"Mr. Hooke's Reflecting Box": Modeling the Projected Image in the Early Royal Society

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ABSTRACT From the early 1660s through the late 1690s, Robert Hooke conducted experiments with the camera obscura and other methods of optical projection, demonstrating how they could be used expressly for the purpose of painting. Then described as "Mr. Hooke's reflecting box," the camera obscura is well known in studies of early modern art and visuality, where it has figured as a "model." Drawing upon recent work in analytic philosophy of science, this essay uses Hooke's projected-image experiments to rethink the meanings of the camera obscura's modeling and their broader implications for artistic practice in the long eighteenth century. **KEYWORDS:** Robert Hooke; Joshua Reynolds; Johannes Zahn; camera obscura; modeling; optical projection

IN THE SUMMER OF 1668, St. Florent des Ulmes became a site of wonder. On the outskirts of Saumur, a center of Protestant learning in France's Loire Valley, this small, Catholic church hosted nothing less than a miracle on June 2, 1668. As the priest sang the lines "Verbum caro panem verum" from Thomas Aquinas's Corpus Christi hymn "Pange lingua gloriosi," parishioners saw a curious spectacle: "There appeared in the Remonstrance, instead of the *Hoast*, the form of a Man, whose hair light brown fell upon his Shoulders, his face radiant, his hands crossed one upon the other."[1] This is the description given by Henri Arnauld, Catholic bishop of Angers, who quickly published an account of the event. By Arnauld's view, the apparition was as dazzling as it was indubitable:

1. Henri Arnauld, *Le Grand Miracle arrivé dans le saint Sacrement, en la parroisse des Ulmes de Saint Florent, prés la ville de Saumur* (Angers, France, 1668). Arnauld's text was simultaneously published in Italian as *Il Gran miracolo auuenuto dentro il santissimo Sacramento* (Venice, 1668) and in two English versions: *An Extract out of a Pastoral Letter of the Bishop of Angers in France, Concerning a late Miracle* (Paris, 1668); and *The True Exact Copy of the Pastoral Letter of the Bishop of Angiers in France Concerning a late Miracle* (Antwerp, 1668). All references here are to the Antwerp edition. On Aquinas's hymn, see H. T. Henry, "Pange Lingua Gloriosi," *The Catholic Encyclopedia*, 15 vols. (New York, 1911), 11:441–44.

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> This Apparition continued for the space of the quarter of an hour, as well upon the Tabernacle, where the said Blessed Sacrament was exposed, as upon the Altar, after the Pastor had taken it down, to give unto the People a more full view of it. In sequel to this, a little cloud did appear which involved him on all sides, and being dispersed, immediately, the holy *Hoast* was seen in its ordinary Figure, as before this Miracle.[2]

Tales of such miraculous transformations were, of course, widely circulated in medieval devotional literature. Explained in Aristotelian terms as a momentary exchange of the host's accidents, or external appearance, for its true substance, this apparitional mechanism could be seen as echoing the transubstantiation in the ritual of the Eucharist while redoubling the sacred mysteries of the feast of Corpus Christi.[3]

Bishop Arnauld proceeded more cautiously. Interviewing witnesses and examining firsthand the monstrance in which the apparition had unfolded, Arnauld methodically eliminated the possibility of the vision's production by "any Artifice, by reflection of light, nor by the ordinary wayes of Nature."[4] What Arnauld was seeking in this rigorous verification was as much proof of divine presence as propagandistic firepower sparked by a poor Catholic church on the very doorstep of a Protestant academy that, since its founding in 1599, had been a focal point for France's Huguenot community.[5] For Arnauld, the miracle's lessons were clear. The apparition offered a warning to Catholics of the true nature of the Eucharist, to be heeded by those "many bad Christians, who eat his body unworthily."[6] In the larger, confessionally divided ambit of Saumur, the miracle was sent "to confound the errour of *Heretiques*, who by a blindnesse (of which his mercy seems willing to cure them) they deny the Reality of the Body and Bloud of Jesus Christ in the Holy *Eucharist*."[7] To one and all, the transformative event made the real-but-invisible temporally perceptible, thus providing a reassuring reminder of Christian semiotics. No more could it be held that "the divinity shut up within this dreadfull *Hoast* of our Altars . . . be a figure or simple signe, when the Majesty of Jesus Christ hath evidence by a visible forme, that he is invisibly contained under the veyle of holy Species."[8]

2. Arnauld, *True Exact Copy*, 4.

3. For a concise account of the principles underpinning the distinction between substance and accidents, see Sabine MacCormack, *Religion in the Andes: Vision and Imagination in Early Colonial Peru* (Princeton, N.J., 1991), 25–29. More broadly, see Miri Rubin, *Corpus Christi: The Eucharist in Late Medieval Culture* (New York, 1991); and Aden Kumler, "The Multiplication of the Species: Eucharistic Morphology in the Middle Ages," *RES: Anthropology and Aesthetics* 59/60 (2011): 179–91.

4. Arnauld, *True Exact Copy*, 4.

5. On Saumur and its Huguenot culture, see *Saumur, capitale européenne du protestantisme au XVIIe siècle* (Fontevrault-l'Abbaye, France, 1991); and Scott Mitchel Marr, "Urban Encounters and the Religious Divide: Catholic-Protestant Coexistence in Saumur, France, 1589–1665" (PhD diss., Boston University, 2011). For an interesting account of then-recent confessional debates within the influential Arnauld family involving Henri Arnauld and his brother, the leading Jansenist theologian Antoine Arnauld, see Alexander Sedgwick, *The Travails of Conscience: The Arnauld Family and the Ancien Régime* (Cambridge, Mass., 1998), esp. 163–94.

6. Arnauld, *True Exact Copy*, 5.

7. Ibid., 3.

8. Ibid., 5.

In Restoration London, members of the fledgling Royal Society read Arnauld's text with interest. Mere months after the apparition's occurrence, the secretary of the Royal Society, Henry Oldenburg, sent to a correspondent in France named William Brereton "a tacit refutation of the late French pretended miracle, said to be done in a village near Saumur; the narrative of which was sent hither in French, and here translated and printed in English."[9] The way Oldenburg told it, Arnauld's report had imagined Christ appearing "by way of a picture, on ye altar, at the time of ye masse, for a quarter of an houre, many people seeing it with astonishment, wch afterwards was examined by ye Bp of Angiers, and declared for a miracle in print."[10] But, Oldenburg was having none of it. As was disclosed by "the inclosed print" conveyed with his missive, the supposed miracle was nothing more than a clever piece of theatrical chicanery, one that had been replicated "in the presence of several members of the R. Society, among whom the Publisher."[11]

Oldenburg found his "tacit refutation" of the apparition at Saumur in the first article published in the thirty-eighth issue of his *Philosophical Transactions*: "A Contrivance to make the Picture of any thing appear on a Wall, Cub-board, or within a Picture-frame, &c. in the midst of a Light room in the day-time; or in the Night-time in any room that is enlightened with a considerable number of Candles; devised and communicated by the Ingenious Mr. Hook."[12] The Curator of Experiments to the Royal Society, Keeper of its Repository, and emerging architect of post-Fire London's rebuilding, Robert Hooke accomplished this display through some ingenious feats of optical projection. His contrivance required a powerful light source; an inverted image or object to be projected; an aperture discreetly punctured in a wall and fitted with "a broad Convex-glass, ground of such a convexity, as that it may represent the Object distinct"; and a viable surface for receiving projections.[13] Hooke concedes that some projections would be trickier to pull off than others. "If the Object cannot be *inverted* (as 'tis pretty difficult to do with Living Animals, Candles, &c.)," he explains, "then

9. Henry Oldenburg to William Brereton, September 22, 1668, *The Correspondence of Henry Oldenburg,* vol. 5, *1668–1669*, ed. and trans. A. R. Hall and M. B. Hall (London, 1968), 60.

10. Ibid.

11. [Robert Hooke], "A Contrivance to make the Picture of any thing appear on a Wall, Cub-board, or within a Picture-frame, &c. in the midst of a Light room in the day-time; or in the Night-time in any room that is enlightened with a considerable number of Candles; devised and communicated by the Ingenious Mr. Hook," *Philosophical Transactions* 3 (1668): 743.

12. Ibid., 741–43.

13. Hooke's full description of his setup is as follows: "Opposite to the place of wall, where the Apparition is to be, let a Hole be made of about a foot in diameter, or bigger; if there be a high Window, that hath a Casement in it, 'twill be so much the better. Without this hole, or Casement open'd at a convenient distance, (that it may not be perceived by the Company in the room) place the Picture or Object, which you will represent, inverted, and by means of Looking-glasses placed behind, if the picture be *transparent*, reflect the rayes of the Sun so, as that they may pass through it towards the place, where is to be represented; and to the end that no rayes may pass besides it, the picture be encompass'd on every side with a board or cloath. If the Object be a *Statue*, or some living Creature, then it must be very much enlightn'd by casting the Sun beams on it by Refraction, Reflexion, or both. Between this Object, and the Place where tis to be represented, there is to be placed a broad Convex-glass, ground of such a convexity, as that it may represent the Object distinct on the said place; which any one, that hath any insight in the *Opticks*, may easily direct." Ibid., 742–43.

there must be *two* large Glasses of convenient Spheres, and they plac'd at their appropriate distances (which are very easily found by tryals) so as to make the representations *erect* as well as the Object."[14]

Although flying dogs—and not radiant, brown-haired gods—were the primary objects of his inquiry, Hooke was certainly cognizant of the powerful effects his projection technique could wield upon "Spectators, not well versed in Opticks, that should see the various Apparitions and Disappearances, the Motions, Changes, and Actions, that may this way be represented."[15] Images projected posed a threat, especially to the ignorant populations typically targeted by clerical tyrants:

> Had the Heathen Priests of old been acquainted with it, their Oracles and Temples would have been much more famous for the Miracles of their Imaginary Deities. For by such an Art as this, what could they not have represented in their Temples? Apparitions of Angels, or Devils, Inscriptions and Oracles on Walls; the Prospect of Countryes, Cities, Houses, Navies, Armies; the Actions and Motions of Men, Beasts, Birds, &c. the vanishing of them in a cloud, and their appearing no more after the cloud is vanished: And indeed almost any thing, that may be seen, may by this contrivance be very vividly and distinctly represented, in such a manner, that, unless to very curious and sagacious persons, the means how such apparitions are made, shall not be discoverable.[16]

Whereas Hooke's published text of August 1668 drew no connection between such projected schemes and the visionary event near Saumur, Oldenburg was explicit. To his correspondent Brereton, he wrote: "I have sent a copy of these Transactions to my correspondent at Paris, a true Hugenot, with a desire to render the first head of this Book [that is, Hooke's essay] French, and to send it to the place, where that appearance of our Savior was made, to undeceive, if possible, the poor people and to discover ye cheat of those clergymen, yt could father a lye upon Alm. God."[17] Henri Justel, a secretary to Louis XIV and Oldenburg's aforementioned Huguenot in Paris, thanked his correspondent for Hooke's disclosure.[18] "I shall profit from the information you give me," Justel wrote to London in late September 1668, "about the art of constructing painted apparitions [*lart de fair des apparitions peintes*]. It is a thing capable of being used to deceive the common people, and even some credulous gentlefolk. I do not doubt that some similar invention was employed in the miracle at Saumur."[19]

14. Ibid., 743, 742.
15. Ibid., 743.
16. Ibid., 742–43.
17. Oldenburg to Brereton, *Oldenburg Correspondence*, 60.
18. For more on Justel and his correspondence with Oldenburg, see David S. Lux and Harold J. Cook, "Closed Circles or Open Networks? Communicating at a Distance During the Scientific Revolution," *History of Science* 36 (1998): 179–211.
19. Henri Justel to Henry Oldenburg, September 29, 1668, *Oldenburg Correspondence*, 74. Justel's original text reads as follows: "Je profiterai de lavis que vous me donnez touchant lart de fair des

FIGURE 1. Paul Sandby, *Satire with Hogarth as a magic lantern projecting a parody of Paul before Felix,* etching, 1753. British Museum, 1904,0819.708. © Trustees of the British Museum.

Devices of trickery, cunning contrivances for priestly manipulation, revelatory instruments of disenchantment in the hands of enlightening savants: projected images appear in this visionary episode as laden with a tellingly weighty affect, epistemological investment, and even cosmological stakes.[20] As anticipated by Oldenburg and Justel, moreover, conversations about projecting images "by way of a picture" bled easily and persistently into "the art of constructing painted apparitions." Consider Paul Sandby's *Magic Lantern* (1753), a weird and brilliant satire of painter William Hogarth (fig. 1).[21] With a foot outstretched and his left hand clasping his stomach, Sandby's Hogarth reclines in an ink-darkened studio as he vomits forth a triangular wedge of light onto the wall. Projecting a distorted image of Hogarth's own *Paul before Felix* (painted 1748,

apparitions peintes. Cest une chose qui peut servir les peuples et mesmes quelque honnestes gens qui sont credules. Je ne doubte pas qu'on ne se soit servi d'une invention pareille pour faire le miracle de Saumur"; *Oldenburg Correspondence*, 72–73. More broadly, see Victor I. Stoichiță, *Visionary Experience in the Golden Age of Spanish Art* (London, 1995).

20. Expressive of this persisting affective investment have been responses to David Hockney, *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters* (New York, 2001). See "Optics, Instruments, and Painting, 1420–1720: Reflections on the Hockney-Falco Thesis," ed. S. Dupré, special issue, *Early Science and Medicine* 10 (2005): 125–339.

21. For Sandby's numerous satires of Hogarth, see David Bindman, *Hogarth and His Times: Serious Comedy* (Berkeley, Calif., 1997). On the political context of these satires, see Douglas Fordham, *British Art and the Seven Years' War: Allegiance and Autonomy* (Philadelphia, 2010), 56–64.

etched 1751), Sandby's vision gives pictorial credence to the contemporaneous accusation that his rival was congenitally defective in his external projects and internal projections alike. "The darling passion of Mr. *Hogarth*," John Wilkes would put it, "is to shew the *Faulty* and *Dark* side of every object. . . . The reason is plain. All objects are painted on his *retina* in a grotesque manner."[22]

The fact that this nexus of optical projection and its artistic consequences imagined by Wilkes and visualized by Sandby now appears so plausibly explicable is due in large part to Svetlana Alpers's *The Art of Describing* (1983)—a work that has greatly informed subsequent scholarship on the early Royal Society's visual culture and scientific visuality more broadly.[23] Taking as her point of departure the naturally occurring phenomenon whereby a single aperture into a darkened space can project an inverted, reversed image of the visual field over against it, Alpers imagines the camera obscura as a veritable shibboleth, distinguishing a Northern European pictorial tradition from that promoted by theorists of the Italian Renaissance. Although allowing that the device likely was used in the early modern period as a painter's aid, Alpers also insists upon a more fundamental role for the camera obscura than workshop practice.[24] By her view, Johannes Kepler's isolation of the agency of the retina in optical perception gave new epistemological value to the projected image: "The power of his strategy is that he deanthropomorphizes vision. He stands aside and speaks of the prior world picturing itself in light and color on the eye. It is a dead eye, and the model of vision, or of painting if you will, is a passive one."[25]

Though critical of her geographical distinctions, Jonathan Crary has more recently shared Alpers's conception of the camera obscura as model. From the late sixteenth century, Crary claims in *Techniques of the Observer* (1990), "the camera obscura is no longer one of many instruments or visual options but instead the compulsory site from which vision can be conceived or represented. Above all it indicates the appearance of a new model of subjectivity, the hegemony of a new subject-effect."[26] Tool for instrumental use and paradigm for thought, the camera obscura acts as model for Crary insofar as it historically gathers a network of socio-epistemic constructs, undergirding and exceeding practice.[27] In accord with Alpers, he writes: "Even if Vermeer

22. John Wilkes, *The North Briton* (September 25, 1762), in *The North Briton from No. I to No. XLVI inclusive* (London, 1769), 51–52.

23. For the influence of Alpers's work on studies of the Royal Society in particular, see Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, N.J., 1985); Ann Bermingham, *Learning to Draw: Studies in the Cultural History of a Polite and Useful Art* (New Haven, Conn., 2000), esp. 33–73; and Janice Neri, *The Insect and the Image: Visualizing Nature in Early Modern Europe, 1500–1700* (Minneapolis, 2011), esp. 105–38.

24. On this point, see Alpers's cagey correspondence with David Hockney on the role of optical devices in what she calls "the making of 'realistic' images"; Hockney, *Secret Knowledge*, 242.

25. Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago, 1983), 36.

26. Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge, Mass., 1990), 38.

27. For passages in which the camera obscura appears as a model for practical and theoretical use, see ibid., 29, 40, 86.

never touched the mechanical apparatus of the camera obscura … his paintings are nonetheless profoundly embedded in the larger epistemological model of the camera."[28] A recent historian puts the point still more concisely: "In the decades around 1600, the optical camera obscura became *the* model of the eye."[29] Whether of painterly aspiration, epistemological ordering, or optical anatomy, thinking about the camera obscura and its projected images in early modern scientific visuality has come to mean thinking about a model.

What exactly is entailed in thus conceptualizing the camera obscura as "model"? If, as the present essay collection and sympathetic research suggest, visualizations were not only expensive, time-consuming, and labor-intensive adornments to the philosophical texts of early Royal Society Fellows but also crucial tools in the making of knowledge itself, how might the modeling imagined around the camera obscura be seen to inflect our larger conceptions of experimental-philosophical visual practice?[30] As I argue in this essay, the lives lived by projected images in Robert Hooke's early Royal Society ambit offer a felicitous vantage point from which to explore and expand upon the model's recent allure. For, as indicated by the response of Oldenburg's correspondent Henri Justel upon learning of Hooke's contrivance, practical doing and speculative imagining abutted and adjoined repeatedly around projected images. Confronted with Hooke's disclosure of the means behind priestly manipulations, Justel wanted precise, technical details. Had the Curator really achieved this projective feat with convex lenses? "We think," he noted to Oldenburg, "this must be done by means of concave lenses, although it seems to me that the *Transactions* say that he uses convex lenses."[31] Following Hooke's evolving engagements with projected images from the early 1660s through the late 1690s, this essay aims, first, to consider the camera obscura's status as model in early Royal Society visual practice in light of this iterative traffic between intensely mechanical and more metaphorical uses. Second, I suggest how recent work in analytic philosophy of science might enable us to view operative conceptions of the modeling done around the camera obscura differently. In this way, the essay is concerned less with the multifarious practices of modeling undertaken in early Enlightenment England—a vital field for research though that is. Instead, as a prolegomenon to that historical project, it offers a recalibration of the conception of "model" formulated around the camera obscura and influentially generalized to the interpretation of scientific visuality. And, signaled by Sandby's Hogarth, I aim to show how a revised conception of modeling afforded by Hooke's projected-image experiments challenges us to reconsider visualization in the early Royal Society and its interfaces with artistic practice more broadly.

28. Ibid., 46.

29. Wolfgang Lefèvre, "The Optical Camera Obscura I: A Short Exposition," in *Inside the Camera Obscura: Optics and Art under the Spell of the Projected Image,* ed. Lefèvre (Berlin, 2007), 8.

30. For recent examples, see Meghan C. Doherty, "Discovering the 'True Form': Hooke's *Micrographia* and the Visual Vocabulary of Engraved Portraits," *Notes and Records of the Royal Society* 66 (2012): 211–34; and "History Comes to Life," ed. A. M. Roos, special issue, *Notes and Records of the Royal Society of London* 66 (2012): 313–409.

31. Justel to Oldenburg, *Oldenburg Correspondence*, 78.

A Projector's Chronicle

Surviving evidence suggests that Robert Hooke's practical involvement with projected images was less a matter of sustained, systematic inquiry than of periodic, intensely focused episodes.[32] Hooke could draw from the seminal texts of Giambattista della Porta and Athanasius Kircher; the artificial eyes, anamorphic paintings, and other mechanical wizardry of Christopher Wren; and the Baroque theatrical scenography then recently introduced into London's restored playhouses. His early, documented work with the camera obscura coincides with the production of his own optical wonder, *Micrographia* (1665).[33] On October 12, 1663, Hooke was encouraged by the Royal Society "to try the casting of a picture on a wall in a light room; and to bespeak a concave glass for it."[34] Six months later, as John Wilkins "contrived optical pictures, and devised how to cast a picture upon a wall in a light room" in anticipation of Charles II's planned visit to the institution, Hooke was instructed to develop "his picture on a wall in a light room."[35] Since Oldenburg described the Curator's contrivance of optical projection in 1668 as having been demonstrated "some years since," we might surmise that it too dated to that period of research activity in 1663 and 1664.[36] While it is tempting to imagine that some projection technique may have assisted in the production of *Micrographia*'s stunning images, the material evidence of the few surviving drawings from that project actually militates against such an inference.[37]

Slightly better documented are Hooke's activities from the spring and summer of 1670, which mark a second period of work with optical projections. Perhaps inspired by the purpose-built, telescoping, "portable darkned Roome" described by Robert Boyle

32. What I propose here is a symptomatic, if not necessarily exhaustive account, of Hooke's engagements with projected-image techniques. A fuller account might well draw into conversation his cartographic and surveying interests, for example; see E. G. R. Taylor, "Robert Hooke and the Cartographical Projects of the Late Seventeenth Century (1666–1696)," *The Geographical Journal* 90 (1937): 529–40; and M. A. R. Cooper, "Robert Hooke (1635–1703): Proto-Photogrammetrist," *Photogrammetric Record* 15, no. 87 (April 1996): 403–17.

33. For a comprehensive survey of spectacular early modern projection techniques, see Laurent Mannoni, *The Great Art of Light and Shadow: Archaeology of the Cinema*, trans. R. Crangle (Exeter, U.K., 2000). For Wren's plans for "an artificial Eye . . . truly and dioptrically made (which I would have at least as big as a Tennis-ball) [that] . . . would represent the Picture as Nature makes it," see Christopher Wren Jr., *Parentalia, or, Memoirs of the Family of the Wrens* (London, 1750), 226. For an account of Wren's lost anamorphoses, see Nehemiah Grew, *Musaeum Regalis Societatis: or A Catalogue and Description of the Natural and Artificial Rarities Belonging to the Royal Society and Preserved at Gresham College* (London, 1681), 375–76. On Restoration theatrical devices, see Edward A. Longhams, "The Theatre," in *The Cambridge Companion to English Restoration Theatre*, ed. D. P. Fiske (Cambridge, 2000), 19–39. Hooke's interest in the camera obscura has recently been noted in Doherty, "Discovering the 'True Form,'" esp. 217.

34. Thomas Birch, *The History of the Royal Society of London for Improving of Natural Knowledge*, 4 vols. (London, 1756–57), 1:313.

35. Ibid., 1:391, 397.

36. [Hooke], "Contrivance," 743.

37. On this point, see Matthew C. Hunter, *Wicked Intelligence: Visual Art and the Science of Experiment in Restoration London* (Chicago, 2013), 49–50, 236n80. For a different view of these techniques, see Thomas Ketelson et al., "New Information on Jan van Eyck's Portrait Drawing in Dresden," *Burlington Magazine* 147, no. 1224 (March 2005): 170–75.

in *Of the Systematical and Cosmical Qualities of Things* (1670), which could project "such a lively representation; not only of the Motions, but shapes and Colours of outward Objects," Hooke can be seen in the Society's minutes using projections expressly for the purpose of painting.[38] In the minutes for May 26, 1670, we read:

> Mr. Hooke produced an optical experiment, whereby the representation of objects in a dark room furnished with a lens is made applicable to painting, so as to exhibit and draw in colors the face of a man or any other object as big as the life. It was ordered, that against the next meeting something should be designed, and, if it could be, painted, by the means of this instrument. It was suggested, that whereas the pictures represented in the darkened box are inverted, they might be reverted by the reflexion of a flat piece of metal; though others were of opinion, that this would alter the colours of the objects represented.[39]

Hooke's demonstration was repeated the following week (June 2, 1670), when it was queried "whether any false line were drawn this way, the painter could correct it."[40] To resolve this question, Hooke was again asked to create a painting with the instrument at the following meeting.

Despite the dearth of extant instruments that plagues inquiries into seventeenth-century camera obscura research generally, Hooke's trials of 1670 pledge an intensely practical range of concerns.[41] Beyond exploring the means for rectifying inverted images and overcoming chromatic distortions, Hooke was repeatedly challenged by the Fellows to improve the technique's functionality. On June 9, 1670, it was noted: "The dark box for painting all sorts of objects was produced again with some improvements, which were chiefly two, viz. The changing it into a convenient posture for drawing, and the representing the figures direct."[42] Acknowledging that his technique for reflecting projected images by a mirror to overcome inversions and reversals did compromise "much of the brightness of the picture," Hooke proposed that the approach could be improved with "a metalline plate well polished" in place of the mirror.[43] According to Royal Society Fellow and gentleman-artist John Evelyn, though, Hooke's results were already impressive. As he noted in his diary: "There was this day producd in the R: Society, an invention by intromitting the Species into a dark large box, to take the profile of ones face as big as the life; which it did perform very accurately."[44] In the absence of physical evidence, Evelyn's comments are particularly interesting. If Hooke's projected images of human faces truly were "as big as the life," then his

38. Robert Boyle, *Of the Systematical and Cosmical Qualities of Things* [1670], in *The Works of Robert Boyle*, vol. 6, *Publications of 1668–71*, ed. M. Hunter and E. B. Davis (London, 1999), 294–95.

39. Birch, *History of the Royal Society*, 2:436.

40. Ibid., 2:439.

41. On this point, see Lefèvre, "The Optical Camera Obscura I," 8.

42. Birch, *History of the Royal Society*, 2:440.

43. Ibid.

44. *Diary of John Evelyn*, ed. E. S. De Beer, 6 vols. (Oxford, 2000), 3:549.

demonstration camera must have been of substantial size. Indeed, accommodating this instrument to practical application was a concern voiced at the Society meeting on July 7, 1670: "Mr. Hooke produced again his darkened box improved, so that it was now proper for the hand to draw a picture conveniently, by a metalline speculum and a moveable bottom, whereby the picture that appeared both erect and direct."[45] By the end of this second period of activity in the summer of 1670, then, Hooke would seem to have addressed the concerns typically leveled against claims for the instrument's use in the early modern period. He had contrived a metal mirror that could counter the inversion and reversal of the camera obscura's projected images, while making the device practical for drawing pictures (especially portraits) "conveniently."[46]

In the years after Hooke's death in 1703, his friend and editor Richard Waller cast the Curator's 1670 procedures in nearly mythic terms. Whereas Filippo Brunelleschi had founded Florentine perspectival painting by fusing upon a single panel a depiction of urban space seen by a lone, static eye and the mobile, effervescing arch of skies reflected onto his painted panel by "silver well burnished so that . . . even the clouds could be seen in this silver, moved by the wind as it blew," Hooke is described as effectively splitting those worlds apart into discrete representational regimes.[47] Recounting Hooke's trials of the summer of 1670, Waller tells us that the Curator "showed an Experiment with a Solution of Copper to represent the appearance of Clouds and other aerial Meteors, by dropping into it several Salts, &c. and at the same time shew'd the use of introducing the Species into a dark Room for Painting, and contriv'd a Box for that purpose."[48] Seen during the early 1670s, however, Hooke's image-projecting practices were less epochal interventions than they were serviceable means for practical graphic concerns shared among the Curator's close associates. In 1672, John Hoskyns advised Hooke's impoverished friend and biographer John Aubrey not to pursue a position on a plantation in the American colonies, but instead to write a natural history of Britain. Hoskyns adjured Aubrey: "Prevail with Mr. Surveyor [that is, Christopher Wren] to tell the most exemplary ways of taking inaccessible distances and landskips (e.g. Mr. Hooke's reflecting box)."[49] At a favorite coffee house near the Royal Exchange in early 1675, Hooke noted that "Ramsey told T. Flaxman of my picture box."[50] Two days after Christmas in 1675, Hooke met with Peter Lely, the painter to

45. Birch, *History of the Royal Society,* 2:442.

46. For a defense of period artists' ability to resolve such concerns, see Philip Steadman, "Allegory, Realism, and Vermeer's Use of the Camera Obscura," *Early Science and Medicine* 10 (2005): 287–313.

47. Antonio Manetti, *Vita di Filippo Brunelleschi* [ca. 1480], ed. D. de Robertis (Milan, 1976), 58. For the broader literature on Brunelleschi's panel, compare Martin Kemp, "Science, Non-Science and Nonsense: The Interpretation of Brunelleschi's Perspective," *Art History* 1 (June 1978): 134–61; Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven, Conn., 1990), 9–21, 344–45; and Hubert Damisch, *A Theory of /Cloud/: Toward a History of Painting*, trans. J. Lloyd (Stanford, Calif., 2002).

48. Richard Waller, "The Life of Dr. Robert Hooke," in *The Posthumous Works of Robert Hooke*, ed. Waller (London, 1705), xiv.

49. John Hoskyns to John Aubrey, August 21, 1672, Bodleian Library, MS Aubrey 12:204.

50. *The Diary of Robert Hooke, 1672–1680*, ed. H. W. Robinson and W. Adams (London, 1935), 150.

whom he had been apprenticed upon his arrival to London from the Isle of Wight. The two men discoursed about "helping the sight and of the picture box."[51] Thus, by the mid-1670s, Hooke's projection of images was not only recognized among his friends as a useful technique but also known as an incarnated, material object. Once procedural "trials" and then a situated "contrivance," Hooke's projections had come to be identified with the physical form of the box.

In the early 1680s, that material object was replicating and morphing anew. When analyzing the physiological structure of the visual organs in his *Lectures of Light* in 1681, Hooke refers the reader to a diagrammatic "Scheme" of the eye seen in horizontal cross section as he patiently walks through a recitation of the organ's intricately nested coats, humors, nerves, and nets (fig. 2). Claiming to have fabricated "a large artificial Eye . . . with Glass, Water, and Jelly, figured according to the shapes represented in the Scheme" (see his Fig. 6), Hooke juxtaposes the difficulty of repeating that ingenious act with the necessity of physical demonstration "for a thorough Knowledge of Opticks."[52] Therefore, he encourages his reader to fashion "a darkned Room, or Perspective Box" set to the specifications of a second, accompanying diagram (his Fig. 7).[53] Articulating the most detailed account of his image-projecting devices we have, Hooke directs the reader to create a box in the conical form of his schematic figure. It should be "four or five foot long from A to DE" and capable of telescoping to still further length once the moveable inset B C is extended. Inside the box, Hooke prescribes an intricate space of projective media, which are to serve expressly representational function:

> At A place a Convex Glass of the length of the Box in a Hole as large as the Glass, which the larger it is the better, because of several Tryals that may be made with it, which cannot be made with a smaller. To this Hole cut several, as eight or ten Pieces of Past-board that may each of them serve to cover it, and in every of them cut a Hole of a Round, or other Figure you would use, and either in the middle of it, or out of the middle of it, and of a greater or less Figure, according to the Tryals you design by them; let the inside of the Concave bottom be made very White, to receive and reflect the Points of Light, and make a Hole in the side of the Box *H*, covered about with Leather, or thick Wollen Cloth, with a Hole large enough to put one's Face into it, so as to see the Species or Picture of outward Objects upon the bottom, then turning the end A where the Glass is placed toward the Object (if the Sun shine upon it, it is the better because of the great Reflection of Light from such Objects,) slide the moveable bottom B C, to or fro, 'til by looking in at the Hole H, you perceive the Representation of the outward Objects very perfect, then take notice of the distance of the Object, and likewise the distance of the bottom; the Position, Magnitude, Brightness, Colour, and all the other

51. Ibid., 204.
52. Robert Hooke, "Sect. V," *Lectures of Light*, in *Posthumous Works*, 127.
53. Ibid.

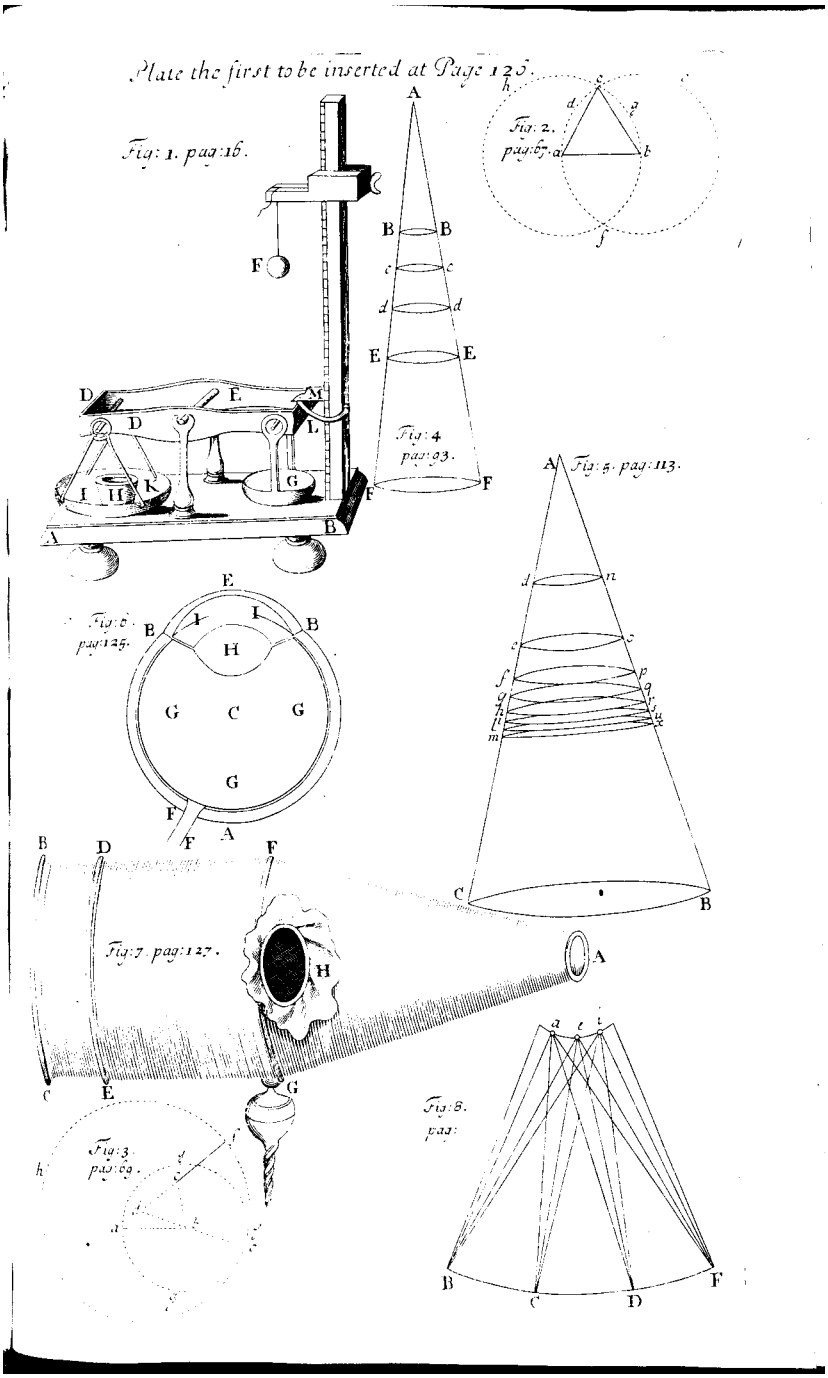

FIGURE 2. Anonymous engraving representing a cross section of a human eye (Fig. 6) and Robert Hooke's design for a camera obscura (Fig. 7) from *The Posthumous Works of Robert Hooke*, ed. R. Waller (London, 1705), plate 1 (at p. 126). Huntington Library, 29130.

> Remarks that appertain to the explaining the several Appearances that may happen to the Eye, then fit it for representing Objects at a greater distance, and take notice of the distance of the bottom, and all the other Remarks necessary for explaining your Inquiry.[54]

In contrast to the like-for-like artificial organ he claimed to have fashioned, wherein the eye's gelatinous crystalline humor was recreated with jelly, Hooke prescribes a simplified representation here. Made from the humble materials of wood, wool, pasteboard, and glass, the perspective box is redeployed as a pedagogical instrument for demonstrating the role of the pupil's dilation in producing optical focus. Noting how various combinations of cut pasteboard could be inserted into the focal plane "to explain all that might happen to the Eye, by the contracting and dilating the Pupil . . . and so for all other Questions that may happen concerning what light is in the Eye, and what Effects it there produces," Hooke equally scales up the size of his projections significantly from the one-to-one correspondence achieved in his trials from 1670.[55] Through cloth-covered aperture H, the device now allows the user the experience of, as it were, inserting her head inside her own eye.

Hooke's do-it-yourself pedagogical instrument appears to have been more than a conjectural thought experiment. On the back flyleaf of his personal copy of Waller's *Posthumous Works of Robert Hooke* (1705) now in the British Library, John Evelyn scrawled a barely legible inscription that reads: "Description of the Dark Chamber, to introduce [intromit?] the Species, wch is in my Library at Wotton [?] p. 127."[56] Does this note refer to a material replica that Evelyn had fashioned by following Hooke's instructions? Had Evelyn perhaps acquired an object made or commissioned by Hooke himself? Although we have frustratingly little evidence on these matters, Hooke's writings from a final period of projected-image research in the 1690s indicate a continuing insistence on the practical application of his process-cum-object-cum-representation. In a noted lecture from December 1694, Hooke reminded his colleagues of the use of "a small Picture-Box, much like that which I long since shewed the *Society*" as an aid to mariners, travelers, and anyone else in need of graphic assistance.[57] Though a fascinating meditation on the waywardness of prints and their capacity to delude the experimental imagination, Hooke's brief essay is light on details concerning his projective apparatus. The little we can infer of its design derives from an anonymously produced woodcut published by editor William Derham more than twenty years after Hooke's

54. Ibid., 127–28.

55. Ibid., 128. For an interesting account of Hooke's approaches to scale, see Paul Emmons, "Size Matters: Virtual Scale and Bodily Imagination in Architectural Drawing," *Architectural Research Quarterly* 9 (2005): 227–35.

56. British Library, EVE.B.48, back flyleaf. As E. S. De Beer notes, the Evelyn family had a home at Wotton that John Evelyn took over following the death of his brother George in 1699; *Diary of John Evelyn*, 1:35–36.

57. Robert Hooke, "An Instrument of Use to take the Draught or Picture of any Thing," in *Philosophical Experiments and Observations of the Late Eminent Dr. Robert Hooke*, ed. W. Derham (London, 1726), 292.

FIGURE 3. Anonymous woodcut depicting Robert Hooke's design for a portable camera obscura from *Philosophical Experiments and Observations of the Late Eminent Dr. Robert Hooke*, ed. W. Derham (London, 1726), 295. © The Royal Society.

death, and reconcilable with no surviving plans by the Curator (fig. 3). Derham's figure flanks the right-hand edge of the print, the curvaceous hatchings of his pantaloons and waistcoat accentuating his slight contrapposto stance. Scaled at roughly three quarters of the figure's height and thus approximating the five-foot length Hooke had prescribed in his 1681 lecture, the camera obscura spans the upper vertical plane of the print as it tracks a target of investigation invisible to the beholder. What is perceptible through the pictorial intervention of a cut-away view is the action of the draftsman. Head and shoulders encapsulated within this jutting device, the draftsman appears to trace the boundaries of a sight as projected onto a white, paper support sealed off in inky darkness from the surrounding seaside landscape.

If his 1694 text indicates what Alpers has called "Hooke's interest in right seeing and its record," the darkened isolation from an environing world in which Derham's figure places this draftsman could perhaps also signal the alienated subjectivity described by Crary.[58] Lecturing on the camera obscura in July 1697, though, Hooke had

58. Alpers, *Art of Describing*, 73.

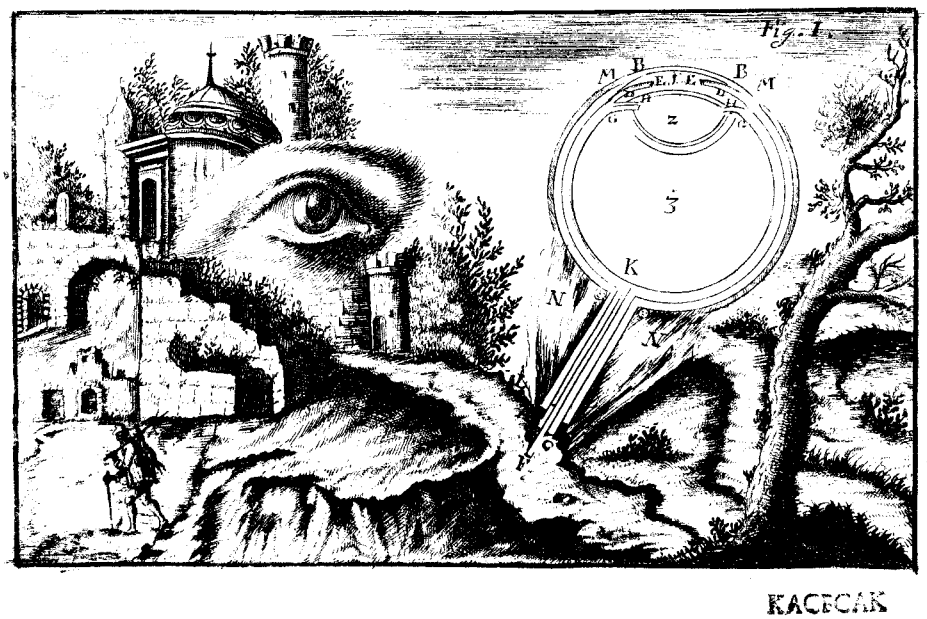

FIGURE 4. Anonymous etching and engraving of optical principles from Johannes Zahn, *Oculus artificialis teledioptricus sive telescopium* (Herbipoli [Würzburg], 1685), 16. Huntington Library, 487000.

different worries in mind. Plausibly claiming to have demonstrated the pictorial application of the camera obscura "about 30 years since," he goes on to assert more fanciful rights of priority. His had been, he attests, "an improvement of the Experiment of the Dark room to a use which noe one writer of opticks had before that hinted or mentioned that I could find though some years after that it was described by Zane in his Oculus Artificialis and diverse others since time" (figs. 4 and 5).[59] A canon of the Premonstratensian order, Johannes Zahn had indeed visualized numerous optical devices in his *Oculus artificialis teledioptricus* (1685). In strange etched and engraved plates, Zahn's images embed schematic diagrams into picturesque vignettes of a kind visible in Florentius Schuyl's influential edition of Descartes's *Traité de l'homme* (1664).[60] Although Hooke does not make the point explicitly, it is as if his 1697 lecture is designed to intervene into those inscrutable plates, insisting as it does on the agency of the camera obscura for assisting and correcting errors endemic to print production. Useful to anyone keen to magnify an object "to a great degree ~~and~~ <as> a fly for instance may be made to appear as big as an Oestridge or Cassaware," Hooke particularly

59. Royal Society, Robert Hooke, Classified Papers XX: 89, fol. 207.

60. For a stimulating reading of Schuyl's Descartes and its images, see Claus Zittel, "Conflicting Pictures: Illustrating Descartes' *Traité de l'homme*," in *Silent Messengers: The Circulation of Material Objects of Knowledge in the Early Modern Low Countries*, ed. S. Dupré and C. H. Lüthy (Berlin, 2011), 217–60.

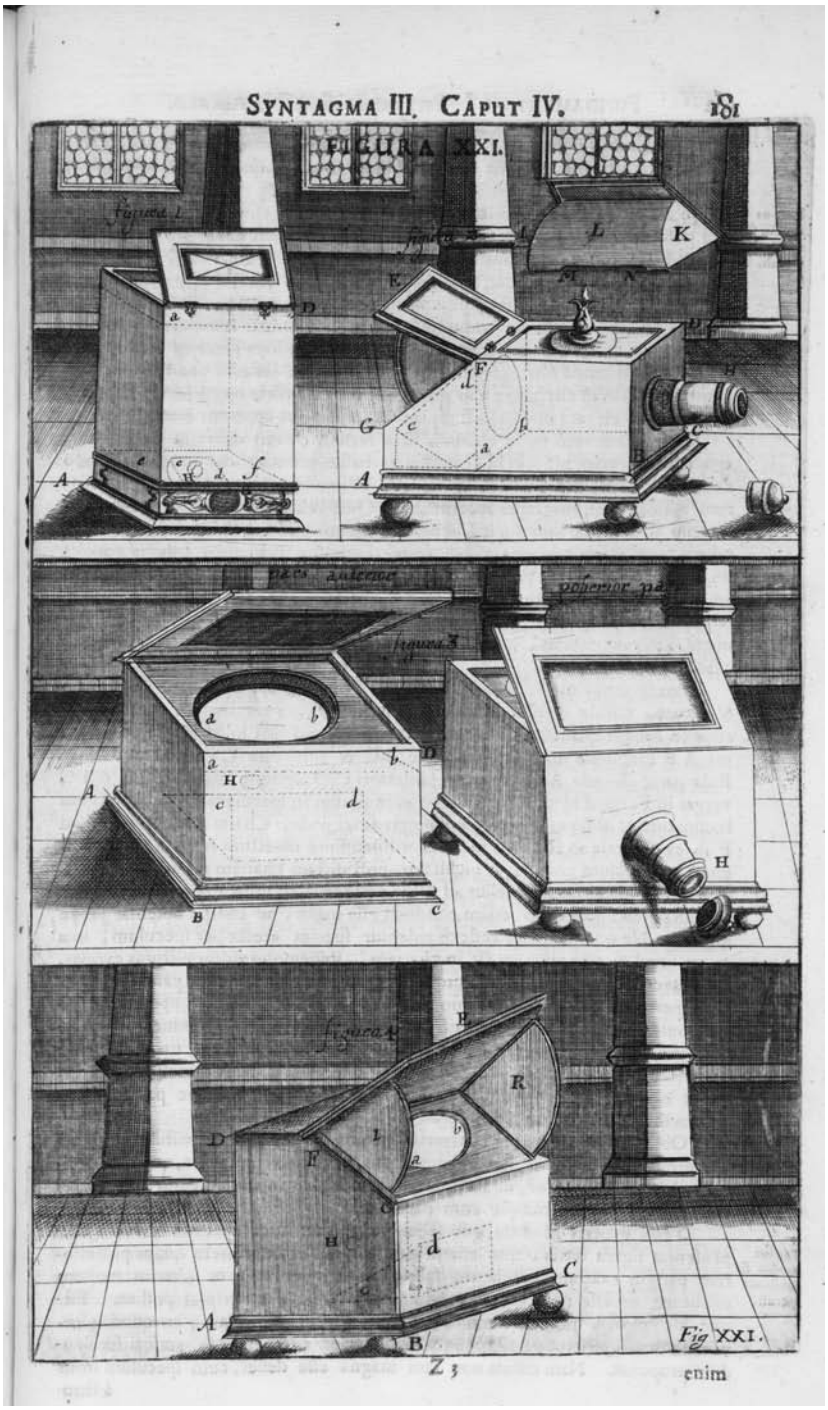

FIGURE 5. Anonymous etching and engraving of projection instruments from Zahn, *Oculus artificialis teledioptricus sive telescopium*, 181. Huntington Library, 487000.

recommends those images projected by the camera obscura to "an etcher graver or one that is to Doe a picture in Mezzotino."[61] He expands on the point in this way:

> The picture that is projected upon the white fund or bottom of the box and soe appears by Reflection <will give not only magnified by the Object as it is desired but> the True Representation of the Object as it is to be graved or etched <or scratched or burnishd> on the Plate by the artist, which be according Done all the parts of the objects will <not only> be truly Represented and figured <of their due magnitude I say> but they will be also properly situated in the prints that shall be taken or wrote off from such a plate, that is the Right side will appear to be the right and the Left the Left.[62]

In these last known writings on the camera obscura, projected images are less crucially located in that graspable object known as "Mr. Hooke's reflecting box" or figured as components in a demonstration representing the structure of the eye. Instead, they are instruments, tools used in an exceptionally early attempt to rectify print's left–right reversals.[63]

Process, object, representative demonstration, and tool: the camera obscura and its projected images move through three decades of Hooke's thinking, we might say, in the manner of what early modern English speakers called "a maggot." As novelist John Fowles reminds us, a maggot could designate "a whim or a quirk. By extension it was sometimes used in the late seventeenth and early eighteenth century of dance-tunes and airs that otherwise had no special title . . . Mr Beveridge's Maggot, My Lord Byron's Maggot, The Carpenter's Maggot, and so on."[64] As with Hooke's recurrent appeals to the projected image, maggots like these were held together by the very desire that drove their repetition and variation. They were propelled, in Fowles's words, by an "obsession with a theme."[65]

Model, Remodeled

There is a different way to explain this evolving, instrumental figure that persistently impinges upon the thought of Hooke and his contemporaries, however. Writing in the early twentieth century, the physicist and theorist Pierre Duhem saw the force of such mechanical devices in the writings of English scientists as disclosing the telling structure of an enduring national *mentalité*. Astonishing to a French reader of English science, Duhem claimed, is "that element, which nearly invariably accompanies

61. Hooke, Classified Papers, XX: 89, fol. 207.

62. Ibid.

63. I thank Peter Parshall for noting this to me. More broadly, see David Landau and Peter Parshall, *The Renaissance Print, 1470–1550* (New Haven, Conn., and London, 1996).

64. John Fowles, *A Maggot* (London, 1985), 5.

65. Ibid.

the exposition of a theory, . . . the model [*le modèle*]."[66] Whereas French and German national schools privileged the rigorous, mathematical clarity yearned for by "espirits abstraits," the ample, weak English mind ("l'espirit ample et faible") imagined generalities only through the quiddity, the material particularity that models abundantly provide.[67] Duhem frames that charge and its distracting environs in the following manner:

> The employment of . . . mechanical models [modèles mécaniques], recalling by certain more or less rough analogies the particular features of the theory being expounded, is a regular feature of the English treatises on physics. Here is a book intended to expound the modern theories of electricity and to expound a new theory. In it there are nothing but strings which move around pulleys, which roll around drums, which go through pearl beads, which carry weights; and tubes which pump water while others swell and contract; toothed wheels which are geared to one another and engage hooks. We thought we were entering the tranquil and neatly ordered abode of reason, but we find ourselves in a factory.[68]

Dangerously mechanical and tyrannically industrial, models for Duhem are material analogies that stand in marked opposition to the theoretical abstraction he sees as essential to the doing of science.[69]

This pejorative opposition of model to theory persists, of course.[70] But a robust, recent conversation on modeling in the analytic philosophy of science offers much to historical studies of visualization and to humanistic interpretation more broadly. Since that work remains little known outside of analytic circles, I offer a brief summary of three points that can be particularly salient when trying to understand what it might mean to call the camera obscura a "model" as wielded by visual practitioners in the early Royal Society. Admittedly generalizing what is a new, controversial conversation, I stress here how modeling appears in this literature as partial, procedural, and semiautonomous. First, while often used to do representational work, models are frequently pragmatically selective and, consequently, plentiful. Since the buzzing, blooming worlds explored by scientific investigators are variously too big, distant, or complicated to study directly, this literature stresses, researchers construct models that idealize, abstract, or otherwise stylize features of interest, while omitting other key aspects of targeted phenomenon entirely from the model. "The liquid drop model is

66. Pierre Duhem, *The Aim and Structure of Physical Theory*, trans. Philip P. Wiener (Princeton, N.J., 1954), 69. For the French, see Duhem, *La théorie physique: Son objet et sa structure* (Paris, 1906), 108–9.

67. Duhem, *Théorie*, 87, 100.

68. Duhem, *Aim and Structure*, 70–71; *Théorie*, 111.

69. For a scintillating reading of Duhem's work as a tool for interpreting scientific visualization, see Josh Ellenbogen, *Reasoned and Unreasoned Images: The Photography of Bertillon, Galton, and Marey* (University Park, Pa., 2012), esp. 55–73.

70. For but one recent example, see Emanuel Derman, *Models Behaving Badly: Why Confusing Illusion with Reality Can Lead to Disaster, on Wall Street and in Life* (New York, 2011).

useful for the production of nuclear fission," Mary S. Morgan and Margaret Morrison note of nuclear physics, "while the optical model serves as the basis for high energy scattering experiments."[71] Distinct and incompatible, these nucleus models each "fail to incorporate significant features of the nucleus . . . they nevertheless are able to map onto technologies in a way that makes them successful, independent sources of knowledge."[72] Yet, rather than providing demonstrative evidence of models' cognitive waywardness as it had for Duhem, this distance from theory and observational data alike is seen as offering epistemic advantage through its provisional flexibility. Philosopher Peter Godfrey-Smith nicely captures this sense: "A variety of people can use the same model while interpreting it differently. One person might use the model as a predictive device, something that gives an output, without caring how the inner workings of the model relate to the real world. . . . Another person might treat the model as representing *some* features, but only a few, of what is going on in the real system."[73] Just as an entity or phenomenon can be modeled in many ways, so the same model may be variously construed according to researchers' discrete concerns or circumstances.

A second insight follows quickly from this usage. Reducible neither to theory nor to observation and deployed to study targeted components or no target at all, models are often highly stylized, indirect representational enterprises. This point has productively been highlighted by recent studies that have built upon Nelson Goodman's devastating critique of imitation theories of representation to stress instead models' conventionalized, denotative core.[74] The key claim, then, exceeds the Goodmanian insight that "virtually anything can be stipulated to be a representational vehicle for the representation of virtually anything," as Craig Callender and Jonathan Cohen have put it in a deflationary mood.[75] Instead, these studies stress how the kinds of representation practiced by modelers are complex, often multistage processes. Whereas older work by Ronald Giere detailed just how much distance stands between the pendulum in a grandfather clock and the axiomatic laws of motion in a physics textbook, Michael Weisberg has emphasized that scientists frequently stipulate a textual or mathematical "model description" as a way to direct work done with a model, possibly in physical manifestation.[76] "Take a very clear long cylindrical glass," so Robert Hooke instructs the reader of his *Cometa* (1678) along these lines: "Fill it three

71. Margaret Morrison and Mary S. Morgan, "Models as Mediating Instruments," in *Models as Mediators: Perspectives on Natural and Social Sciences*, ed. Morrison and Morgan (New York, 1999), 23.

72. Ibid., 23–24. For an expanded meditation on this problem of inconsistency, see Margaret Morrison, "One Phenomenon, Many Models: Inconsistency and Complementarity," *Studies in the History and Philosophy of Science* 42 (2011): 342–51.

73. Peter Godfrey-Smith, *Theory and Reality: An Introduction to the Philosophy of Science* (Chicago, 2003), 188.

74. See, for example, R. I. G. Hughes, "Models and Representation," *Philosophy of Science* 64, Supplement (December 1997): S325–S336. For Goodman's arguments, see Nelson Goodman, *Languages of Art: An Approach to a Theory of Symbols* (New York, 1968), 3–43.

75. Craig Callender and Jonathan Cohen, "There Is No Special Problem about Scientific Representation," *Theoria* 21, no. 1 (2006): 67–85 at 74.

76. Ronald Giere, *Explaining Science: A Cognitive Approach* (Chicago, 1990), 62–90; Michael Weisberg, "Who Is a Modeler?," *British Journal for the Philosophy of Science* 58 (2007): 207–33 at 217.

quarters full with water, and put into it a quarter of a pound of Oyl of Vitriol [sulfuric acid], and in the midst of this suspend by a small silver wire, a small wax-ball, rolled in filings of iron or steel."[77] Not simply a recipe for experimental procedure, these utterances might better be seen to constitute a model description. They stipulate the means for fabricating what Hooke calls "a perfect representation of the Head, Halo, and Tail of the Comet."[78]

Model description then becomes a material model with its own internal dynamic. This temporally evolving "comet"—made visible once the iron filings embedded into that wax ball begin to yield a gravitationally bound trail of hydrogen gas bubbles moveable through its bath of diluted sulfuric acid—departs in important ways from Hooke's model description. Similarly, the chemical model itself betrays fundamental differences from both the elegant comet theory it nominally visualizes *and* the celestial observations on which it was based.[79] This traffic between text, model, and world commensurately opens a broader view. Because model descriptions ask us to stylize and then explore a trial scenario to generate insights that may or may not ultimately correspond to real-world phenomena, several philosophers have begun to investigate relations between modeling and fiction.[80] "When modeling the solar system as consisting of ten perfectly spherical spinning tops," Roman Frigg claims, "physicists describe (and *take themselves* to be describing) an imaginary physical system. . . . These are scenarios we can talk about and make claims about, yet they don't exist."[81] Consequently, Frigg argues for an approach that foregrounds the fictional allowances required for scientists to make and move among models: "The view of model systems that I advocate regards them as imagined physical systems, i.e. as hypothetical entities that, as a matter of fact, do not exist spatio-temporally but are nevertheless not purely mathematical or structural in that they would be physical things if they were real."[82] Even more importantly for the present considerations, each stage of this modeling process—from the model description to its material incarnations and the mathematical formalisms possibly applied to it, along with various combinations of these parts—may be referred to as "the model."[83] Unlike older views that posited modeling as fundamentally analogical or governed by criteria of resemblance, this recent literature thus stresses the cognitive utility and practical necessity of models

77. Robert Hooke, *Cometa*, in *Lectures and Collections* (London, 1678), 31.

78. Ibid.

79. For a provisional analysis of this model, see Matthew Hunter, "Experiment, Theory, Representation: Robert Hooke's Material Models," in *Beyond Mimesis and Convention: Representation in Art and Science*, ed. R. Frigg and Hunter (New York, 2010), 193–219.

80. See, for example, *Fictions in Science: Philosophical Essays on Modeling and Idealization*, ed. M. Suárez (New York, 2009); Adam Toon, *Models as Make-Believe: Imagination, Fiction, and Scientific Representation* (New York, 2013); and Marion Vorms, "Representing with Imaginary Models: Formats Matter," *Studies in History and Philosophy of Science* 42 (2011): 287–95.

81. Roman Frigg, "Fiction and Scientific Representation," in *Beyond Mimesis and Convention*, ed. Frigg and Hunter, 101.

82. Roman Frigg, "Models and Fiction," *Synthese* 172 (2010): 253.

83. Frigg, "Fiction and Scientific Representation," 121–22.

that represent indirectly, through multistage processes, and by means of substantial fictional intervention.[84]

Fabricated often physically, invested with imagined properties, and combined into internally inconsistent aggregates, models make for messy business. "The successes of models," as Margaret Morrison has noted, "are directly connected with highly questionable, sometimes explicitly false, assumptions. . . . We are left with little reason to give credence to any particular model or group of models."[85] Nonetheless, models offer epistemic interest insofar as they still appear able to teach users more than was previously—or could otherwise be—known. Allotted degrees of "autonomy" and "independence," models are often described in this literature as possessing "a life of their own."[86] "Model systems are interesting," Frigg writes, "exactly because more is true of them than what the initial description specifies; no one would spend time studying models if all there was to know about them was the explicit content of the initial description."[87] Tarja Knuuttila and Atro Voutilainen put the point more succinctly: "A model has an existence of its own. For this reason we cannot be totally in charge of it, however purposefully fabricated it may be."[88] If verging here upon the false consciousness that Hooke had feared would be readily engendered by priestly optical projections, the salient features of this recent philosophical literature for expanding the conception of camera obscura as "model" advanced by Alpers, Crary, and others can now be stated succinctly. Just as Godfrey-Smith's scientific researchers treat the same model in vastly different ways, so the camera obscura appears in Hooke's investigations in evolving guises, variously weighted in their material and theoretical implications. A procedure shown to the Royal Society in the early 1660s, optical projection was recruited in 1668 to explain supernatural occurrences at Saumur. Incarnated as a proprietary object in the early 1670s ("Mr. Hooke's reflecting box"), it was redeployed as an explanatory demonstration of the eye's physiological mechanisms for producing optical focus when so stipulated and redesigned by Hooke in 1681, before returning to instrumental service in the 1690s for the replication of graphic images.

Like the physical objects imaginatively enhanced to become models analyzed by Giere, Weisberg, and Frigg, moreover, the camera obscura performs representational work once certain imaginative allowances are made by the user confronting its textual, haptic, or theoretical expressions. Explicitly simplifying even from the intricate, artificial organ he claimed to have made, Hooke's camera obscura became a salient representation of the eye in 1681 once the reader entered into the game of make-believe stipulated by his model description. Selecting from among various, competing

84. For a classic account of modeling that stresses analogy, see Mary B. Hesse, *Models and Analogies in Science* (Notre Dame, Ind., 1966).

85. Morrison, "One Phenomenon," 351.

86. See Morrison and Morgan, "Models," 18.

87. Frigg, "Models and Fiction," 258.

88. Tarja Knuuttila and Atro Voutilainen, "A Parser as an Epistemic Artifact: A Material View on Models," *Philosophy of Science* 70 (2003): 1489.

conceptions of the eye that he knew well, Hooke articulated how wood, wool, pasteboard, leather, and glass can model specified features of ophthalmic structure relating to optical focus.[89] Other aspects of potential philosophical interest relating to eyes are omitted entirely.[90] Abstracted and idealized though it is, such simplification does not signal unremitting cognitive loss. Indeed, thanks to its radically enhanced scale, Hooke's five-foot-long, telescoping eye model allows the user to explore (in fact, inhabit) optical space in simulation, studying the focal effects of moveable, ophthalmic components in ways that could never be accomplished with real eyes. More than a singular, organizing topos as it appears in influential readings of scientific visuality, then, the camera obscura as model in this sense enables us to grasp the ways in which projected images' features were variously researched, materialized, mobilized into representational conception, and then returned back as instruments to the hurly-burly of experimental visual practice. The camera obscura is a model not so much because it presents a unifying paradigm of painterly aspiration or a concatenation of epistemic virtues, but through its cloven flexibility—its capacity to sustain and reward materialized speculation, mechanized theory, and the interface between them. And taking up a lead from Svetlana Alpers, I want to conclude by suggesting how Joshua Reynolds might also be seen as a modeler of the camera obscura in this sense.

Projecting, Modeling, Drawing

In *The Art of Describing*, Alpers opens with a sequence of quotations from Joshua Reynolds (1723–1792), first president of Britain's Royal Academy of Arts and leading theorist of "grand manner" aesthetics. The works of Jan van der Heyden possess, Alpers quotes, "'very much the effect of nature, seen in a camera obscura.'"[91] So Reynolds had written when traveling through the Netherlands in the early 1780s. Beyond presenting this hostile witness testimony, Alpers cites Reynolds's "knowledge of the techniques used and effects created by the Italian *vedusti*" as effectively initiating a tradition linking Dutch art to images made in cameras, whether photographic or otherwise.[92] "If we suppose a view of nature represented with all the truth of the *camera obscura*, and the same scene represented by a great Artist," the painter would put it in his thirteenth *Discourse*, "how little and mean will the one appear in comparison with the other."[93] The

89. For example, Hooke might have explored the muscular movement of the eyes or the musical/harmonic account of vision contemporaneously being advanced by William Briggs that Hooke himself would publish as [William] Briggs, "A New Theory of Vision," *Philosophical Collections* 6 (1682): 167–78. I thank Richard Spiegel for sharing his essay "Sound and Vision: Visuality and the Role of Acoustics in the Birth of Modern Ophthalmology" with me.

90. Hooke's model does not address the transmission of sensorial information through the optical nerve or the problem of the rectification of the retinal image, which were both concerns explored in period optical literature. A useful survey of that tradition and its concerns remains David Lindberg, *Theories of Vision from Al-Kindi to Kepler* (Chicago, 1976). For a more capacious approach, see Stuart Clark, *Vanities of the Eye: Vision in Early Modern European Culture* (New York, 2007).

91. Alpers, *Art of Describing*, xvii.

92. Ibid., 29.

93. Joshua Reynolds, *Discourses on Art*, ed. R. W. Wark (New Haven, Conn., 1997), 237.

camera obscura thus discloses Reynolds's enmity to Dutch painting, as both stand opposed to the ambitious, generalizing aims of great art.

In the decades since the publication of *The Art of Describing*, scholars have come to offer a more nuanced view of Reynolds's relations to Netherlandish painting.[94] Technical analyses of his pictorial facture have demonstrated just how attentively Reynolds studied seventeenth-century Dutch and Flemish pictorial traditions, from their techniques of dead coloring and glazing to the use of wood-panel supports.[95] Charting a general softening of the president's critical writing on Netherlandish pictures over the span of his career, moreover, Harry Mount astutely notes that nearly a third of the paintings in Reynolds's own collection were by Dutch and Flemish artists.[96] And, while Reynolds could indeed complain to Edmund Burke that "Dutch pictures are a representation of nature, just as it is seen in a Camera Obscura," which quickly lost their appeal after a first viewing, Reynolds's contemporaries assessed that network of relations in very different terms.[97] Writing to one of Reynolds's major interpreters in 1777, Horace Walpole described a newly invented device for "perfecting of the camera obscura . . . called *the delineator*."[98] With the instrument placed in artistic hands, Walpole expected great things to follow. "Sir Joshua Reynolds and [Benjamin] West are gone mad with it," he claimed of this enhanced camera obscura, "and it will be their own faults if they do not excel Rubens in light and shade, and all the Flemish masters in truth."[99] Rather than tarring lowly Dutch art with the disfiguring brush of the camera obscura, Walpole encourages us to posit Reynolds as being capable of a more ecumenical view—one informed by his interests in Netherlandish painting and refracted through the profusion of optical contrivances available in later Georgian London.[100]

It is in this light that the camera obscura owned by Reynolds himself deserves renewed consideration.[101] Now in the collection of London's Science Museum, his is a

94. These points are made with special panache in a brilliant essay by Neil de Marchi and Hans J. Van Miegroet: "Ingenuity, Preference, and the Pricing of Pictures: The Smith-Reynolds Connection," in *Economic Engagements with Art*, ed. N. de Marchi and C. Goodwin (Durham, N.C., 1999), 379–412.

95. For a classic assessment of Reynolds's technical debts to Netherlandish practice, see Charles Lock Eastlake, *Materials for a History of Oil Painting*, 2 vols. (London, 1847), esp. 1:546. On the Dutch inspiration for Reynolds's use of mahogany supports, see Rica Jones, "Joshua Reynolds's *George VI when Prince of Wales*," in *Paint and Purpose: A Study of Technique in British Art*, ed. S. Hackney et al. (London, 1999), 146.

96. See Sir Joshua Reynolds, *A Journey to Flanders and Holland*, ed. and intro. H. Mount (New York, 1996), lviii.

97. Joshua Reynolds to Edmund Burke, August 14, 24, 30, 1781, in *The Letters of Sir Joshua Reynolds*, ed. J. Ingamells and J. Edgcumbe (New Haven, Conn., 2000), 100.

98. Horace Walpole to William Mason, September 21, 1777, in *Horace Walpole's Correspondence with William Mason*, vol. 1, ed. W. S. Lewis, G. Cronin Jr., and C. H. Bennett (New Haven, Conn., 1955), 328.

99. Ibid., 328–29.

100. For the larger visual culture of optical devices in Reynolds's ambit, see especially Ann Bermingham, *Sensation & Sensibility: Viewing Gainsborough's Cottage Door* (New Haven, Conn., 2005); and "Technologies of Illusion: The Art of Special Effects in Eighteenth-Century Britain," ed. A. Bermingham, special issue, *Huntington Library Quarterly* 70 (2007): 203–310.

101. This object is not mentioned by Alpers, but it has been noted elsewhere; see, for example, John H. Hammond, *The Camera Obscura: A Chronicle* (Bristol, U.K., 1981), 47–48, 79–81. The object

remarkable artifact (figs. 6 and 7). Outwardly, the object resembles a large folio-sized book, bound in tanned calfskin and accented with gilt ornamentation. Once unfolded like a suitcase, its side boards extended, and the adjustable lens and mirror mechanism fitted into a telescoping, accordion-like focal plane, the book transforms into a light-fast space for optical projection. If neither attributed to a maker nor dated, the object is similar in its convertible design and its materials to a specimen manufactured in London around 1765 by Benjamin Martin (1704–1782), which is now in the collection of Harvard University.[102] Possible functions for the object in Reynolds's studio remain an open question, especially given his well-known hostility to the "mechanical" aspects of painting and the surreptitious concealment afforded by this camera obscura's book form.[103] The design historian Jackie Hawkins has perceptively noted that the rectangular base of the camera obscura (measuring eighteen by twenty-four inches) matches precisely the dimensions of a late landscape painting by Reynolds included by David Mannings and Martin Postle in their authoritative catalogue raisonné.[104] Others have observed that, less than a tool for mechanical image-transfer, the device more likely served Reynolds as a source of compositional inspiration—as a means for visually apprehending "solid form as it emerges into the prominence of full illumination and then recedes and is lost in shadow and gloom."[105] But, did Reynolds actually employ this object to make paintings? *Could* he have used it for some practical purpose, however broadly conceived? Or is it better seen as an ingenious (and attractively discreet) novelty?

Through some extraordinary curatorial generosity, I was able to put these questions to a modest test in the autumn of 2011 when I was allotted a three-hour drawing session with the device at the Science Museum's storage facility at Blythe House in west London.[106] Aided by Rebecca Storr, collections access coordinator, the work proceeded in this way. After carefully unfolding the device, we used two laboratory-quality fiber optic lights to illuminate the props (apples, pears, oranges, and cloths

was also prominently featured, juxtaposed with a painting by Reynolds, in the exhibition *Open Book* (Dulwich Picture Gallery, 1996), curated by Martha Fleming, who kindly discussed her project with me.

102. See David P. Wheatland, *The Apparatus of Science at Harvard, 1765–1800* (Cambridge, Mass., 1968), 126–27.

103. For an illuminating account of Reynolds's conception of "the mechanical," see Joel Snyder, "Res Ipsa Loquitur," in *Things That Talk: Object Lessons from Art and Science*, ed. L. Daston (New York, 2004), 195–221, esp. 200–202. In interesting contrast to the legend "Camera Obscura" gilded into the spine of Martin's object now at Harvard, Reynolds's instrument bears no such identification.

104. See Jackie Hawkins, "An 18th Century Book Form Camera Obscura Once Owned by Sir Joshua Reynolds: An In-Depth Study" (MA essay, Royal College of Art, and Victoria and Albert Museum, History of Design, 2001), 31; this unpublished paper is archived in the object file for Science Museum, T 1875/28. For the painting, which is now untraced, see David Mannings and Martin Postle, *Sir Joshua Reynolds: A Complete Catalogue of His Paintings* (New Haven, Conn., 2000), 579 (item 2196).

105. Catherine Moody, "The Camera Obscura," *Leisure Painter* 23, no. 8 (August 1989): 7.

106. I thank Jane Wess and Rory Cook for this opportunity and Rebecca Storr, who kindly assisted me on the day. Thanks also to Joel Snyder for supplying a list of queries to ask of the object. For a more ambitious approach to the use of historical instruments, see Peter Heering, "The Enlightened Microscope: Re-enactment and Analysis of Projections with Eighteenth-Century Solar Microscopes," *British Journal for the History of Science* 41 (2008): 345–67.

FIGURE 6. Folding camera obscura in the form of a book, used and owned by Sir Joshua Reynolds, as seen closed. Science Museum, London, T 1875/28. © Science Museum / Science & Society Picture Library. See color plate 6.

FIGURE 7. Folding camera obscura in the form of a book, used and owned by Sir Joshua Reynolds, as seen opened. Science Museum, London, T 1875/28. © Science Museum / Science & Society Picture Library. See color plate 7.

capable of yielding distinct, colorful incidents across a visible field), which I arrayed on a table behind the instrument in a triangulated, "still-life" composition. No image was perceptible inside the box. Likely exacerbated by the corrosion visible on the movable mirror's surface, the difficulty in obtaining the amount of light required for projecting an image inside the camera proved daunting. Only once we had shut off all the suspended, fluorescent illumination on the floor of Blythe House—and, more importantly, lined the box's dark, wooden interior base with a sheet of white paper—did any image become visible at all. Even then, the work was difficult. Approximately forty-five minutes were required to adjust the arrangement of lighting and the position of the mirror simply to "find" the image projected onto the page. Focusing that image by moving the mirror and lens up or down was more problematic still.[107] Finally, once I had sacrificed my artful triangulation of props for a more pragmatic, frieze-like arrangement and trained both powerful lights upon them, I was able to see a compelling sight. Brilliantly colored, blobby objects rested on a ledge-like space before a sheer, completely undifferentiated black wall of shadow. Extremely limited in depth of field and resolved nowhere into perfect focus, the image dissolved rapidly at its margins as circles of confusion punctured its most brightly illuminated, central highlights.

Weak though Reynolds's draftsmanship is often accused of being, the humble scratches I produced after hours of labor with the device suggest to me that expedient production of drawings may indeed not have been the object's primary purpose.[108] Yet, that the object could support some practical application is interestingly asserted in the testimony accompanying its transmission to what is now the Science Museum's collection in the later nineteenth century. Communicating the camera obscura to the South Kensington Museum in 1875, donor N. Clothier explained that the object had come into his possession through a highly practical route:

> Some years ago I was presented with Sir Joshua Reynolds's "Camera Obscura" which Sir Joshua had made to see views &c. It was given by Sir Joshua to Lady Yates who was a great friend of the artist's, and to whom Sir Joshua lent his pictures for her Ladyship to copy in silk the same [?] as the Originals and wonderful productions they are. Lady Yates taught Miss Linwood . . . at the request of Sir Joshua[,] Miss Linwood having been badly off at the time. Sir Joshua telling Lady Yates, "he was sure she had great talent," which turned out to be correct.[109]

107. The difficulty involved in bringing the projected image into focus led me to question whether the device's original lens might have been replaced with window glass, a query that merits chemical assays beyond the scope of this essay.

108. For a familiar assessment of Reynolds's drawing ability, see Luke Hermann, "The Drawings by Sir Joshua Reynolds in the Herschel Album," *Burlington Magazine* 110 (1968): 650–58. I have posted examples of the drawings I made with the device on my website: https://sites.google.com/site/matthewhuntersite/Home/artwork/reynolds-co-drawings.

109. N. Clothier to Richard Redgrave, Art Department, South Kensington Museum, March 30, 1875; Science Museum, T 1875/28.

FIGURE 8. Mary Linwood, *Napoleon Bonaparte*, embroidery, ca. 1825. © Victoria and Albert Museum, London. See color plate 8.

Though it is not presently possible to verify which works might have been informed by such instrumental assistance, Clothier's story is not pure invention. Several examples of needlework "paintings" by Mary Linwood (1756–1845) do survive (fig. 8). Active in Leicester, where she ran a school that trained female artists, including lithographer Fanny Palmer, Linwood was more famously associated with Leicester Square, where she operated a gallery exhibiting her needlework transformations of grand manner oil paintings.[110] An exhibition guide, *Miss Linwood's Gallery of Pictures in Worsted* (1813), lists versions of Raphael's *Madonna della Sedia* and Carlo Dolci's *Salvator Mundi*, along with several pictures once produced by her "neighbor" on Leicester Square, Joshua Reynolds.[111] One of John Constable's first paying patrons, Linwood saw her gallery and the surrounding Square in a sorry state at the time of her death in 1845—this, three decades before Clothier invoked her name in his donation.[112]

110. For more on Linwood and her circles, see Charlotte Streifer Rubinstein, "The Early Career of Frances Flora Bond Palmer (1812–1876)," *American Art Journal* 17 (1985): 71–88; and Heidi A. Strobel, "Royal 'Matronage' of Women Artists in the Late-18th Century," *Woman's Art Journal* 26 (2005–6): 3–9. I thank Heidi Strobel and Elisabeth Fairman for discussing Mary Linwood with me.

111. Reynolds's studio was located on Leicester Square, although the painter had died over a decade prior to the establishment of Linwood's Gallery in 1805. See *Miss Linwood's Gallery of Pictures in Worsted, Leicester Square* (London, 1813), 4, 24. For works after Reynolds, see pictures identified as *Head of King Lear*, *Laughing Girl*, *Sleeping Girl*, and *Girl and Kitten* in *Linwood's Gallery*, 19, 9, 12, 16.

112. Richard Altick describes Linwood's Gallery and its fate in this way: "It would be difficult to conceive of a public exhibition more staunchly decorous than one of famous paintings imitated in colored wool. Nevertheless, the decline of the neighborhood had already begun, and by the forties the

Despite Reynolds's professed hostility to the mechanical side of painting and his acknowledged use of the camera obscura as a term of derision, then, the material evidence offers us a different view. As Hooke, Oldenburg, and Justel had done when confronted with Arnauld's talk of apparitions, it was through the model of the projected image that Reynolds interpreted a curious visual field. Dutch painting looked like "nature, just as it is seen in a Camera Obscura." Different from the darkened defects of Hogarth's purported projections, the camera obscura is a model for Reynolds in one of the senses argued for here insofar as it offers a heuristic, explanatory tool for understanding aspects of visible phenomena. That modeling, in turn, is not exclusively a conceptual act of cerebration. Instead, it is informed by the array of the projection devices to which Reynolds had access, that he owned, and that he reportedly gave to other artists for the production of images anew. While more needs to be said about the crucial, complicated meanings of modeling in Reynolds's own practice, the lessons afforded by projected images are suggestive nonetheless. Reducible to neither theory *nor* practice and indeed animated by the fitful traffic between them, the modeling traceable in the camera obscura's penumbra signals less that we see "passivity" as an organizing character of scientific visuality, but that we might think again about the interfaces of grand manner art and technology. Perhaps it should be seen as more than an honorific, then, that Joshua Reynolds was proposed as a "Gentleman of learning, a lover of Philosophical enquiries" in 1760 and elected Fellow of the Royal Society of London in the following year.[113]

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square itself, its railings long since removed for firewood, had become one of the ugliest eyesores in London, a spacious dustbin for dead cats, deposits of oyster shells, broken crockery, old bricks, and the miscellaneous refuse of a considerable portion of the West End"; Richard Altick, *The Shows of London* (London, 1978), 229–30; see also 400–401.

113. See Royal Society, EC/1760/14.