledge, 2007).

10 Many ways of thinking about circulation may be found, beginning with the classic statements of artistic geography by George Kubler, ranging to the world-systems of Janet Abu-Lughod and Immanuel Wallerstein, and to the cultural flows of Arjun Appadurai. On these approaches (classics among many contenders), see George Kubler, *The Shape of Time* (New Haven: Yale University Press, 1962), esp. 118–19; Janet Abu-Lughod, *Before European Hegemony: The World System A.D. 1250–1350* (New York: Oxford

- University Press, 1989), esp. 3–42; Immanuel Wallerstein, *The Modern World System: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century* (New York: Academic Press, 1974), esp. 347–57; and Arjun Appadurai, “Disjuncture and Difference in the Global Cultural Economy,” *Public Culture: Bulletin of the Project for Transnational Cultural Studies* 2.2 (April 1990): 1–24. What is not so clear is how to pause the flows in order to understand the mechanics of the transactions. In the case of premodern China, a handful of essays attempt to isolate specific moments of art-historical contact to reveal how such flows work. See, for example, Cheng-hua Wang, “A Global Perspective on Eighteenth-Century Chinese Art and Visual Culture,” *The Art Bulletin* 96.4 (2014): 379–94. I have engaged such questions in multiple publications, including Purtle, “Objects without Borders: Cultural Economy and the World of Artifacts,” in *Crossing Cultures: Conflict, Migration, Convergence*, ed. Jaynie Anderson (Melbourne: The Miegunyah Press, an imprint of the University of Melbourne Press, 2009), 127–32; Purtle, “Money Making Nation: Picturing Political Economy in Banknotes of the Qing-Republican Transition,” in *Looking Modern: East Asian Visual Culture from the Treaty Ports to World War II*, ed. Jennifer Purtle and Hans Thomsen (Chicago: Center for the Art of East Asia, The University of Chicago, 2009), 106–39; Purtle, “The Far Side: Expatriate Medieval Art and Its Languages in Sino-Mongol China,” *Medieval Encounters* 17 (2011): 167–97; Purtle and Ryan Whyte, “China fabrizieren: Textile Chinoiserien aus St. Gallen,” in *Kirschblüte und Edelweiss: Der Import des Exotischen*, ed. Michaela Reichel and Hans Thomsen (St. Gallen: Textilmuseum St. Gallen, 2014), 56–92; and Purtle, *Peripheral Vision: Fujian Painting in Chinese Empires, 909–1646* (Honolulu: University of Hawai‘i Press, forthcoming).
- 11 Literally hundreds, if not thousands, of works could have been used to illustrate the same argument. Given the focus of this paper, and on account of it being presented at the Thirty-fourth International Congress of the History of Art (CIHA) in Beijing in 2016, I have chosen contemporary PRC artists to represent China; on account of representing Canada at this forum, I have chosen works by two of the most significant living Canadian artists. Every work of scholarship requires the arbitrary and subjective selection of data from larger data sets, and this is the rationale for the selection of these artists.
- 12 On *A Sudden Gust of Wind (After Hokusai)* and its photographic and post-photographic sensibility, see Laura Mulvey, “*A Sudden Gust of Wind (After Hokusai)*: From After to Before the Photograph,” *Oxford Art Journal* 30.1 (2007): 27–37; on Xu Bing’s use of backlit projection in his *Background Story* series, see Robert E. Harrist, Jr., “Background Stories: Xu Bing’s Art of Transformation,” in Reiko Tomii et al., *Xu Bing* (London: Albion, 2011), 33–43.
- 13 Some texts state the Western origins of optics explicitly. For example, Friedrich Kittler, in his lectures published first in German as *Optische Medien Berliner Vorlesung 1999*, and subsequently in English as *Optical Media Berlin Lectures 1999*, writes, “In addition to countless other sciences, classical Greece also founded the science of optics which at least managed to establish the law of reflection, if not also the law of refraction. At least since the time of Euclid, who in addition to his famous *Elements of Mathematics* also wrote about optics and the path of light (Edgerton, 1975, 68), it was clear to the Greeks that rays of light travel in straight lines.” Friedrich Kittler, *Optical Media*, trans. Anthony Enns (Cambridge, UK; Malden, MA: Pity Press, 2010), 50; the “(Edgerton, 1975, 68)” to which Kittler refers is Samuel Y. Edgerton, *The Renaissance Rediscovery of Linear Perspective* (New York: Harper and Row, 1976).
- 14 See, for example, Barbara Stafford and Frances Tepak, *Devices of Wonder: From the World in a Box to Images on Screen* (Los Angeles: Getty Research Institute, 2001); and Lisa Gitelman and Geoffrey B. Pingree, eds., *New Media, 1740–1915* (Cambridge, MA: MIT Press, 2003), xi–xxii.
- 15 See, for example, Needham and Kleutghen, as quoted in the epigraphs above.
- 16 For overviews of Mo Di’s work on optics that contradict Kleutghen’s statement at the beginning of this article, see Needham, *Science and Civilization in China*, 81–87; A.C. Graham and Nathan Sivin, “A Systematic Approach to Mohist Optics,” in *Chinese Science*, ed. Shigeru Nakayama and Nathan Sivin (Cambridge, MA: MIT Press, 1973), 105–52; and Dai Nianzu, “Physics,” in *A History of Chinese Science and Technology*, vol. 1, ed. Yongxiang Lu (New York: Springer Verlag, 2015), 302–19. Kleutghen’s passage also denies the inquiry in the Chinese tradition that follows Mo Di on the subject of optics. See Needham, *Science and Civilization in China*, 78–124; Dai Nianzu, “Physics,” 302–19; and Wang Jinguang, *Zhongguo guangxue shi* 中国光学史/*The History of Optics in China* (Changsha: Hunan jiaoyu chubanshe, 1986).
- 17 The classic study of Chinese optics, used by Needham as a foundation for his work, is Tan Jiefu 譚戒甫 (1887–1974), *Mojing yijie* 墨經易解 (Analysis of the Mohist canon) (Shanghai: Commercial Press for Wuhan University, 1935).

- 18 Wang Chong 王充 (27–97), *Lun heng* 論衡 (Balanced discourses), reprint of *Sibu congkan* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 2:15b; see also Needham, *Science and Civilization in China*, 111.
- 19 On this lens, see, for example, David Brewster, “On an Account of a Rock-crystal Lens and Decomposed Glass found in Niniveh,” *The Athenaeum: Journal of Literature, Science, and the Fine Arts* (September 11, 1852): 979; Austen Henry Layard, *Discoveries in the Ruins of Nineveh and Babylon: With Travels in Armenia* (London: G.P. Putnam and Co, 1853), 197–98, 674; Walter Gasson, “The Oldest Lens in the World: A Critical Study of the Layard ‘Lens,’” *The Ophthalmic Optician* (December 9, 1972): 1267–72; and “The Nimrud Lens/the Layard Lens,” *Collections Database*, The British Museum, <http://www.britishmuseum.org> (last accessed October 1, 2016).

On crystal lenses in the Middle East and the Mediterranean during antiquity, see George Sines and Yannis A. Sakellarakis, “Lenses in Antiquity,” *American Journal of Archaeology* 91.2 (April 1987): 191–96; and Dimitris Plantzos, “Crystals and Lenses in the Graeco-Roman World,” *American Journal of Archaeology* 101.3 (July 1997): 451–64. On the unknown uses of these devices, see Brian Ford, *Single Lens: The Story of the Simple Microscope* (New York: HarperCollins, 1985), 13–14.

In ancient Greece and Rome, glass spheres filled with water served as lenses, a use that persisted into the Middle Ages. See Plantzos, “Crystals and Lenses,” 459; and Jay M. Enoch, “The Enigma of Early Lens Use,” *Technology and Culture* 39.2 (1998): 273–91. Subsequently, glass lenses appeared throughout Europe. See, for example, Berthold Laufer, “Geschichte der Brille,” *Mitteilungen zur Geschichte der Medizin und der Naturwissenschaften* 6.4 (1907): 379–85; and Needham, *Science and Civilization in China*, 118–22.

Subsequent use and theorization of lenses in Europe culminated in their use in refracting telescopes, which emerged in the Netherlands early in the seventeenth century, followed by reflecting telescopes, the first of which is credited to Isaac Newton (1643–1727) in 1668. On the history of the telescope, see Geoff Anderson, *The Telescope: Its History, Technology, and Future* (Princeton, NJ: Princeton University Press, 2007), 32–34.
- 20 For *ying*, see Mo Di 墨翟, *Mozi* 墨子 ([The works of] Master Mo), reprint of Ming dynasty, Jiajing era (1522–67) *Sibu congkan* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), *juan* 9, 10, 13 *passim*. On the term *ying* 景 as the precursor to the modern term *ying* 影, see *Hanyu dacidian* 汉语大词典 (Comprehensive dictionary of Chinese words), vol. 5 (Shanghai: Hanyu dacidian chubanshe, 1990), 759; on the modern term *ying* 影, which can also mean “reflection,” see *Hanyu dacidian*, vol. 3 (Shanghai: Hanyu dacidian chubanshe, 1989), 1132; see also Graham and Sivin, “A Systematic Approach to Mohist Optics,” 114. For *zhong*, see Mo Di, *Mozi*, 10.41:4a–b; see also Graham and Sivin, “A Systematic Approach to Mohist Optics,” 118–20. For *xian*, see Mo Di, *Mozi*, 10.43:18b. For *ku*, see Mo Di, *Mozi*, 10.42:8a. For *duan*, see Mo Di, *Mozi*, 10.41:4b. For *jingdao*, *zhengjian*, *jianwei*, and *jiantuan*, see Mo Di, *Mozi*, 10.41:4a. For all of these terms, see also Needham, *Science and Civilization in China*, 81–85.
- 21 On the geometrical theorems of Euclid’s *Optics*, see David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler* (Chicago: University of Chicago Press, 1996), 12. These formed the basis of Euclid’s understanding of the relation of vision and geometry more broadly. On this topic, see Lindberg, *Theories of Vision*, 11–17.
- 22 On optical media, see Kittler, *Optical Media*.
- 23 Sima Qian 司馬遷 (145–86 BCE), *Shi ji* 史記 (Records of the historian) (Beijing: Zhonghua shuju, 1975), 12:458–59; Ban Gu 班固 (32–92 CE), *Han shu* 漢書 (History of the Han dynasty) (Beijing: Zhonghua shuju, 1970), 25a:1219–20. See also Needham, *Science and Civilization in China*, 122.
- 24 *Xijing zaji* 西京雜記 (Miscellaneous records of the Western capital), attr. Ge Hong 葛洪 (283–343), reprint of *Sibu congkan* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 3:3b; see also Needham, *Science and Civilization in China*, 123.
- 25 Later types of such lanterns were called “horse-riding lanterns” (*maqideng* 馬騎燈) and “pacing-horse lanterns” (*zoumadeng* 走馬燈). On these lanterns, especially in the texts of Song (960–1279) and Southern Song (1127–1279) authors, see Jennifer Purtle, “Scopic Frames: Devices for Seeing China c. 1640,” *Art History* 33.1 (2010): 72 nn. 50, 51; see also Needham, *Science and Civilization in China*, 123.
- 26 *Xijing zaji*, 3:3b; see also Needham, *Science and Civilization in China*, 123.
- 27 The importation of such media to Europe by the Jesuits is discussed below.
- 28 Duan Chengshi 段成式 (d. 863), *Youyang zazu* 酉陽雜俎 (Miscellaneous morsels from Youyang), reprint of *Sibu congkan* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 4.4:7a; see also Needham, *Science and Civilization in China*, 98.
- 29 Gao Yanxiu 高彦休 (fl. 874–79), *Tang que shi* 唐闕史 (Tang memorabilia), reprint of 1588 Tan Cangong

- manuscript edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 2:11–12b; Sun Guang-xian 孫光憲 (d. 968), *Bei meng suo yan* 北夢瑣言 (Northern dreams and trifling talk), ca. 930, reprint of Ming-dynasty edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 8:7a–b; see also Needham, *Science and Civilization in China*, 122. Needham's reading of a text by Tan Qiao 譚峭 (ca. 860–976) also indicates that shadow puppets might also have produced these images. In his text, Tan Qiao names and describes the properties of what appear to be four mirrors (*jing* 鏡), the functions of which suggest that these *jing* might instead be lenses, noting, "One is named *gui* 圭 [literally 'sceptre'; Needham takes this to be a bi-concave lens]; one is named *zhu* 珠 [literally 'pearl'; Needham takes this to be a bi-convex lens]; one is called *zhi* 砥 [literally 'whetstone'; Needham takes this to be a plano-concave lens]; one is called *yu* 盂 [literally 'bowl'; Needham takes this to be a plano-convex lens]. As for that which is viewed with the *gui*, [it is] bigger [than the image; that is, the object is bigger than the image]; as for that which is viewed with the *zhu*, [it is] smaller [that is, the object is smaller than the image]; as for that which is viewed with the *zhi*, [it appears] upright; as for that which is viewed with the *yu*, [it appears] inverted." Tan Qiao 譚峭, *Qiqiuzi* 齊丘子 ([The works of] Master [Song] Qiqiu), reprint of Ming dynasty Wanli-era (1573–1620) *Zihui congshu* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 1:3b–4a; translation adapted from Needham, *Science and Civilization in China*, 117; see also 116, 123.
- 30 Shen Kuo 沈括, *Mengxi bitan* 夢溪筆談 (Dream pool essays), reprint of *Sibu congkan xubian* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 3:1b–2a; see also Needham, *Science and Civilization in China*, 97. Specifically, Shen notes, "[It is] also like the image of a pagoda [that] passes through a [pin-]hole in the window [paper; n.b.: in traditional China, window panes were made of opaque paper]: inside, on account of the window [pinhole, the image] is collected, [and] moreover completely inverted, hanging [upside] down. [The principle behind the pinhole] and the 'burning mirror' (*yangsui*) is the same: the 'burning mirror' [has] a face [that is] concave, [so that if you] take one finger, go near, and then illuminate it, then [the image will be] upright; [but if you] gradually go further away, [then] nothing will appear, [and if you] pass this [point, the image will] unexpectedly [reappear and] invert. The place [where] it has nothing appear is exactly like the window [pin-]hole." 又如窗隙中樓塔之影: 中間為窗所束, 亦皆倒垂; 與陽燧一也。陽燧面窪, 以一指迫而照之則正; 漸遠則無所見; 過此遂倒。其無所見處, 正如窗隙。 Translation modified significantly from Needham, *Science and Civilization in China*, 97.
- 31 Shen Kuo, *Mengxi bitan*, 3:1b–2a; see also Needham, *Science and Civilization in China*, 97–99. While part of the Mozi was lost, sixty-one of the original seventy-one chapters still circulated during Shen's lifetime, making such continuity and correction possible. At present, only fifty-three of the seventy-one chapters of the Mozi survive, as compiled and edited by Sun Yirang 孫詒讓 (1853–1908). See A.C. Graham, "Mo tzu 墨子," in *Early Chinese Texts—A Bibliographical Guide*, ed. Michael Loewe (Berkeley, CA: Society for the Study of Early China and Institute of East Asian Studies, University of California Berkeley, 1993), 336–41; see also David R. Knechtges, "Mozi 墨子," in David R. Knechtges and Taiping Chang, *Ancient and Early Medieval Chinese Literature: A Reference Guide, Part One* (Leiden: E.J. Brill, 2010), 677–81.
- 32 For Euclid and Aristotle on the pinhole, see Harry Edwin Burton, "Euclid's Optics," *Journal of the Optical Society of America* 35.5 (May 1945): 357–72; and Lindberg, *Theories of Vision*, 6–14.
- 33 Much as it is tantalizing to contemplate the transmission of optical knowledge between Europe and China via the Islamic world, at present no evidence of this phenomenon has been found.
- 34 Mo Di, Mozi, 10.43:13a; see also Needham, *Science and Civilization in China*, 82.
- 35 Mo Di, Mozi, 10.43:13b; see also Needham, *Science and Civilization in China*, 83.
- 36 On this point, see also Needham, *Science and Civilization in China*, 86.
- 37 Euclid describes the phenomenon of extromission as "... [T]he eye . . . , from which let the rays of vision fall," Burton, "Euclid's Optics," 357. On Euclid's theories of vision, see also A.C. Crombie, "Expectation, Modeling, and Assent in the History of Optics: Part I Alhazen and the Medieval Tradition," *Studies in the History and Philosophy of Science* 21.4 (1990): 606–7.
- Art historians such as Gisela Richter, John White, and A.M.G. Little have all sought to argue for the Greek understanding of perspective—and thus of its optical foundations—prior to Euclid's treatise. On this point, see Wilfred Robert Theisen, "The Medieval Tradition of Euclid's *Optics*" (PhD diss., University of Wisconsin, 1972), 25, 25 n. 61.
- Plato narrates his understanding of vision thus: "So much of fire as would not burn, but gave a gentle light, they formed into a substance akin to

- the light of every-day life; and the pure fire which is within us and related thereto they made to flow through the eyes in a stream smooth and dense, compressing the whole eye, and especially the centre part [i.e., the pupil], so that it kept out everything of a coarser nature, and allowed to pass only this pure element. When the light of day surrounds the stream of vision, then like falls upon like, and they coalesce, and one body is formed by natural affinity in the line of vision, wherever the light that falls from within meets with an external object. And the whole stream of vision, being similarly affected in virtue of similarity, diffuses the motions of what it touches or what touches it over the whole body, until they reach the soul, causing that perception which we call sight." Plato, *Timmaeus* 45b–d, trans. Benjamin Jowett (New York: Liberal Arts Press, 1949), 27–28; see also Lindberg, *Theories of Vision*, 3–6.
- 38 Aristotle explains his objection to Plato's extramissive theory of vision: "The theory is wholly absurd that sight is effected by means of something which issues from the eye and that it travels as far as the stars or, as some say, unites with something else after proceeding a certain distance. Than this latter a better theory would be, that the union is effected in the eye—the starting point; . . ." Aristotle, *De Sensu and De Memoria*, trans. G.R.T. Ross (Cambridge: Cambridge University Press, 1906), 51; see also Lindberg, *Theories of Vision*, 6–9.
- 39 For an account of Ibn al-Haytham's understanding of optics and their relation to the working of the eye, see Lindberg, *Theories of Vision*, 58–86. Succinctly put, Ibn al-Haytham states, "Now it is evident that sight occurs through the eye; and since this is so, and [by hypothesis] the eye perceives the visible object only when something issues from the eye to the visible object, and since [by the previous arguments] that which issues forth does not perceive the object, therefore that which issues from the eye to the visible object does not return anything to the eye, by which the eye perceives the object. And [therefore] that which issues from the eye is not sensible but conjectural, and nothing ought to be believed except for a sufficient reason." For this translation by David Lindberg from the British Museum edition of *De aaspectibus*, see Lindberg, *Theories of Vision*, 65.
- 40 On Euclid, see notes 21 and 37. For excellent overviews of Leonardo on optics and vision, see Francesca Fiorani, "Leonardo's Optics in the 1470s," in *Leonardo da Vinci and Optics*, ed. Francesca Fiorani and Alessandro Nova (Venice: Marsilio, 2013), 265–92; Dominique Raynaud, "Leonardo, Optics, and Ophthalmology," in *Leonardo da Vinci and Optics*, 293–332; Lindberg, *Theories of Vision*, 154–68; and Frank Fehrenbach, "Leonardo's Point," in Alina Payne, *Vision and its Instruments: Art, Science, and Technology in Early Modern Europe* (University Park, PA: Pennsylvania State University Press, 2015), 76–82.
- 41 Kepler states in his *Paralimpomena*, as translated by Lindberg: "And since the cornea and the aqueous humour beneath it (which I take to be a single medium as far as density is concerned) are of greater density than air, rays from a point sent obliquely at the cornea are refracted towards the perpendicular. Therefore, rays that first diverged in the air converge upon entering the cornea to such an extent that although the largest circle described on the cornea by rays that [subsequently] descend to the edges of the pupil is larger than the pupil, nevertheless these rays are made to converge so greatly in the small depth of the aqueous [humour] before they reach the pupil that the extreme rays graze the edge of the pupil, and by their further descent they illuminate a portion of the surface of the crystalline smaller than the pupil." Lindberg, *Theories of Vision*, 193. On this phenomenon, see also Vincent Ilardi, *Renaissance Vision from Spectacles to Telescopes* (Philadelphia, PA: American Philosophical Society, 2007), 4–5, 29, 244; see also Alan Shapiro, "Kepler, Optical Imagery, and the Camera Obscura: Introduction," *Early Science and Medicine* 13 (2008): 217–18.
- 42 Bu Shang 卜商 (507–400 BCE), *Zixia yizhuan* 子夏易傳 (Bu Shang's commentary on the *Changes*), reprint of *Tongzhitang* edition, ca. 1644–1911 (Beijing: Beijing Erudition Digital Research Center, 2001–15), 1:25b, 5:23b; on the word *miao* 眇 ("one-" or "small-eyed") and its use in the latter passage, see also *Hanyu dacidian*, vol. 7 (Shanghai: Hanyu dacidian chubanshe, 1991), 1167a.
- This material, and that which follows, is drawn from my forthcoming article, "The Mathematics of Space in Song Painting."
- 43 Chao Buzhi 晁補之, "Meng di fu" 夢觀賦 (Rhyme-prose on a dream-meeting), in *Jibei Chao xiansheng jile ji* 濟北晁先生雞肋集 (The "Chicken-Bone" anthology of Mr. Chao of Jibei), reprint of *Sibu congkan xubian* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 1:7a–8a, esp. 7b.
- 44 See, for example, Chen Tuan 陳搏 (d. 989), *Shen xiang quan bian* 神相全篇 (Complete treatise on physiognomic fortune-telling), reprint of Ming-dynasty edition (Taipei: Xinwenfeng chubangonsi, 1989) *shou*: 1; 9:43–46.
- 45 Shen Gai 沈該, *Yi xiao zhuan* 易小傳 (A small commentary on [the Book of] *Changes*), reprint of

- Wuxing congshu* edition, ca. 1912–49 (Beijing: Beijing Erudition Digital Research Center, 2001–15), 5b:23a.
- 46 See note 43 above.
- 47 Any number of Song-dynasty texts use the term “two-eyed” or “[with] two eyes.” A digital text search will produce a vast array of uses of this term drawn from a variety of disciplinary and generic contexts.
- 48 On the printing history of *The Nine Chapters on the Art of Mathematics*, see Li Yan and Du Shiran, *Chinese Mathematics: A Concise History*, trans. John N. Crossley and Anthony W.-C. Lun (Oxford: Clarendon Press, 1987), 109; see also Shen Kangsheng, John N. Crossley, and Anthony W.-C. Lun, *The Nine Chapters on the Mathematical Art: Companion and Commentary* (Oxford: Oxford University Press, 1999), 1–3. On the printing history of *The Sea Island Mathematical Treatise*, see Frank J. Swetz, *The Sea Island Mathematical Manual: Surveying and Mathematics in Ancient China* (University Park, PA: Pennsylvania State University Press, 1992), 9.
- 49 Guo Si 郭思, *Linquan gaozhi* 林泉高致 (Lofty treatise on forests and springs), reprint of *Baichuan xuehai* edition, Ming dynasty (Beijing: Beijing Erudition Digital Research Center, 2001–15), 9b.
- 50 The gaze is described in the text as follows: “Mountains have three [types of] distance [that is, three spatial axes. The distance] from the bottom of the mountain looking up (*yang* 仰) to the summit of the mountain is what is called ‘high distance’ [that is, height; the distance] from in front of the mountain spying past (*kui* 窺) the back of the mountain is what is called ‘deep distance’ [that is, depth; the distance] from a nearby mountain gazing into the distance (*wang* 望) at distant mountains is what is called ‘level distance’ [that is, breadth or width. Up-and-down] the height [of a painting, its colors] are clear and bright; [into] the depth [of a painting, its] colors become incrementally dim; [across] the width [of a painting, its] colors are both bright and indistinct. The terrain of height is lofty and towering (*tuwu* 突兀); the idea of depth is overlapping and superimposition (*chongdie* 重疊); the idea of width is washing and melting [away] and thus becoming dimly discernable as though in mist.” 山有三遠。自山下而仰山顛，謂之高遠；自山前而窺山石後，謂之深遠；自近山而望遠山，謂之平遠。高遠之色清明，深遠之色重晦，平遠之色，有明有晦。高遠之勢突兀，深遠之意重疊，平遠之意沖融而縹緲。其人物之在三遠也，高遠者明瞭，深遠者細碎，平遠者沖淡。 Guo Si, *Linquan gaozhi*, 9b; translation modified heavily from Susan Bush, *Early Chinese Texts on Painting*, ed. Susan Bush and Hsio-yen Shih (Cambridge, MA: Harvard-Yenching Institute, 1985), 168–69; translation informed more significantly by that of Benjamin March, which is far more accurate than that of Bush. See Benjamin March, “Linear Perspective in Chinese Painting,” *Eastern Art* 3 (1931): 129.
- 51 Guo Si, *Linquan gaozhi*, 9b.
- 52 In the *Sea Island Mathematical Treatise*, the verb *wang* is used more than sixty times to describe the act of looking at a thing from multiple points in order to take a measurement. Liu Hui 劉徽, *Haidao suan jing* 海島算經 (Sea Island mathematical treatise), reprint of Qing dynasty Qianlong-era (1736–96) *Wuyingdian qu zhenban congshu* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), *passim*.
- 53 In the *Sea Island Mathematical Treatise*, the adjective *ping* 平 is used to describe flat, literally “level” land. For example, problem number five seeks to measure a building as viewed from a hill (*deng shan wang lou* 登山望樓); the text of the problem specifies that “the building is on level ground” (*lou zai ping di* 樓在平地). Liu Hui, *Haidao suan jing*, 6a.
- 54 Liu Hui, *Haidao suan jing*, 1a, 2b, 6a, 5a, 7b, 6b, and 8b, respectively.
- 55 For an early analysis of the issues of Chinese vision and perspective, see March, “Linear Perspective in Chinese Painting,” 115–17. The impetus to consider pictorial representation of three-dimensional space together with optics is bound inherently into the study of such phenomena in “the West,” where the codependence of Euclidean optics and geometry makes these two fields of study indivisible, for reasons discussed below. It is for this reason that studies such as Wolfgang Iefèvre, ed., *Inside the Camera Obscura: Optics and Art under the Spell of the Projected Image* (Berlin: Max-Planck-Institut für Wissenschaftsgeschichte, 2007), emphasize the relation of optics, optical devices, and perspective.
- 56 For an early comparative description of the differences in Chinese and Western constructions of three-dimensional space in painting, see March, “Linear Perspective in Chinese Painting”; for an overview of spatial construction in Chinese art, see Lillian Lan-ying Tseng, “Traditional Chinese Painting Through the Modern Eye: The Case of Ludwig Bachhofer,” in *Tradition and Modernity: Comparative Perspectives* (Beijing: Peking University Press, 2007), 508–33.
- 57 In “On Painting,” Alberti proposes new methods for showing distance in painting. Specifically, he replaces conical projections of vision with planar ones, to posit how lines of sight, passing from the viewer’s eye to the landscape, strike the picture

- plane. Alberti, *On Painting and On Sculpture: The Latin Texts of De Picture and De Statua*, ed. and trans. Cecil Grayson (London: Phaidon, 1972), 36–59, esp. 40–43. Alberti then shows how this enables the artist to calculate the apparent height of a distant object using two proportional (or similar) triangles. Alberti, *On Painting*, 50–51. Although Alberti does cite the mathematical source of his theory, it is Euclid who formulated the mathematics of similar triangles. Euclid, *Elementa* (Basel, 1553), 137–68, esp. 153–55; Xu Guangqi 徐光啓 and Li Madou 利瑪竇 [Matteo Ricci], *Ji he yuan ben* 幾何原本 (The original text on geometry), in *Congshu jicheng chubian* 叢書集成初編 (First collection of the complete collection of collectanea) (Changsha: Shangwu yinshu guan, 1939), 6:277–356, esp. 309–17. This point has been made previously in Purtle, “Scopic Frames,” 73 n. 64.
- 58 Ogawa Hiromitsu 小川裕充, “Early Spring by Guo Xi” (Kaku Ki fude Sōshun zu 郭熙筆早春圖), *Kokka* 1035 (1980): 14–19, esp. 17.
- 59 On Euclid’s *Catoptrica*, see Lindberg, *Theories of Vision*, 210.
- 60 In modelling vision on geometry, Euclid articulates seven postulates, the first three of which describe vision in geometric terms: “1. Let it be assumed that lines drawn directly from the eye pass through a space of great extent; 2. and that the form of the space included within our vision is a cone, with its apex in the eye and its base at the limits of our vision; 3. and that those things upon which the vision falls are seen and that those things upon which the vision does not fall are not seen; . . .” Burton, “Euclid’s Optics,” 357. See also Lindberg, *Theories of Vision*, 11–14; and Needham, *Science and Civilization in China*, 85.
- 61 Most recently this attribution has been made by Hans Belting. Belting, *Florence and Baghdad: Renaissance Art and Arab Science*, trans. Deborah Lucas Schneider (Cambridge, MA: The Belknap Press of Harvard University Press, 2011), 95. See also A. Mark Smith, “Hans Belting, *Florence and Baghdad: Renaissance Art and Arab Science*” (review), *Journal of the Economic and Social History of the Orient* 56.3 (2013): 525. Smith argues for a fuller understanding of optics in the Islamic world, to include figures such as al-Kindī (ca. 801–873), Ḥunayn ibn ʿIshāq (809–873), and Qusṭā ibn Lūqā (820–912).
- 62 Fiorani, “Leonardo’s Optics in the 1470s”; Raynaud, “Leonardo’s Optics and Ophthalmology”; Belting, *Florence and Baghdad*, 91, 94–95; Fehrenbach, “Leonardo’s Point,” 76–82.
- 63 For ancient Greek texts on the pinhole, see note 32. On *De aëspectibus*, see Abdelhamid I Sabra, “Alhazen’s Optics in Europe: Some Notes on What It Said and What It Did Not Say,” in *Inside the Camera Obscura*, ed. Lefèvre, 53. On the original Arabic text on the *camera obscura*, see *The Optics of Ibn Al-Haytham*, trans. A.I. Sabra, vol. 1 (London: The Warburg Institute, 1989), 38. To compare the Arabic edition of Book I, Chapter 3 with its Latin translation, which does not mention the *camera obscura*, see *The Optics of Ibn Al-Haytham*, 13–51; and *Alhacen’s Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen’s De aëspectibus, the Medieval Latin Version of Ibn al-Haytham’s Kitāb al-Manāẓir*, trans. A. Mark Smith, in *Transactions of the American Philosophical Society* 91.5, vol. 2 (Philadelphia, PA: American Philosophical Society, 2001), 346.
- On Ibn al-Haytham not equating the *camera obscura* with the human eye, see Sabra, “Alhazen’s Optics in Europe,” 53; and Smith, “Hans Belting, *Florence and Baghdad*,” 525. On Ibn al-Haytham’s understanding of the physical structure of the eye, the selection of visual images, the functional structure of the eye, and the preconditions of sight, see *The Optics of Ibn Al-Haytham*, 55–62; and *Alhacen’s Theory of Visual Perception*, 348–55. The Arabic text clearly shows an understanding of the mechanics of binocular vision, beginning with a diagram of the two eyes and their relation to the brain. *The Optics of Ibn Al-Haytham*, 63. Both the Arabic text and its Latin translation describe the mechanics of binocular vision, making the use of the *camera obscura* as a model for human vision problematic. See *The Optics of Ibn Al-Haytham*, 85–86; and *Alhacen’s Theory of Visual Perception*, 376–78.
- 64 On this phenomenon, see Shapiro, “Kepler, Optical Imagery, and the Camera Obscura,” 217–18; see also Lindberg, *Theories of Vision*, 178–208.
- 65 Leonardo da Vinci, *Codex Atlanticus*, 337 recto-a; see also Donald Sanderson Strong, “Leonardo da Vinci on the Eye: The Ms D in the Bibliothèque de l’institut de France, Paris, Translated into English and Annotated with a Study of Leonardo’s Theories of Optics” (PhD diss., University of California Los Angeles, 1972), 105; Fehrenbach, “Leonardo’s Point,” 76–82; Norma Wenczel, “The Optical Camera Obscura II: Images and Texts,” in *Inside the Camera Obscura*, ed. Lefèvre, 24; and Lindberg, *Theories of Vision*, 154–68.
- 66 Leonardo da Vinci, *Manuscript D*, 337 recto-a; see also Strong, “Leonardo da Vinci on the Eye,” 105. Leonardo writes, “How the species of any object,

- which pass through some aperture to the eye, imprint themselves in its pupil upside down, and the common sense see them upright." Strong, "Leonardo da Vinci on the Eye," 47; see also Lindberg, *Theories of Vision*, 164.
- 67 Leonardo da Vinci, *Manuscript D*, 5 recto; see also Strong, "Leonardo da Vinci on the Eye," 62–63. Leonardo writes, ". . . Moreover the ventricle situated in the brain of man called the *imprensiva* is more than ten times the size of the entire eye of man and the pupil in which sight has its origin is less than a thousandth part of the eye. . . . In the case of the long-eared owl the pupil at night is considerably larger than the ventricle of the *imprensiva* situated in its brain. Whereby, the *imprensiva* in man being greater in proportion to its cornea, in fact ten thousand times greater, in the horned owl they are almost equal. And this *imprensiva* of man in comparison with that of the long-eared owl is like a great room illuminated through a small hole as compared with a small room completely open. For within the great room there will be night at midday and in the small open one there will be day at midnight providing the weather is not overcast. And by means of the anatomy of the eyes and the *imprensiva* of these two animals, namely of man and of the horned owl, the most important reasons for the differences in the diameter of the pupil may be demonstrated." Leonardo da Vinci, *Manuscript D*, 5 recto; Strong, "Leonardo da Vinci on the Eye," 62–63. For Leonardo on the binocularity of human vision, see Strong, "Leonardo da Vinci on the Eye," 82. In fact, Leonardo wore spectacles, tools of binocular vision. Ilardi, *Renaissance Vision from Spectacles to Telescopes*, 241.
- 68 For Descartes on light and the function of the eye, see René Descartes, "Optics," in *Discourse on Method, Optics, Geometry, and Meteorology*, trans. Paul J. Olscamp (Indianapolis, IN: Bobbs-Merrill, 1965), 65–173. For Locke on light and the function of the eye, see John Locke, *An Essay Concerning Human Understanding* (London: Offor, 1819), *passim*, esp. "Of Perception."
- 69 Shen Kuo, *Mengxi bitan*, 3:1b–2a; see also Needham, *Science and Civilization in China*, 97.
- In particular, Shen Kuo understood the idea of a focal point, a place where the image "was collected" (*suoshu* 所束), as integral to the transmission of a light-based image by both lenses and mirrors. Shen Kuo, *Mengxi bitan*, 3:1b; see also Needham, *Science and Civilization in China*, 97.
- 70 Indeed, the optical properties of mirrors were known in ancient Greece, as in the case of Euclid's *Catoptrica*. Lindberg, *Theories of Vision*, 210.
- 71 Shen Kuo, *Mengxi bitan*, 19:3b–4a; Mo Di, *Mozi*, 10.41:4a; Needham, *Science and Civilization in China*, 84, 93, 94.
- 72 David Hockney, *Secret Knowledge* (London: Thames and Hudson, 2001), 238; Sarah J. Schechner, "Between Knowing and Doing: Mirrors and their Imperfections in the Renaissance," *Early Science and Medicine* 10.2:141–60; Anderson, *The Telescope*, 25–36.
- 73 Xie Zhaozhe 謝肇淛 (1567–1624), *Wuzazu* 五雜俎 (Five miscellanies), *Lidai biji congkan* 歷代筆記叢刊 (Comprehensive series of historical miscellaneous writings) (Shanghai: Shanghai shudian, 2001), 12:242.
- 74 Adam Schall von Bell 湯若望, *Yuanjing shuo* 遠鏡說 (Speaking of the telescope), 1626, reprint of Jiaqing-era (1796–1820) *Yihai zhuchen* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 5b–6b, 11a, b. For an excellent account of the various types of bronze mirrors and their properties known by literati during the late Ming period, see Xie Zhaozhe, *Wuzazu*, 12:242.
- 75 Schall, *Yuanjing shuo*, 14b. On early Chinese familiarity with the *camera obscura* and the principle of the pinhole on which it is based, see notes 28–31, 34 above.
- 76 Purtle, "Scopic Frames," 68.
- 77 On the telescope, see Fang Yizhi 方以智, *Wu li xiao shi* 物理小識 ([Some] Small knowledge of the physical world), reprint of the Guangxu-era (1875–1908) *Ningjing tang* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 1:7b, 1:22b, 1:27b, 1:29b, 2:6a; on the *camera obscura*, see 8:14a; on the *camera obscura* fitted with a glass mirror, see 12:13a.
- 78 On this concept, see Joel Snyder, "Picturing Vision," *Critical Inquiry* 6.3 (1980): 499–526.
- 79 Geronimo Nadal, *Evangelicae Historiae Imagines* (Images from the New Testament) (Antwerp: [Martinus Nutius], 1593); João da Rocha 羅儒望, *Song Nianzhu guicheng* 誦念珠規程 (Method of saying the rosary), reprint of Ming-dynasty edition of ca. 1619–23 (Taipei: Ricci Institute, 2002); Giulio Aleni 艾儒略, *Tianzhu jiangsheng chuxiang jingjie* 天主降生出像經解 (Illustrated explanation of the incarnation of the Lord of Heaven) (Jinjiang, Fujian, 1637); Adam Schall von Bell, *Jincheng shuxiang* 進呈書像 (Images from a book presented to the emperor), reprint of 1640 edition (Sankt Augustin: Steyler Verlag, 2007).
- 80 Purtle, "Scopic Frames," 58–59.
- 81 Luke 1:26–38.
- 82 Nadal, *Evangelicae Historiae Imagines*, 11r.
- 83 Da Rocha, *Song Nianzhu guicheng*, 3b. While the image is not captioned, earlier in the text the first

- joyful mystery of the rosary is described as follows: "The angel Gabriel announced to the Holy Mother that the Lord had chosen her to be the mother [of his son]" (*Anruo Jiabi'er, Shengmu bao shuo Tianzhu xuan ta wei mu* 諳若嘉俾阿爾、聖母報說天主選他為母). Da Rocha, *Song Nianzhu guicheng*, 1b.
- 84 Aleni, *Tianzhu jiangsheng chuxiang jingjie*, 8a.
- 85 Schall, *Jincheng shuxiang*, 5a.
- 86 Nadal, *Evangelicae Historiae Imagines*, 5r. For the text on which the image is based, see Luke 2:21.
- 87 Da Rocha, *Song Nianzhu guicheng*, 9b. While the image is not captioned, earlier in the text the fourth joyful mystery of the rosary is described as follows: "Forty days after the birth of our Lord the Holy Mother presented Jesus to the Lord" (*Shengdan hou sishi ri, Shengmu song Yesu yu tianzhu* 聖誕後四十日、聖母送耶穌於天主). Da Rocha, *Song Nianzhu guicheng*, 2a. For the text on which the image is based, see Luke 2:23–24.
- 88 For the *Pvificatio*, see Nadal, *Evangelicae Historiae Imagines*, 8r.
- 89 Aleni, *Tianzhu jiangsheng chuxiang jingjie*, 7b. For the text on which the image is based, see Luke 1:5–25.
- 90 Schall, *Jincheng shuxiang*, 11a; see also Purtle, "Scopic Frames," 59. For the text on which the image is based, see Luke 2:41–52.
- 91 Benjamin March has noted that any system of perspective requires compromise between the system and pictorial effectiveness. March, "Linear Perspective in Chinese Painting," 139. As Timothy Kitao has shown, Baroque art emphasizes movement, binocularity, and non-fixity. See Timothy Kitao, "Prejudice in Perspective: A Study of Vignola's Perspective Treatise," *The Art Bulletin* 44 (1962): 173–94; and "Imago and Pictura: Perspective, Camera Obscura and Kepler's Optics," in *La prospettiva rinascimentale—codificazioni e trasgressioni*, ed. Marisa Dalai Emiliani (Florence: Centro di Firenze, 1980), 499–510.
- 92 Xu Guangqi, "Preface," in *Ji he yuan ben, Xu*: 2; Matteo Ricci, "Preface," in *Ji he yuan ben, Xu*: 5; see also Shen et al., *The Nine Chapters on the Mathematical Art*, 21.
- 93 In *De Pictura* (On Painting) of 1435, Alberti proposed new methods for showing distance in painting. Among his innovations, Alberti replaced conical with planar projections of vision, to posit how lines of sight, passing from the viewer's eye to the landscape, strike the picture plane. Alberti, *On Painting*, 36–59, esp. 40–43. Alberti then showed how this enabled the artist to calculate the apparent height of a distant object using two proportional (or similar) triangles. Alberti, *On Painting*, 50–51. Alberti cites the mathematical source of his theory, but it is Euclid who formulated the mathematics of similar triangles. Euclid, *Elementa*, 137–68, esp. 153–55; Xu Guangqi and Ricci, *Ji he yuan ben*, 6:277–356, esp. 6:309–17; Purtle, "Scopic Frames," 67, 73.
- 94 Purtle, "Scopic Frames," 67.
- 95 Hui-hung Chen, "Chinese Perception of European Perspective: A Jesuit Case in the Seventeenth Century," *The Seventeenth Century* 24.1 (2009): 111–14. The earliest of these works included multiple copies of the work of John Peckham (ca. 1230–1292), as well as copies of works by Euclid, Daniele Barbaro (1513–1570), Hans Lenckner (d. 1585), Martino Bassi (fl. 16th century), and Giambattista Benedetti (1530–1590) published during the sixteenth century.
- 96 Purtle, "Scopic Frames," 58–59. For example, Schall's *Image of the Lord Jesus Praying in the Mountain Park* (*Tianzhu Yesu shanyou qidao xiang* 天主耶穌山園祈禱像) of 1640, based on a print by Jacques de Gheyn II (ca. 1565–1629) and Zacarias Dolendo (1561–1601) after *The Agony in the Garden* by Karel van Mander (1548–1606), limits the mobility of the eye. In van Mander's composition, fore-, middle, and distant ground do not share a continuous ground-plane; this compositional feature is not only replicated but underscored in Schall's image. For these images see, respectively, Schall, *Jincheng shuxiang*, 34b; and Nicolas Standaert, *An Illustrated Life of Christ Presented to the Chinese Emperor: The History of the Jincheng shuxiang* (Sankt Augustin: Institut Monumenta Serica, 2007), 251. Rather differently, *Praying in the Garden*, [His] Sweat [Like] Blood (*Yuan zhong qidao han xue* 園中祈禱汗血), a landscape image from Aleni's *Tianzhu jiangsheng chuxiang jingjie*, reproduces its precursor from Nadal's *Evangelicae Historiae Imagines* (see fig. 23), translating the pictorial space and cautiously continuous groundplane of the original—suited to viewing by a single, fixed eye or to an eye with limited mobility—into the idiom of the Chinese woodblock print without interpolating Chinese literati spatial sensibilities. For Aleni's image, see Aleni, *Tianzhu jiangsheng chuxiang jingjie*, 27b.
- 97 Nadal, *Evangelicae Historiae Imagines*, 107r. For the text on which the image is based, see Luke 22:43–44.
- 98 James Cahill, *The Compelling Image: Nature and Style in Seventeenth-century Chinese Painting* (Cambridge, MA: Harvard University Press, 1982), esp. 75–105.
- 99 Da Rocha, *Song Nianzhu guicheng*, 9b. While the image is not captioned, earlier in the text the first sorrowful mystery of the rosary is described as follows: "The night before Jesus was crucified, [while] praying in the garden at the Mount of Olives (*Aliwa shan* 阿利瓦山 [that is, Gethsamane in Greek]),

- the Lord renounces temptation three times" (*Yesu shounan qian yi xi, zai Aliwa shanyuan zhong daogao, Tianzhu ba de le sanci* 耶穌受難前一夕、在阿利瓦山園中禱告、天主罷德肋三次). Da Rocha, *Song Nianzhu guicheng*, 2a.
- 100 It has been argued that the fifteen woodcuts for *Song Nianzhu guicheng* may have been made by students of the famous Chinese painter Dong Qichang. *Storia dell'introduzione del cristianesimo in Cina Scritta da Matteo Ricci S.I.*, ed. Pasquale d'Elia S.I., *Fonte Ricciane*, vol. 1 (Rome: Libreria dello Stato, 1942), 384; Gianni Criveller, "Jesuits' Visual Culture Accommodated in China during the Last Decades of Ming Dynasty," in *Ming Qing Studies 2010*, ed. Paolo Santangelo (Rome: CIVIS s.n.c./ScriptaWeb.eu, 2010), 223. While the textual evidence for this proposition is not fully persuasive, the compositional structures of the landscape images suggest that this is possible. Additionally, Richard Barnhart has argued that Dong struggled to address the challenge to Chinese painting made by the mathematical proportionality of single-point perspective in Chinese terms, namely, "to divide and join" (*fenhe* 分合). See Richard M. Barnhart, "Dong Qichang and Western Learning: A Hypothesis in Honor of James Cahill," *Archives of Asian Art* 50 (1997/1998): 13.
- 101 On these points, see Purtle, "Scopic Frames," 56–58. On images that depict visual experience, see Snyder, "Picturing Vision"; on images that embody epistemic structures, see Lorraine Daston, "Epistemic Images," in Payne, *Vision and its Instruments*, 13–35, esp. 17–20; on an alternative type of epistemic image in China, see Jennifer Purtle, "The Pictorial Form of a Zoomorphic Ecology: Dragons and their Painters in Song and Southern Song China," in Jerome Silbergeld and Eugene Wang, *The Zoomorphic Imagination in Chinese Art and Culture* (Honolulu: University of Hawai'i Press, 2016), 253–288, esp. 253–54, 261.
- 102 Purtle, "Scopic Frames," 63–64.
- 103 Purtle, "Scopic Frames," 63–64.
- 104 Christiaan Huygens, *Oeuvres Completes* (The Hague, 1888–1950), 4, 102–4, 111–12. This passage substantially follows my previous work, Purtle, "Scopic Frames," 69, 73.
- 105 Kaspar Schott (1608–1666), *Magia universalis naturae et artis* (Herpiboli [Würzburg], 1657), 426; Craig Clunas, *Pictures and Visuality in Early Modern China* (London: Reaktion Books, 1997), 132; Purtle, "Scopic Frames," 69, 73. On the Jesuits and optical media more broadly, see Kittler, *Optical Media*, 76–88.
- 106 Schott, *Magia universalis naturae et artis*, 426; Clunas, *Pictures and Visuality*, 132; Purtle, "Scopic Frames," 69, 73.
- 107 On Constantijn Huygens and his relation to contemporary Dutch ideas about images and seeing, see Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago: University of Chicago Press, 1983), 1–25; and Purtle, "Scopic Frames," 69, 73.
- 108 John Bate, *The Mysteryes of Natvre and Art, Contained in 4 Severall Tretises* (London, 1634), 27, 28. For images of Chinese zoetropic lanterns, see Purtle, "Scopic Frames," figs. 12–15.
- 109 Bate, *The Mysteryes of Natvre and Art*, 98, 107, 109.
- 110 Athanasius Kircher, *China monumentis qua sacris qua profanis illustrata* (Amsterdam, 1667); Purtle, "Scopic Frames," 69.
- 111 Athanasius Kircher, *Ars magna lucis et umbra* (Rome, 1646), 887; Purtle, "Scopic Frames," 69, 73.
- 112 Athanasius Kircher, *Ars magna lucis et umbra* (Amsterdam, 1671), 768–69; Purtle, "Scopic Frames," 69.
- 113 Purtle, "Scopic Frames," 69–70. Further devices shown in Kircher's works appear to have been developed through knowledge of Chinese optical devices.
- 114 For the texts published between 1607 and 1671 (all mentioned previously), see notes 57, 74, 79, and 110–12 above; see also Purtle, "Scopic Frames," 67, 69–70, 73 n. 63. Sun Yunqiu 孫雲球, *Jing shi* 鏡史 (A history of lenses) (Suzhou, 1681). On this text, see Sun Chengsheng 孫承晟, "Ming Qing zhi ji xifang guangxue zhishi zai Zhongguo de chuanbo ji qi yingxiang: Sun Yunqiu 'Jing shi' yanjiu" 明清之際西方光學知識在中國的傳播及其影響: 孫雲球《鏡史》研究, "The Dissemination of Western Optical Knowledge in China during the Ming and Qing Dynasties and Its Influence: A Study of Sun Yunqiu's *History of Lenses*," *Ziran kexue shi* 2007.10:363–76; and Kristina Kleughen and S.E. Kile, "Seeing through Pictures and Poetry: A History of Lenses (1681)," *Late Imperial China* 38.1 (2017): 47–112.
- 115 Joseph McDermott, "Chinese Lenses and Chinese Art," *Kaikodo Journal* 19 (2001): 9–29, esp. 11–12; Purtle, "Scopic Frames," 70.
- 116 Purtle, "Scopic Frames," 70.
- 117 Elisabetta Corsi, "Envisioning Perspective: Nian Xiyao 年希堯 (1671–1738)'s Rendering of Western Perspective in the Prologues of the 'Science of Vision,'" in *A Life Journey to the East. Sinological Studies in Memory of Giuliano Bertuccioli (1923–2001)*, ed. Antonino Forte and Federico Masini (Kyoto: Italian School for East Asian Studies, 2002), 201–43. Nian was trained by the Italian Jesuit painter Giuseppe Castiglione 郎世寧 (1688–1766), who had studied with the Italian Jesuit painter Andrea Pozzo (1642–1709), and who translated Pozzo's *Perspectiva pictorum et architectorum* into French and Flemish. See Elisabetta Corsi, "Perspectiva iluminadora

- e Iluminación de la Perspectiva: De la Perspectiva, de Nian Xiyao (1671–1738) en los Prólogos a la ‘Ciencia de la Visión,’ *Estudios de Asia y Africa* 36.2 (2001): 378–79; and Jodi O’Toole, “Andrea Pozzo: The Joining of Truth and Illusion” (M.Arch. thesis, McGill University, 1999), 22.
- Translated by Nian Xiyao as *xianfa* 線法 (literally “line method”), linear perspective was also known as *Xiyang fa* 海西法 (literally “methods [from] the Western seas”), underscoring the foreignness of the technique. Hu Jing 胡敬 (1769–1845), *Guochao yuanyuan lu* 國朝院畫錄 (Record of the painting of the [court] Academy of This [Qing] Dynasty), reprint in *Hushi shuhuakao sanzong* 胡氏書畫考三種 (Mr. Hu’s investigations of calligraphy and painting of three types) (Shanghai: Zhongguo shuhua baocunhui, 1924), 1:1a–2a; see also Anita Chung, *Drawing Boundaries: Architectural Images in Qing China* (Honolulu: University of Hawai’i Press, 2004), 49. The expanded use of this technique is found in so-called Suzhou perspective prints. On these prints, see, for example, Wang Cheng-hua, “Prints in Sino-European Artistic Interactions of the Early Modern Period,” in *The Transcendence of the Arts in China and Beyond: Historical Perspectives*, ed. Rui Oliveira Lopes (Lisbon: Centro de Investigação e Estudos em Belas-Artes, 2014), 424–57, esp. 440–43.
- 118 Jean-Baptiste du Halde (1674–1743), *Description géographique, historique, chronologique, et physique de l’empire de la Chine et de la Tartarie chinoise*, vol. 3 (Paris, 1735), 268–69; see also Elisabetta Corsi, “Agreeable but Useful: Notes on Jesuitical Visual Culture during the Seventeenth Century,” unpublished lecture script posted to the author’s institutional open access website at La Sapienza Università di Roma: <http://www.lettere.uniroma1.it> (last accessed May 18, 2017), 3. It is possible that the Jesuits transmitted Kepler’s theory of the retinal image to China; yet, given the established Chinese knowledge of the workings of the eye, this would not have been profound. Corsi, “Agreeable but Useful,” 2.
- 119 Purtle, “Scopic Frames,” 70. It is from this encounter, at least in part, that Europeans developed the optical devices collectively referred to as “pre-cinema.” On pre-cinema, see, for example, Hermann Hecht, *Pre-Cinema History: An Encyclopedia and Annotated Bibliography of the Moving Image before 1896* (London: Bowker-Saur, 1993); Stephen Herbert, *A History of Pre-Cinema* (London: Taylor and Francis, 2000); and Laurent Mannoni, *The Great Art of Light and Shadow: Archaeology of the Cinema*, trans. Richard Crangle (Exeter: University of Exeter Press, 2000); see also Purtle, “Scopic Frames,” 70, 73 n. 89.
- 120 On shadows, mirror images, projected shadows, shade, and specular images, see Lihong Liu, “Shadows in Chinese Art: An Intercultural Perspective,” in *Qing Encounters: Artistic Exchanges Between China and the West*, ed. Petra ten-Doesschate Chu and Ning Ding (Los Angeles: Getty Research Institute, 2015), 190–213; and Purtle, “Scopic Frames,” 55.
- 121 Lihong Liu, “Pyrotechnic Profusion: Fireworks, Spectacles, and Automata in Time,” *Journal* 18, online and unpaginated; Lihong Liu, “Vitreous Views: Materiality and Mediality of Glass in Qing China through a Transcultural Prism,” *Getty Research Journal* 8 (2016): 17–38.
- 122 On the zoetropic lantern, see, for example, Dun Lichen 敦禮臣 (1855–1911), *Yanjing suishi ji* 燕京歲時記 (A record of festivals in Yanjing [Beijing]) (Beijing: Wenzhai, 1906), 53a–b; on magic mirrors, see, for example, Zheng Fuguang 鄭復光 (1780–ca.1853), *Jingjing ling chi* 鏡鏡鈴癡 (A folly for hawking mirrors and lenses), reprint of Daoguang-era (1820–50) *Yunyunyi congshu* edition (Beijing: Beijing Erudition Digital Research Center, 2001–15), 5:5a. On the *vues d’optique* that took China as their subject and subsequently shaped Chinese peepboxes, see Barbara Stafford and Frances Terpak, *Devices of Wonder: From the World in a Box to Images on Screen* (Los Angeles: Getty Research Institute, 2001), 349–54; and Kleutghen, “Peepboxes,” 763–77, esp. 763.
- 123 Purtle, “Scopic Frames,” 70.
- 124 Zheng Fuguang noted the commonplace nature of mirrors of unequal curvature in nineteenth-century China: “[These] are called ‘Light-transmitting Mirrors.’ People vie to possess [them] for this reason [that is, their ability to project an image], not knowing that ‘Double Happiness Mirrors’ [that is, light-transmitting mirrors that project a double happiness symbol] cast in Huzhou [in Zhejiang], however, [have] become ordinary articles for everyday use.” Zheng Fuguang, *Jingjing ling chi*, 5:5a; translation modified significantly from Dai Nianzu, “Physics,” 310. Beginning in 1832, European scholars engaged these mirrors intensely, in multiple publications, their secret not fully explained in European-language texts until 1932. On the endeavors and hypotheses of these many scholars, see Needham, *Science and Civilization in China*, 94–97.
- 125 On *Jingjing ling chi*, see Dai Nianzu, “Physics,” 312–15; specifically, these pages address Zheng Fuguang’s distinction between mirrors and lenses, effected by the creation of a new vocabulary for mirror imaging.

- This vocabulary included terms such as “transillumination” (*tongguang* 透光) to indicate the passage of light through a glass lens (as opposed to its reflection by a mirror). See, for example, Zheng Fuguang, *Jingjing ling chi*, 1:3a–b; see also Dai Nianzu, “Physics,” 314. On the “invention” of the zoetrope in the United States, see William Ensign Lincoln, U.S. Patent No. 64,117, dated April 23, 1867. See also Purtle, “Scopic Frames,” 65–67, 69–70, 72–73.
- 126 On the interrelation of notions of vision and representation, see E.H. Gombrich, *Art and Illusion: A Study in the Psychology of Pictorial Representation*, The A.W. Mellon Lectures in the Fine Arts (Princeton, NJ: Bollingen Series in the Fine Arts/Princeton University Press, 1969), esp. “The Analysis of Vision in Art,” 291–329. European devices (for example, the stereoscope and the reflecting stereoscope) also took advantage of knowledge of binocularity and mobile vision to produce optimal images. See Laura Burd Schiavo, “From Phantom Image to Perfect Vision: Physiological Optics, Commercial Photography, and the Popularization of the Stereoscope,” in *New Media, 1740–1915*, ed. Gitelman and Pingree, 113–37.
- 127 The Manchu aristocrat Dun Lichen, for instance, took pacing-horse lanterns to exemplify the Chinese failure to modernize. Dun Lichen, *Yanjing suishi ji*, 53a–b; translation adapted significantly from *Annual Customs and Festivals in Peking, as Recorded in the Yen-ching sui-shih-chi by Tun Li-ch'en*, trans. Derk Bodde (Hong Kong: Hong Kong University Press, 1965), 80–81. See also Purtle, “Scopic Frames,” 70, 73 n. 90; and Needham, *Science and Civilization in China*, 124.
- 128 Jordan Bear, “Self-Reflections: The Nature of Sir Humphry Davy’s Photographic ‘Failures,’” in *Photography and Its Origins*, ed. Tanya Sheehan and Andrés Mario Zervigón (London and New York: Routledge, 2015), 185–94.
- 129 Liang Qichao 梁啟超 (1873–1929), *Zhongguo jin sanbainian xueshushi* 中國近三百年學術史 (Chinese intellectual history of the last three hundred years) (Beijing: Dongfang chubanshe, 2004), 382; Yi Gu, “Photography and its Chinese Origins,” in *Photography and Its Origins*, ed. Sheehan and Zervigón, 162–64; see also Dai Nianzu, “Physics,” 317–19.
- 130 For example, the studio Tong Hing 同興, active in Fujian during the 1860s and 1870s, experimented with producing photographic images that matched previously published woodblock-printed images, and also created panoramas using multiple plates, thus making works that, like handscrolls, required a mobile eye to account for multiple vanishing points. In a different genre of photography, Yang Chia-ling has addressed the use of photography to create portraits that met pre-existing Chinese notions of visual representation. See Yang Chia-ling, “The Crisis of the Real: Portraiture and Photography in Late Nineteenth Century Shanghai,” in *Looking Modern*, ed. Purtle and Thomsen, 20–37.
- 131 Yi Gu, “Photography and its Chinese Origins,” 161.
- 132 On the European symbiosis of painting and photography, see Stephen Bann, *Parallel Lines: Printmakers, Painters, and Photographers in Nineteenth-Century France* (New Haven, CT, and London: Yale University Press, 2001).
- 133 Marshall McLuhan, *Understanding Media: The Extensions of Man* (Toronto: McGraw-Hill, 1964), 7.