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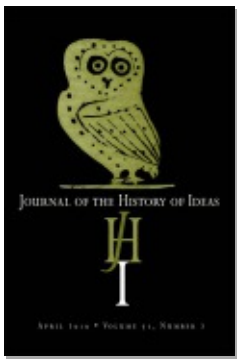

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Baroque Optics and the Disappearance of the Observer: From Kepler's Optics *to Descartes' Doubt*

Ofer Gal and Raz Chen-Morris

INTRODUCTION

In the seventeenth century the human observer gradually disappeared from optical treatises. It was a paradoxical process: the naturalization of the eye estranged the mind from its objects. Turned into a material optical instrument, the eye no longer furnished the observer with genuine representations of visible objects. It became a mere screen, on which rested a blurry array of light stains, accidental effects of a purely causal process. It thus befell the intellect to decipher one natural object—a flat image of no inherent epistemic value—as the vague, reversed reflection of another, wholly independent object. In reflecting on and trespassing the boundaries between natural and artificial, orderly and disorderly, this optical paradox was a Baroque intellectual phenomenon; and it was the origin of Descartes' celebrated doubt—whether we know anything at all.

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JOHANNES KEPLER: *ARTIFICIOSA OBSERVATIONES*

The human observer began to slip out of optics when Kepler discussed the concept of artificial observations in his *Paralipomena Ad Vitellionem*[1]:

> On 1602 21/31 December at 6^h in the morning, through a . . . [*camera obscura*] and an instrument made for this purpose . . . the moon made an image of itself brightly upon the paper lying below, inverted in situation, just as it was in the heavens, gibbous. . . . You should not think that . . . the moon's ray was in the paper, for both the gibbous face and the spot in its middle were carried over to all parts of the paper . . . indeed, it was from moving the paper that the spot was first discovered.[2]

The observation, Kepler stressed, was not *his*. It was no one's. The image of the moon was not the culmination of a cognitive process. It did not require an observer; a piece of paper was enough, and the paper could be moved around without affecting the production of the image. Image production is the main concern of *Ad Vitellionem*; being "The Optical Part of Astronomy," it is about the making of observations rather than their content. Earlier in the book Kepler established the legitimacy and efficiency of his main instrument of *artificiosa observationes* (the term he used in one of the subtitles), the *camera obscura*, by demonstrating that the image obtained through it is indeed that of the observed object.[3] He went on to elucidate its underlying principle—the formation of an image on a screen behind a small aperture—by way of physical simulation. He set "a book on a high place to stand as a luminous body" and "a tablet with a polygonal

[1] Johannes Kepler, *Ad Vitellionem*, in *Gesammelte Werke* (*GW*) 1571–1630, ed. Walther von Dyck and Max Caspar (Munich: C. H. Beck, 1937–); *Optics*, trans. William H. Donahue (Santa Fe, N. M.: Green Lion Press, 2000). We will use *Ad Vitellionem* to refer to the original Latin in *GW* and *Optics* to refer to Donahue's translation.

[2] Kepler, *Optics*, 259.

[3] The relation between the camera obscura and the eye is at the heart of the historiographic debate concerning Kepler's optics. For Stephen Straker (*Kepler's Optics*, and c.f. A. C. Crombie's *Robert Grosseteste*) the instrument represents Kepler's novel commitment to the mechanization of the eye and his indebtedness to the artisanal tradition. David Lindberg, in contrast, arguing for Kepler's reliance on the perspectivist tradition, stresses that "only on one occasion did [Kepler] explicitly compared the eye to a camera obscura" (Lindberg, *Theories of Vision from Al-Kindi to Kepler* [Chicago: University of Chicago Press, 1976], 206). We argue that Kepler's main motivation is the legitimation of *artificiosa observationes*.

hole'' under it. He stretched threads from the book's corners grazing the edges of the hole and found that the four images of the hole were reproduced on the floor in reverse order. When this process was repeated from (ideally) every point of the book, ''a narrow row of infinite figures'' similar to the hole ''outline the large quadrangular [reversed] figure of the book on the pavement.''[4]

This was a novel solution to an age-old mystery, formulated already by Pseudo-Aristotle: ''why does the sun penetrating through quadrilaterals form not rectilinear shapes but circles?''[5] It was novel, indeed revolutionary, because it abandoned the fundamental assumption of all previous attempts to answer the question: that the pinhole image is a unique *re-presentation* of the sun.[6] For Kepler's perspectivist predecessors, the circular image was not *caused* by the sun and by light; it was the true form of the sun or the perfect dissemination proper of light; the circularity of the image was a sign of its indubitable authenticity. ''The spherical shape is associated with light,'' John Pecham characteristically explained, ''therefore, light is naturally moved toward this shape.''[7] Even Francesco Maurolyco, who replaced this ''natural association'' with a geometrical account, preserved the essential similarity between source and image: the image cast through the aperture is composed of many images, not of the hole, but *of the luminous body*.[8]

This similarity completely disappeared from Kepler's account, together with the exactness of representation it ensured. There was nothing unique to the circularity of the pinhole image: a rectangular body, like the book, would produce a rectangular image. Neither did the pinhole image represent light; light was simulated by the threads pulled through the hole, but

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[4] Kepler, *Ad Vitellionem*, *GW*, 56.

[5] Aristotle, ''Problems'' in *The Complete Works of Aristotle*, ed. Jonathan Barnes (Princeton: Princeton University Press, 1984), Bk 15, Ch. 6, 911b1, 2:1417.

[6] David Lindberg, ''The Theory of Pinhole Images from Antiquity to the Thirteenth Century,'' *Archives for the History of Exact Sciences* 5 (1968): 154–76; ''The Theory of Pinhole Images in the Fourteenth century,'' *Archive for the History of Exact Sciences* 6 (1969): 299–328; E. Broydrick Thro, ''Leonardo's Early Work on the Pinhole Camera,'' *Achademia Leonardi Vinci* 9 (1996): 20–54; John Pecham, *John Pecham and the Science of Optics*, ed. and trans. David Lindberg (Madison: University of Wisconsin Press, 1970), 67; Giora Hon and Yaakov Zik, ''Geometry of Light and Shadow,'' *Annals of Science* 64 (2007): 549–78.

[7] Pecham, *John Pecham and the Science of Optics*, 70–71. See also Lindberg's ''Laying the Foundations of Geometrical Optics,'' in *The Discourse of Light from the Middle Ages to the Enlightenment* (Los Angeles: William Clark Memorial Library, 1985), esp. 26–29.

[8] Lindberg, ''Laying the Foundations,'' esp. 37–40; Hon and Zik, ''Geometry of Light and Shadow,'' esp. 561.

the image projected on the pavement could be of any object, not necessarily luminous—a book, for example. The trustworthiness of the projection, for Kepler, did not rest on its perfect loyalty to the object projected but on understanding the physical process of projection. Indeed, Kepler discovered, one could not hope for such loyalty: the book-pattern on the floor was created by a "narrow row" of partially overlapping "figures," so not only was the image reversed, its boundaries were fuzzy. Finally, these stains were reflections of the *aperture*. Kepler's "figures" bore no resemblance to the light source. The "outline . . . on the pavement" was only a "large quadrangular figure" comprising aperture-like light stains. It bore no essential resemblance to the book.

THE CHALLENGE OF ASTRONOMY

Kepler's interest was in the legitimation of the instrument he presented, not its demise. The challenge he took in *Ad Vitellionem* was "to preserve astronomy's dignity and subdue the hostile fortress of doubt,"[9] and his worry was real. One of the first tasks assigned to Kepler by Tycho Brahe was to defend the epistemological integrity of the new astronomy against the charges of Aristotelians like Ursus,[10] that the heavens were too far properly to observe and that "the evidence [concerning celestial bodies] is furnished but scantily by sensation."[11] That Tycho's observations were mediated by instruments made their defense that much more complex.

But the most acute need for epistemological justification was created by Kepler's own astronomical ambitions. "Physicists, prick up your ears!" he would declare in his *Astronomia Nova*, "for here is raised a deliberation involving an inroad to be made into your province."[12] Physical claims were clearly beyond the realm of astronomy, as astronomers themselves stressed:

[9] Kepler, *Ad Vitellionem*, *GW*, 6.
[10] Nicholas Jardine, *The Birth of History and Philosophy of Science* (Cambridge: Cambridge University Press, 1984). One finds similar Aristotelian complaints in Zabarella, Carbone, and others: Heikki Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences* (Helsinki: Suomen Historiallinen Seura, 1992); W. R. Laird,. "Galileo and the Mixed Sciences," in *Method and Order in Renaissance Philosophy of Nature*, ed. D. A. Di Liscia, Eckhard Kessler, and Charlotte Methuen (Aldershot: Ashgate, 1997), 253–70.
[11] Aristotle, "Parts of Animals" in *The Complete Works* (*CW*), Bk 1.5, 644b, 1003.
[12] Johannes Kepler, *New Astronomy*, trans. William Donahue (Cambridge: Cambridge University Press, 1992), 89.

> God the Creator placed these bodies so far away from our senses that we are unable to produce principles of demonstration for them . . . or to discover . . . the causes of particular appearances.[13]

Even Kepler's own mentors, Tycho and Michael Maestlin, insisted that any claims to "principles" or "causes" in the heavenly realm lay beyond the boundaries of astronomical knowledge. "No one is able to ascend to the aethereal region," remarked Maestlin, "where he would see everything in person,"[14] and the eye was particularly deficient in providing the evidence required for the *physica coelestis* that Kepler envisioned:

> the eyes are attached to the head, so, through the head, they are attached to the body; through the body, to the ship or the house, or to the entire region and its perceptible horizon.[15]

Hopelessly embodied and situated, "the sense of vision is in error about the movable."[16] It was thus unable to adjudicate between "Copernicus, whom I follow,"[17] Ptolemy, and Tycho, let alone support the ambitious physical claims of Kepler's new astronomy. And since (reiterating Maestlin) we do not have "someone . . . to carry us across to the moon or to another of the wandering stars"[18] (which will help little anyhow, he points out), Kepler required a new agent to bridge the epistemological rift and to carry images from far away.

LIGHT AND THE TRANSFORMATION OF OPTICS

Kepler's agent was light:

> From the Sun and the colors illuminated by the Sun, species flow . . . until for whatever reason, they fall on an opaque medium,

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[13] Nicodemus Frischlin, *De Astronomicae Artis* . . . (Frankfurt, 1586), 41, quoted in Nicholas Jardine, "Epistemology of the Sciences," in *Cambridge History of Renaissance Philosophy*, ed. C. B. Schmitt, Quentin Skinner, Eckhard Kessler, and Jill Kraye (Cambridge: Cambridge University Press, 1988), 700. See also Peter Barker and Bernard Goldstein, "Realism and Instrumentalism in Sixteenth Century Astronomy: A Reappraisal," *Perspectives on Science* 6 (1998): 232–58.

[14] Michael Maestlin, *De Astronomiae hypothesibus* . . . (Heidelberg, 1582) A^{2}r. Tycho Brahe, *Epistolarum astronomicarum libri* (Uraniburg, 1596), 111.

[15] Kepler, *Optics*, 336.

[16] Ibid., 335.

[17] Ibid., 338.

[18] Ibid., 336.

> where they paint their source: and vision is produced, when the opaque screen of the eye is painted this way. . . . For, there are certain passions of light . . . illuminating and altering the screens [of the eye] through which colors, that is to say light, are not only poured upon but are also imprinted.[19]

It was light that created images, bouncing off "an opaque medium" and falling on an "opaque screen." If the screen happened to be the eye, "vision is produced," but there was nothing unique to the eye: any screen would do.

With light as the sole agent of all optical phenomena, there was no fundamental epistemological difficulty with observing the distant celestial objects: the mathematical nature of light and the assumption that its rays did not decay, but only dispersed (propositions 6 and 7 of *Ad Vitellionem*), turned distance into nothing but an element in the geometrical analysis of observation.[20] With light, there was also no epistemological difficulty with *artificiosa observationes*. The image on the pavement was reversed and fuzzy, but so was the one on the retina. The instrument was trustworthy not because it did not interfere with the visual flow, but because it was no worse than the eye.

This epistemological gain entailed a transformation of optics. The subject matter of traditional optics was human vision.[21] Vision was a direct acquaintance of the visual faculty with visible objects, and the communication of these objects to the eye was self-evidently teleological: the optical process was *aimed* at providing adequate images of objects for the intellect. "A species produced by a visible object has the essential property of manifesting the object of which it is the likeness," wrote Pecham.[22] This fundamental assumption survived throughout the Renaissance; summarizing scholastic optics for his audience of painters and art patrons, it was the teleology that Alberti chose to stress:

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[19] Kepler, *Ad Vitellionem*, 41–42.

[20] For Kepler's mathematization of light see Ofer Gal and Raz Chen-Morris, "The Archaeology of the Inverse Square Law Part I," *History of Science* 43 (2005): 391–414.

[21] A. Mark Smith, "Getting the Big Picture in Perspectivist Optics," *Isis* 72 (1981): 568–89 and "What is the History of Medieval Optics Really About?" *Proceedings of the American Philosophical Society* 148 (2004): 180–94. For the role of visual impressions in medieval spirituality see: Katherine Park, "Impressed Images: Reproducing Wonders," in *Picturing Science, Producing Art*, ed. Caroline Jones and Peter Galison (New York: Routledge, 1998), 254–71; Jeffrey Hamburger, "Seeing and Believing," in *Imagination und Wirklichkeit*, ed. Alessandro Nova and Klaus Krüger (Mainz, 2000), 47–69.

[22] Pecham, *John Pecham and the Science of Optics*, 161.

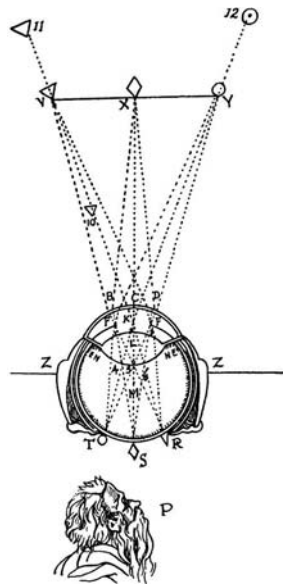

FIGURE 1: Descartes, "Figure 17" from *La Dioptrique*.

> Philosophers . . . say that surfaces are measured by certain rays, ministers of vision as it is [*quasi visendi ministries*], which they therefore call visual rays, since by their agency the images of things are impressed upon the senses. (see Figure 1)[23]

While the physical nature of the "ministers of vision" was debated since antiquity, neither their "agency" nor the "essential likeness" of the "images of things" they "impressed upon the senses" were ever in doubt. For Grosseteste, vision was carried by "a natural agent [which] continuously multiplies its power . . . sometimes called species, sometimes likeness."[24] Roger Bacon underscored this essential relation: "species is similar in essence and definition to the agent and the things generating it."[25] The

[23] Leon Battista Alberti, *On Painting and On Sculpture*, ed. and trans. C. Grayson (London: Phaidon, 1972), 41.

[24] Robert Grosseteste, "De lineis angulis et figuris," in *Die Philosophischen Werke des Robert Grosseteste*, ed. Ludwig Baur, *Beiträge zur Geschichte der Philosophie des Mittelalters* 9 (Münster: Aschendorff, 1912), 60.

[25] Roger Bacon, *Roger Bacon's Natural Philosophy*, ed. and trans. David Lindberg (Oxford: Clarendon Press, 1983), 7. C.f. Smith, "Getting the Big Picture"; Leen Spruit, *Species Intelligibilis: From Perception to Knowledge* (Leiden: E. J. Brill, 1994); Katherine Tachau, *Vision and Certitude in the Age of Ockham: Optics, Epistemology and the Foundations of Semantics 1250–1345* (Leiden: E. J. Brill, 1988); Dallas G. Denery, *Seeing and*

multiplication assured the trustworthiness of the visual agents and turned optics into the epistemological anchor of scholasticism; optics legitimated natural philosophy by accounting for the fundamental knowability of God's creation.[26] The analysis of the eye provided the same assurance of intentionality and veracity of vision, as Pecham stressed: "vision takes place by the arrangement of the species on the glacial humour *exactly* as [the parts] of the object [are arranged] outside."[27] This was so, precisely because "*unless* this were so, the eye would not see the object distinctly."[28] Optics, Pecham assumed, was a theory of visual perception, and any theory that failed to account for the adequacy of the seen image was *ipso facto* false.[29]

Whatever was their essence, the *ministri visendi* were never conflated with light. A necessary condition of vision, light was obviously of interest. It was observed and experimented on, and the results generalized to other, less accessible *species*.[30] Witelo, for example, listed in the preface to his *Perspectiva* "Visual rays, lights, colors and forms" as examples of the emanation of *species*, which had undergone the same "projection, infraction and refraction" and could be dealt through the same "geometrical elements."[31] For Neoplatonists in particular light was the very paradigm of emanation.[32] Yet light was never assumed as the agent vision. Kepler was the first to declare that "genuine vision occurs when the folding door or pupil of the eye is exposed most closely to the arriving ray of light."[33] Naming his book after Witelo, Kepler readily acknowledged his indebtedness to the perspectivist tradition,[34] but his optics was no longer an account of how the "visible object" recreated its "likeness" in the eye; it was a mathematical-physical theory of the formation of images by light.[35]

Being Seen in the Later Medieval World (Cambridge: Cambridge University Press, 2005), esp. 82–96.

[26] Smith, "Getting the Big Picture," 569.

[27] Pecham, *John Pecham and the Science of* Optics, 121 (italics added).

[28] Ibid.

[29] C.f. Stephen Gaukroger in René Descartes, *The World and Other Writing*, ed. and trans. Gaukroger (Cambridge: Cambridge University Press, 1998), 159–61.

[30] C.f. Abdelhamid Sabra, "Alhazen's Optics in Europe," in *Inside the Camera Obscura*, ed. Wolfgang Lefèvre (Berlin: 2007), 53–58. A. Mark Smith, "Saving the Appearances of the Appearances," *Archive for the History of Exact Science* 24 (1981): 73–99; "Ptolemy's Search for a Law of Refraction," *Archive for the History of Exact Science* 26 (1982): 221–40.

[31] Witello, *Perspectiva,* "Ad Lectorem."

[32] Lindberg, "The Genesis," 10.

[33] Ibid., 78 (Prop. 3, chap. 3).

[34] C.f. David Lindberg's *Theories of Vision.*

[35] Carl Boyer, *The Rainbow* (Princeton: Princeton University Press, 1987 [1959]); A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science 1100–1700* (Ox-

THE CONSEQUENCES

One could hardly overstate the significance of Kepler's reformulation of optics. Produced by light, images were mere causal effects; stains of light which accidentally bounced off objects and fell on screens. Kepler's optics had no place for forms and visual rays, and without them the teleology of the optical process was lost, together with the essential veridicality of vision and the importance of optics as an epistemological anchor for all other sciences.[36]

Kepler's optics was as much epistemologically-oriented as traditional optics, but instead of guaranteeing the authenticity of human visual knowledge in general, it was aimed at supporting the empirical underpinning of Kepler's new astronomy, and long distance instrumental observation in particular. Since light was the producer of all images, the similarity of form between the sun and its projection—or the book and the "figure . . . on the pavement"—no longer meant that the process connecting them had any inherent epistemic value. "*All* celestial observation takes place through the mediation of light and shadow"[37]; we can trust images because they are outcomes of a purely natural, causal process which we can investigate through experimenting and theorizing. This meant that we can trust observations of stars as much as those of books, and we can trust instrumental, artificial observations as much as we trust our eye.

Yet this trust comes with a steep epistemological price tag: if the instrument is not prone to error more than the eye, then the eye is as vulnerable to error as the instrument. Passively receiving "illumination" like any instrument, the eye is not merely comparable to "a closed chamber"—it is one: "the pupil takes the place of the window."[38] The cornea is truly nothing but a lens; the retina nothing but a screen, essentially the same as the paper or the pavement. The picture on the retina, like the one on paper or the pavement, is *not* an accurate reflection of the object. It is a fuzzy "row of infinite figures," the shape of each caused by the accidental shape of the aperture; "the pupil" or "the window."

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ford: Oxford University Press, 1953), 281; for Robert Grosseteste, *De Iride*, in Bruce S. Eastwood, *The Geometrical Optics of Robert Grosseteste* (PhD dissertation, University of Wisconsin, 1964); Lindberg, "The Genesis"; Stephen Straker, *Kepler's Optics* (PhD Dissertation, Indiana University, 1971); Antoni Malet, "Keplerian Illusions: Geometrical Pictures versus Optical Images in Kepler's Visual Theory," *Studies in History and Philosophy of Science* 21 (1990): l-40.

[36] Smith, "What is the History," esp. 181–83.

[37] Kepler, *Optics*, 13 (italics added).

[38] Ibid., 184.

Kepler's optics abandoned the epistemological assuredness that traditional optics provided by relinquishing the assumption that "the arrangement of the species [is] *exactly* as the object." For Kepler, "it has been demonstrated most clearly, *from the very structure of vision*, that it frequently happens, that an error befalls the sense of vision."[39] Visual errors were of course nothing new, but Kepler's was a new concept of error.[40] In the Aristotelian paradigm, errors were created by the intervention of the human imagination; the visual data were indubitable. With the new optics the doubt was directed at the very images perceived. "The deficiency impinges on the sense of vision"[41]; the fuzziness is a feature of the optical phenomenon itself, and errors follow "from the very structure of vision."

Kepler was no skeptic. On the contrary, much of *Ad Vitellionem* was dedicated to accounting for the reliability of the retinal image. Indeed, the book experiment demonstrated that the pattern on the screen *did* correspond to the projected object. But the very need for such demonstration was a troubled admission: instead of "likenesses," all the eye could provide were these fuzzy retinal images; causal effects of light. It was left for the intellect to decipher natural objects of one kind (stains of light), as marks for objects of a different kind; how the intellect met the challenge remained a complete mystery:

> How this image or picture is joined together with the visual spirits that reside in the retina and in the nerve, and whether it is arraigned within by the spirits into the caverns of the cerebrum to the tribunal of the soul or of the visual faculty; whether the visual faculty, like a magistrate, given by the soul, descending from the headquarters of the cerebrum outside to the visual nerve itself and the retina, as to lower courts, might go forth to meet this image—this, I say, I leave to the natural philosophers to argue about.[42]

This was the optical paradox: the naturalization of the eye estranges the observer, and a deeper understanding of optics turns vision into a mys-

[39] Ibid., 236 (italics added).
[40] Giora Hon, "On Kepler's Awareness of the Problem of Experimental Error," *Annals of Science* 44 (1987): 545–91; and his "Putting Error to (Historical) Work," *Centaurus* 46 (2004): 58–81.
[41] Hon, "Putting Error to (Historical) Work," 69.
[42] Kepler, *Optics*, 180. In a private communication, Antoni Malet argued that Kepler's reference to the arguments of philosophers is ironic. This may very well be the case, yet it should not obscure his clear awareness to the epistemological query resulting from his new optics.

tery. Years later, in his *Harmonices Mundi*, Kepler would attempt a metaphysical resolution to this mystery, through the mathematical infrastructure divinely endowed in both nature and human intellect.[43] Yet the paradox could not be resolved by optical theory, and Kepler left the resolution "to the natural philosophers," and out of *Ad Vitellionem*.

ANXIETIES, SOLUTIONS, AND COMPROMISES: PRACTITIONERS

Mirrors, lenses, and the *camera obscura* were common instruments of practical optics. Their use, in this tradition, was playful: Giambattista della Porta wrote about "experiments [to] follow the imaginary conceits of the mind," boasting "I have oft made sport with the most fair women with these glasses."[44] Della Porta's playful use of optical devices was based on their ability to distort,[45] but the distortion was not of the eye. These were "imaginary conceits *of the mind*" that his instruments produced. The eyes of the "fair women" received exactly the "forms"[46] that della Porta's lenses and mirrors delivered; it was their feeble minds that could be tricked to judge them "hanging in the air." The weak eye could be helped by instruments like "spectacles, whereby poor blinde people can . . . see all things,"[47] but the sense of vision itself could not be "conceited." "The Image that falls on your sight"[48] was exactly the one that would be made available to the intellect.

For Kepler there was no vision without "the conceits of the mind." The *pictura* on the retina was a natural object, an aggregate of partially overlapping pupil-shaped stains of light. The intellect "meets this image" and constructs a visual representation—three-dimensional, smooth-contoured, and upright. This very separation, the independent existence of an optical object, prior to its being considered by "the tribunal of the soul or of the visual faculty," was completely foreign to della Porta.[49] Even though "images should appear outwardly, hanging in the air," della Porta never sug-

[43] Kepler, *Harmonices Mundi*, in *GW*, 6:104; 223; 303–4.
[44] Giambattista della Porta, *Natural Magick* (London, 1658), 355, 356.
[45] Also to reveal and enhance (della Porta, *Natural Magick*, 361).
[46] Ibid.
[47] Ibid.
[48] Ibid., 356.
[49] Sven Dupré, "Inside the Camera Obscura: Kepler's Experiment and Theory of Optical Imagery," *Early Science and Medicine* 13 (2008): 219–44.

gested that the image *was* in midair. The image had no existence but that perceived. The intellect did not observe images. It observes objects, which it may perceive properly or distorted. This perception is the image.

Kepler's understanding of visual representation as constructed thus placed him outside the cultural milieu of della Porta and the optical magicians. It was closer to the realism (or naturalism[50]) of painters of the Dutch or "northern" school, with their attempt to capture the naked, optical phenomenon that is the retinal image, before being processed by the higher faculties. From this vantage point, high Renaissance painterly tools like Alberti-style perspective, imposed ideal mathematical structure on visual reality which was essentially blurred. Keplerian optics did not imply that the use of these tools is disingenuous or a mere stylistic whim. Rather, it suggested that their success did not stem from capturing independent reality or perfect vision, but from recapitulating the operation of the "visual spirits," which turned inverted and fuzzy retinal images into well-delineated objects of perception.[51]

The detail-loaded paintings from Van Eyck to Bailly as well as Vermeer's and Fabritius's *camera obscura*-like works bore the signs of this adherence to the pure optical image exactly in appearing *wrong* in either perspective (for instance the relative size of the figures in Fabritius's *View of Delft* and Vermeer's *Officer and a Laughing Girl*), lighting (the spots of light and the blurred outlines of Vermeer's *View of Delft*), or both (Vermeer's *Milkmaid*).[52] "Vermeer seems to have been delighted by the optical effects of the lens and tried to recreate them on the canvas" writes David Hockney.[53] Unlike Della Porta, Vermeer's delight did not come from the distortion, but from the ability to recreate the pre-ordered, pre-cognitive visual reality. The realism of the Baroque seized Kepler's "narrow row of infinite figures" just before being "joined together with the visual spirits," and recaptured it as it is on "the opaque screen of the eye."[54]

The *camera obscura* was a mere instrument for Della Porta, at most

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[50] David Summers, *The Judgment of Sense: Renaissance Naturalism and the Rise of Aesthetics* (Cambridge: Cambridge University Press, 1987).

[51] Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago: University of Chicago Press, 1983), 44.

[52] Philip Steadman, *Vermeer's Camera: Uncovering the Truth behind the Masterpieces* (Oxford: Oxford University Press, 2001).

[53] David Hockney, *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters* (New York: Viking Studio, 2001), 58. On Hockney's thesis see *Early Science and Medicine* 10:2 (2005); Michael John Gorman, "Art, Optics and History: New Light on the Hockney Thesis," *Leonardo* 36 (2003): 295–301.

[54] Kepler, *Ad Vitellionem*, 181.

analogically comparable to the eye. For Vermeer, it was a way to recreate the image that light paints on "the white of the retina." For Kepler, the eye and the *camera obscura* were one and the same.

PICTURES AND IMAGES

The naturalization of the eye meant separation between image creation and visual perception; optics was no longer a theory of vision. Despite avowing to "leave to the natural philosophers to argue about" the consequences of this separation, Kepler attempted to ward off at least the implication that *all* visual experience is a fabrication of the human mind, and *ipso facto* distorted. For this purpose he evoked an old definition of the distorted "image" (*imago*): "the image is the vision of a certain object linked to an error of the faculties concurrent with vision . . . better called an imaginary fabrication."[55] Traditionally the error that defined "image" was caused by mediation of a lens or a mirror.[56] Kepler, however, had already established that all human vision involves instrument-like mediation, so in contrast to the erroneous *imago* he had to set up a purely physical entity preceding all intervention of the visual faculties: "up to now an image has been [considered] a rational entity, now figures of objects truly existing on paper, or other screens, are called pictures."[57] The image is a "rational entity" because it is "an imaginary *fabrication*" of the mind. The picture (*pictura*), in contrast, is a genuine physical effect. It can be on the retina "or other screens"—what is important is not that it is unmediated by instruments, but that it is free of any intellection.[58]

The ontological distinction, however, could not alleviate the epistemological worry that all vision is in and of itself distorted. The physical existence of an unmediated, undistorted physical image did not provide for unmediated, undistorted visual perception. Kepler's analysis entails that we have no access to the pre-fabricated retinal images anymore than to the un-

[55] Kepler, *GW*, 2: 60.
[56] Pecham, *John Pecham and the Science of* Optics, 170.
[57] Kepler, *GW*, 2:174. For a technical analysis of the distinction in Kepler and beyond see A. E. Shapiro, "Images: Real and Virtual, Projected and Perceived, from Kepler to Dechales," *Early Science and Medicine* 12 (2008): 270–312.
[58] A. Mark Smith, "Ptolemy, Alhazen, and Kepler and the Problem of Optical Images," *Arabic Sciences and Philosophy* 8 (1998): 9–44; Raz Chen-Morris, "From Emblems to Diagrams: Kepler's New Pictorial Language of Scientific Representation," *Renaissance Quarterly* 62 (2009): 134–70.

mediated objects or to the "pictures" on screens other than the retina. The mind, according to Kepler's own account, is furnished always with an already-constructed image, "arraigned" from a multitude of light stains on the retina by the "visual spirit" or the "visual faculty" itself, "descending from the headquarters of the cerebrum."

SCHEINER AND THE JESUIT COMPROMISE

For the Jesuit mathematician Christoph Scheiner, this tyranny of mediation and its disturbing epistemological ramifications were too much to take.[59] In his *Oculus*, published some fifteen years after the *Ad Vitellionem*, he rejected the reduction of optics to a theory of image production by light and attempted to preserve the Aristotelian teleology of vision:

> In order to see, the eye of the animal is assigned by God to discharge the function of acquiring the presence of the visible things [*rerum videndarum*]. The things are made present to the eye . . . [by rays] admitted into the eye from the objects.[60]

Scheiner's eye had retained—or returned to—its traditional role: the *terminus ad quem* of the optical process; discharging the divine task of "acquiring the presence of the visible things." Its relation to "the things" had also returned to be immediate and self-authenticating; the things themselves "are made present" to the eye.

Scheiner hoped to maintain the empirical achievements of the new optics, especially concerning the physiology of the eye, but without committing himself to its fundamental novelty and the epistemological predicament it implied. He thus admitted that the retina is the visually sensitive part of the eye and that the crystalline humor functioned as a lens while interpreting these findings in the traditional terms of visual rays and species. The title of the first chapter of his third book—"in which it is explained, how

[59] For other Jesuit treatment of Kepler's optics see Franciscus Aguilonius, *Opticae libri VI* (Antwerp, 1613). For Scheiner's indebtedness to Kepler's optics see also: Iasbelle Pantin, "Simulacrum, Species, Forma, Imago: What Was Transported by Light into the Camera Obscura?" *Early Science and Medicine* 13 (2008): 245–69; see also Paolo Mancosu, "Acoustics and Optics" in *The Cambridge History of Science* (Cambridge: Cambridge University Press, 2006), esp. 3: 613–18.

[60] Christoph Scheiner, *Oculus* (Innsbruck, 1619), 2.

the visual ray stimulates the retinal membrane and the reason for the structure of the eye"[61]—is particularly telling:

> In order to avoid confusion with things seen from a distance, and so that the pictures of the visible things be experienced orderly and distinctly, it is required of the vitreous humor to expand, by this adjustment it collects the rays refracted in the crystalline [humor], so that the figure from the crystalline will be painted distinctly on the retina.[62]

Scheiner's picture, like Kepler's and against the perspectivist tradition, was "painted on the retina," and the crystalline humor refracted, rather than absorbed the image. This admission already compromised the veridicality of vision: the picture was a refracted, two dimensional representation of the object. But Scheiner toiled to make this his last concession to the new optics. Vision in the *Oculus* was still created by "visual rays" which came from "visible things" and whose "*beneficio*" was to assure clear and distinct visual perception. Light was nowhere to be found, only "*species*," which Scheiner manipulated in experiments, employing lenses and screens to simulate humor and retina. Most importantly, Scheiner's pictures were well ordered:

> At the terminal point within [the eye] the borders of the remote thing are arranged, so the right appears at the right side of the eye, the left at the left, the above—above.[63]

This final triumph of Jesuit epistemic tactics did not come easily. Scheiner wanted to retain Kepler's analysis of the crystalline humor as a lens, but this implied the inversion of the image on the retina. So in order that in the retinal image the right will "appear at the right side of the eye, the left at the left," he had to assume that the image was already inverted when passing through the humor, namely, that the visual rays crossed paths before entering the eye through the pupil, a strange feat indeed. Moved enough by Kepler's achievements and troubled enough by their naturalistic and skeptic implications, Scheiner claimed just that, dedicating the whole

[61] Scheiner, *Oculus*, 124.
[62] Ibid.
[63] Ibid., 38.

second part of the first book of *Oculus* to demonstrating empirically this pre-eye crossing of rays.

A Jesuit scholar could not overlook, let alone accept the solipsistic implications of Keplerian optics. The attempt to preserve the visual veridicality of Aristotelian epistemology while incorporating the new science was at the heart of the Jesuit project around the turn of the seventeenth century.[64] Scheiner managed to save the teleology of vision while preserving Kepler's empirical and geometrical infrastructure: the rays are refracted, the images are inverted, but the eye is still fully successful in fulfilling the function it was "assigned by God." Yet avoiding Kepler's boldest move—the conversion of optics from visual rays to light—had a price as well. Scheiner could not benefit from those of Kepler's achievements which depended on the mathematical-physical nature Kepler ascribed to light, such as the inverse square law.[65] At the end of his analysis, Scheiner remained committed to the one-to-one correspondence between object and perceived image that was both the great achievement and the clear boundary of the *perspectiva* tradition:

> All rays by which a visible [object] is carried [*derivatur*] into some point in the organ of vision are called visual rays; but some are less important and secondary, whether mediated or diffracted: but one [that is] principal, primary and immediate . . . enters the organ of vision that senses the form of colors, and . . . [this is the ray] that is sensed.[66]

DESCARTES: THE COLORS OF THE RAINBOW

Some Keplerian successes indeed defied the Jesuit compromise. One optical phenomenon which the new light optics was much better equipped to decipher—but at the price of full commitment to turning optics from vision to light—was the rainbow.[67]

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[64] Peter Dear, *Discipline & Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995), esp. Chapter 2; and Rivka Feldhay, "Mathematical Entities in Scientific Discourse" in *Biographies of Scientific Objects*, ed. Lorraine Daston (Chicago: University of Chicago Press, 2000), 42–66.

[65] C.f. Ofer Gal and Raz Chen-Morris, "Archaeology of the Inverse Square Law, Part I," for the dependence of Kepler's inverse square law on his physics of light.

[66] Scheiner, *Oculus*, 73.

[67] Boyer, *The Rainbow*, 134; 150.

The aerial colors of the rainbow presented a difficult challenge to Aristotelian theories of vision and of light because color, according to Aristotle, is a quality of opaque bodies. The rainbow, therefore, could neither be a property of the transparent air, nor of light, which is not a body.[68] This problem continued to bother opticians and Aristotelian commentators through the Middle Ages and the Renaissance, and in 1619 Scheiner's fellow Jesuit Horatio Grassi still insisted: "the air cannot be illuminated."[69]

Kepler noticed early on that taking light as a physical flow suggested a way of solving the mystery of the rainbow by assuming that "the proportion of the angles of refraction constitutes . . . that a color is green, blue, etc."[70] This type of consideration caused Descartes to declare Kepler his "premier maître en optique"[71] and to adopt optics as his model for the mathematical physics at which he was striving.[72] Since the rainbow appeared "whenever there are drops of water . . . illuminated by the sun" Descartes could use Kepler's light optics to explain its colors by the refraction of the "rays of light . . . against those drops, and from there toward our eyes."[73] This became Descartes' paradigm of a mathematical analysis providing causal understanding of a physical phenomenon.[74]

One finds in traditional optics attempts to explain colors in terms of "more or less illumination,"[75] but Descartes' analysis had little to do with those. The various colors, in his account, were direct effects of the very angles of refraction. This was a *physical* hypothesis, albeit formulated mathematically, so the exact details—which angle creates what color—could be filled in experimentally. Simulating a rain drop with the traditional instrument of empirical optics, the water globe, employed in this role at least since Alhacen,[76] Descartes found that when the angle *DEM* between the globe, the eye and the center of the sun was 42, the color observed was

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[68] Aristotle, *De Anima,* Bk. 2, Ch. 7 and *De Sensu et Sensibili*, Bk. I, Ch. 3.
[69] Horatio Grassi, *The Astronomical Balance*, in *The Controversy on the Comets of 1618: Galileo Galilei, Horatio Grassi, Mario Guiducci, Johannes Kepler*, ed. and trans. Stillman Drake and C. D. O'Malley (Philadelphia: University of Pennsylvania Press, 1960), 122.
[70] Kepler, *GW*, 14:50–51.
[71] René Descartes, *Oeuvres*, ed. Victor Cousin (Paris, 1824) 7:161.
[72] John Schuster and Stephen Gaukroger, "The Hydrostatic Paradox and the Foundations of Cartesian Dynamics," *Studies in History and Philosophy of Science* 33A (2002): 535–72.
[73] Descartes, *The World*, 85.
[74] For a recent careful analysis and reproduction of Descartes experimental work on the rainbow see Jed Z. Buchwald, "Descartes' Experimental Journey Past the Prism and Through the Invisible World to the Rainbow," *Annals of Science* 65 (2007): 1–46.
[75] Boyer, *The Rainbow*, 150; Eastwood, *The Geometrical Optics of Robert Grosseteste.*
[76] See, e.g., Antonio de Dominis, *De Radiis Lucis in Vitris Perspectivis et Iride* (1611).

brilliant red, and so, to a lesser degree, when the complimentary angle *KEM* was more or less 52 (see Figure 2, page 209). "If these points are viewed all together, without our noting anything about their position except the angle at which they are seen, they must appear as a continuous band of red,"[77] he concluded.

Maintaining optics' mathematical language and methods, Descartes, following Kepler, turned it into a branch of natural philosophy. Yet despite the new project, his early experiments were still rooted in traditional optics; not only in the use of the water globe, but, more fundamentally, in privileging the eye as *the* significant station of the optical process: the rays "act . . . toward the eye" and the angles are taken from the eye (see Figure 3, page 209). Once the mathematical questions received their causal-physical import, however, the eye lost its privileged status: the angles of the rainbow do not refer to the eye; the rays fall on different screens and appear the same from different viewpoints. Disappearing together with the eye was the water globe; no longer attempting to mimic raindrop and eye, Descartes constructed a physical-experimental model of abstract refraction and abstract projection with a prism (see Figure 4, page 210). The water globe and the raindrop had become particular cases of refracting surfaces, generally represented by the prism; the retina was now a particular case of a screen, generally represented by "cloth or paper." The colors of the rainbow were thus produced strictly by refraction of light rays. The eye was completely incidental to the phenomenon; "nor does the angle under which [the colors] appear need to be of any particular size, for this can be changed without any change in them."[78]

Casting the eye out, Descartes completed Kepler's re-application of traditional optics—the mathematical investigation of lines of sight—to the behavior of light. His optics was now a bona fide experimental-mathematical natural philosophy, which he could direct at investigating the very nature of colors. If colors were not optical phenomena in the traditional sense, neither modifications of the visual rays "on the way to the eye," nor partial reflections of objects' forms (as they were for Aristotle[79]), what could they be? How were colors produced and what did we sense in them? Descartes answered in mechanical terms: the motion of light particles. The homogeneous particles of light moved rectilinearly in uniform velocity. Refraction

[77] René Descartes, *The World and Other Writings*, ed. and trans. Stephen Gaukroger (Cambridge: Cambridge University Press, 1998), 86.
[78] Ibid., 87–88.
[79] Aristotle, *Meteorology*, in *CW*, Book 3, Ch. 2, 600.

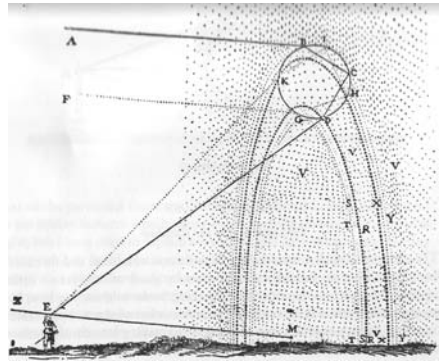

FIGURE 2: "... I discovered ... when the sun came from the part of the sky marked AFZ, my eye being at point E, when I placed this globe at ... BCD, its part D appeared to me completely red and incomparably more brilliant than the rest ... whether [I moved or it moved, so long as] the line DE ... made an angle of approximately 42 degrees with the line EM ... D always appeared equally red" (Descartes, *Discourse 8 of the Meteors*, p. 85). Source: René Descartes, *The World and Other Writings*, ed. and trans. Stephen Gaukroger (Cambridge: Cambridge University Press, 1998), 86.

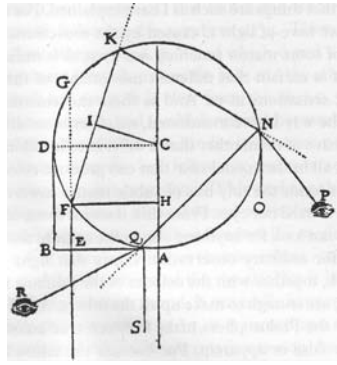

FIGURE 3: "Let AFD be a drop of water ... consider one of these rays in detail: EF ... instead of passing directly through G, is deflected toward K, is reflected from K toward N, from where it goes toward the eye P ... or it is reflected once more from N to Q, and from there is turned toward the eye R" (Descartes, *Discourse 8 of the Meteors*, p. 92). Source: Descartes, *The World and Other Writings*, ed. and trans. Gaukroger, p. 92.

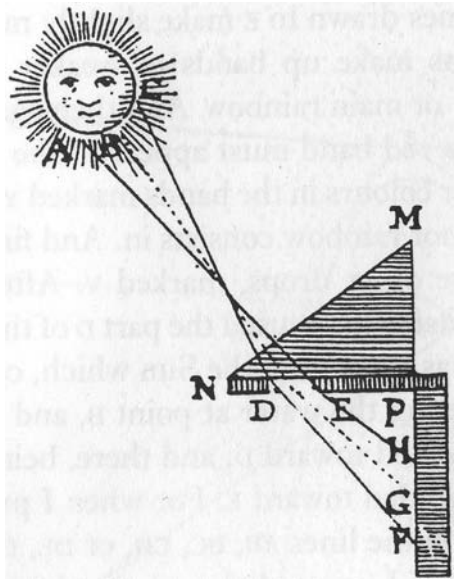

FIGURE 4: "I observed that the ray, passing through this opening and from there making for the cloth or paper FGH, paint all the colors of the rainbow on it" (Descartes, *The World*, 87–88). Source: Descartes, *The World and Other Writings*, ed. and trans. Gaukroger, p. 88.

and reflection imparted rotary motion on the particles, and the velocity of this rotation depended on the relative place of the particle in the ray when touching the refracting surface. The rotation *was* the color: this explained why the same colors were created by the same angles of refraction and were always in the same order. Descartes was quick to point out the epistemological consequence of this mechanization of colors:

> I cannot accept the distinction that Philosophers make between true colors and others which are only false or apparent. For because the entire true nature of colors consists only in their appearance, it seems to me to be a contradiction to say both that they are false and that they appear.[80]

If colors were modifications of light rather than properties of the object, they could not be held to the distinction between true and apparent:

[80] Ibid., 91.

their truth *was* their appearance. It was only when required to provide an intelligent observer with genuine re-presentation of objects that colors, images, and other optical phenomena could be either true or false. Otherwise, especially when "appearances" could be on "cloth or paper" just as on the retina, they were simply causal effects. And if optics was no longer concerned with studying epistemic processes but merely the transportation of light and its effects, it had no place for such an observer.

KEPLERIAN OPTICS AND ITS TRAVAILS

The success of Descartes' theory of the rainbow was predicated on casting the human observer out of optics. Oblivious to the distinction between true and false, optics was thus stripped of its role as an epistemological anchor. Estranging objects and their visual representation it became, instead, a source of epistemological anxiety. This was the anxiety that Kepler attempted, with the aid of irony, to sidestep. Descartes addressed it head on:

> We must take care not to assume—as philosophers commonly do—that in order to have sensory perception the soul must contemplate certain images transmitted by the objects to the brain; or at any rate we must conceive the nature of these images in an entirely different manner.[81]

Whatever comprises our "sensory perceptions," Descartes was claiming, could not be "confined to the requirement that they should resemble the objects they represent."[82] The main assumption of the Aristotelian-perspectivist tradition, that vision carries its own criteria of veridicality, was at best naïve.[83] The "philosophers" took for granted that our senses truly re-*present* the objects, that they furnish the intellect with *resemblances*. However, in assuming that, they had nothing on which to rely but the viciously circular belief that "*unless* this were so, the eye would not see the object distinctly," as Pecham had it, or that the "function" of the eye was "to avoid confusion," as in Scheiner's rendition.

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[81] René Descartes, *The Philosophical Writings of Descartes*, trans. John Cottingham, Robert Stoothoff, and Dugald Murdoch (Cambridge: Cambridge University Press, 1985), 1:165.

[82] Ibid.

[83] Gaukroger in Antoine Arnauld, *On True and False Ideas*, ed. and trans. Stephen Gaukroger (Manchester: Manchester University Press, 1990), 4–10.

Descartes carefully worked his way through the skeptical implications that Kepler attempted to avoid. Retinal images bore no resemblance to the original object. Furthermore, as we have recourse only to these retinal images, we are "uncertain . . . that the light which we see as if in the Sun exists outside us, in the Sun." Thus, when "pain and color . . . are judged to be certain things existing outside our mind, it is absolutely impossible to understand in any way what things they are."[84] In his early *Regulae* Descartes taught his reader how to think of sensual representation without resemblance by turning Aristotle's most celebrated metaphor of vision on its head: "sense perception occurs in the same way that wax takes an impression from a seal," he writes.[85] This was a direct allusion to the "analogy" one finds in *De Anima*,[86] but Aristotle did not use his seal and wax metaphor simply to "explain sense-perception through Touch."[87] It was to explain how it can be that what we sense is not just *true* of the object, but *inseparable* from it, even though the object itself remains remote.[88] This was particularly pertinent, of course, in the case of vision and its remote objects: "the air . . . sets the sight in motion, just as if the impression on the wax were transmitted as far as the wax extends."[89] Tellingly, Aristotle employed the same metaphor to dismiss Plato's separation of matter and form: "it is as meaningless as to ask whether the wax and the shape given to it by the stamp are one."[90]

For Aristotle, then, the wax metaphor stressed the direct contact of the object, through the medium, with the sense organ, and reinforced the teleology, immediacy, and veridicality of sense perception. For Descartes the metaphor conveyed the exact opposite: what touched the "opaque membrane" was *not* the properties of the visible, corporeal body but "the many colors of the light." The same is true concerning all the senses; they

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[84] René Descartes, *Principles of Philosophy*, trans. Valentine Rodger Miller and Reese P. Miller (1644; Dordrecht: Kluwer, 1983), Prop. 67, 30.

[85] René Descartes, "Rules for the Direction of the Mind," in *The Philosophical Writings of Descartes*, 1:40. See also Dennis L. Sepper, *Descartes's Imagination: Proportion, Images, and the Activity of Thinking* (Berkeley: University of California Press, 1996), esp. 211–22, 242–53

[86] Aristotle, *On the Soul* (*De Anima*), J. A. Smith (trans), Bk. 2, Ch. 1.

[87] Aristotle, "Sense and Sensibilia" in *CW*, Ch. 3, 1:696, 700–703. Aristotle's attitude to the issue of touch is complex. In *De Anima* he declares that "the primary form of sense is touch," while in *De Sensu et Sensibili* he mocks "Democritus and most of the natural philosophers [who] proceed quite irrationally" in thinking of "all objects of sense as objects of Touch" (*De Anima*, Bk. 2, Ch. 2; *De Sensu et Sensibili*, Ch. 4).

[88] Aristotle, *De Anima*, Bk. 2, Ch. 12.

[89] Ibid.

[90] *Op. cit.*, Ch. 1.

provided no direct re-presentation of the sensed objects. The unity of the senses, which for Aristotle meant that remote objects of vision were represented as reliably as the immediate objects of touch, meant for Descartes that the images provided by vision did not resemble their objects any more than the sensations of smell or taste.[91]

In the *Regulae* Descartes expressed the opaqueness of the relations between sense perceptions and their objects by envisioning a grammar of line segments and their arrangements which represented the various sensible qualities to their respective sentient organs.[92] There was no inherent correspondence between the "objects of the sense" and the objects they were purported to represent; the relation between those different types of objects was neither transparent nor self-authenticating; sensations needed to be *deciphered*. A few years later, working on his *Le Monde*, Descartes underscored the non-transparency of sense representation, the need to decipher and infer objects from sensations, by replacing the wax metaphor with a linguistic analogy:

> Now if words, which signify something only through human convention, are sufficient to make us think of things to which they bear no resemblance, why could not Nature also have established some sign which would make us a sensation of light, even if that sign had in it nothing that resembled this sensation?[93]

The wax metaphor implied that the relation between objects and sensations was causal and mediated rather than essential; the geometrical analogy stressed that perceptions do not resemble objects; the words metaphor made this relation no more essential a bond than the "human convention" which related words to things. Again, Descartes picked an Aristotelian trope only to subvert its meaning. "Spoken words," writes Aristotle in *De Interpretatione*,

> are the symbols of mental experience, and written words are the symbols of spoken words. . . . mental experiences, which these directly symbolize, are the same for all, as also are those things of which our experiences are the images.[94]

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[91] See Michel Foucault, *The Order of Things* (London: Tavistock, 1970), 50–51.
[92] Descartes, Rule Twelve, "Rules for the Direction of the Mind," 40–41.
[93] Descartes, *The World*, 4; C.f. Stephen Gaukroger, *Descartes: An Intellectual Biography* (Oxford: Clarendon Press, 1995), 276–90.
[94] Aristotle, *De Interpretatione*, in *CW*, Ch. I, 16a, 3–8, 1: 25.

Aristotle specifically limited the contingency of linguistic representation to sounds and written characters: since it was the objects themselves which were re-presented in the human mind, their mental images could be only what they actually were, hence were identical for all humans. Sensual representation, in the Aristotelian tradition, was a series of re-productions of properties of the thing itself: in the medium, in the sense organ, in the mind, in language. This process of representation was contingent *only*, if at all, at the stage of naming mental images with words—the same objects might have been designated by different words. Descartes reversed the analysis: the "action that signifies" was the motion of light which was reflected from the visible thing, through the medium, to the retina, which created on it an image whose relation to the thing—its status as a sign—was no more essential than that of words to concepts. Returning to words in his *Dioptrics*, Descartes stressed again that it was exactly this contingency and the separation "between the object and its image" that his geometrical and linguistic analogies purported to convey:

> our mind can be stimulated by many things other than images—by signs and words, for example, which in no way resemble the things they signify . . . in no case does [even] an image have to resemble the object it represents in all respects, for otherwise there would be no distinction between the object and its image.[95]

These were the full epistemological consequences of Kepler's optics, and Descartes resolutely elaborated them. The process by which the images were created belonged to light. It owed inherent allegiance neither to the eye nor to the objects; both were just accidental points off which light happened to bounce. This was not a random or capricious process: the same image on the retina could be assumed to be the outcome of the same process, and therefore to represent the same object, just as a word always signified the same object. But this uniformity was the only anchor for our trust in our perceptions, and in itself it was nothing more than the regularity of cause and effect: from the epistemological foundation of all science, vision had become dependent on science as the guarantor of its limited reliability.[96]

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[95] Descartes, *Philosophical Writings* 1: 165.

[96] Alison Simmons, "Are Cartesian Sensations Representational?" *Noûs* 33 (1999): 347–69.

DESCARTES' DOUBT

One can discern three competing interpretations of Descartes' skepticism in recent scholarship.[97] A long philosophical tradition presents the anxiety that we may be completely wrong as the very core of "the modern condition," and Descartes as its radically innovative author.[98] Descartes' doubt, in this interpretation, was the result of a failed "quest for certainty." Setting the bar for proper knowledge at no lower than mathematical certainty, Descartes came to worry if we can know anything at all. This was altogether different from the ancient skeptical warning that we are often mistaken, and it stems from Descartes' novel concept of the mind: an enclosed internal space, in which mental entities "represent" through the "veil of ideas" a world made out of entities of a completely different kind.[99]

A competing interpretation rejects the revolutionary modernity of Descartes and situates him within skeptical trends of his time, relating to demons, madness, dreams, and, most significantly, vision.[100] This interpretation puts particular stress on the rediscovery of ancient skeptical texts and the subsequent revival of Pyrrhonianism,[101] though the full indebtedness of Descartes' "hyperbolic doubt" to the ancients is debated.[102]

Closest to our analysis are recent studies of the relation between Descartes' skepticism and his science. According to one approach, the worry about the failure of the senses to represent reality is an implication of the mechanistic philosophy underlying his science: the qualities of physical objects include only extension, figure and motion, completely unlike the ideas in our mind. Consequently, "human beings . . . are systematically and constantly deceived in ordinary sense experience."[103] Another approach presents Descartes' skepticism as a critique of Aristotelian sense-based science, serving him in clearing the way for his "method," which, empirical and

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[97] José Luis Bermúdez, "Scepticism and Science in Descartes," *Philosophy and Phenomenological Research* 57 (1997): 743–72.
[98] Paul Edwards, *Encyclopedia of Philosophy* (London, 1967).
[99] Richard Rorty, *Philosophy and the Mirror of Nature* (Princeton, 1979).
[100] Stuart Clark, *Vanities of the Eye: Vision in Early Modern European Culture* (Oxford: Oxford University Press, 2007), esp. 334–43.
[101] Richard H. Popkin, *The History of Scepticism from Erasmus to Spinoza* (Berkeley: University of California Press, 1979).
[102] M. F. Burnyeat, "Can the Skeptic Live his Skepticism," in *Doubts and Dogmatism: Studies in Hellenistic Epistemology*, ed. Malcolm Schofield, Myles Burnyeat, and Jonathan Barnes (Oxford: Clarendon Press, 1980), 20–53; Gail Fine, "Descartes and Ancient Skepticism," *The Philosophical Review* 109 (2000): 195–234.
[103] Margaret Wilson, "Skepticism without Indubitability," *The Journal of Philosophy* 81 (1984): 538–39.

hypothetically deductive, has little to do with an *a priori* quest for certainty.[104]

The development of optics from Kepler to Descartes suggests a reversal: it was the science—theoretical optics and astronomical observation—that gave rise to the philosophical skepticism.[105] The optical angle provides clear answers on the points of contention between the different interpretations of Descartes' skepticism. It *is* a novel worry, even if it is sometimes elaborated in traditional terms. It is founded on an analysis of perception which would have been completely foreign to people living in both the ancient and medieval eras; on Cartesian science, modeled after Kepler's optics, preceding and prompting metaphysical reflection. It is also a wholly genuine anxiety, not rhetorical or argumentative, and it is not directed against old science. The doubt stems immediately and disturbingly from the very success of the New Science.

Descartes' skepticism was expressed in its full power not in any of his overly-read "philosophical" writings but at the heart of his properly "scientific" texts, and most vividly in the famous illustration from the *Dioptrique* (see Figure 1, page 197). It is a depiction of a real experiment, conducted also by Scheiner and Schott: observing the world as it projected on the retina of an ox eye.[106] Yet it is as much an emblem of the success of the new optics and the disconcerting ramifications of this success, in all their paradoxical entanglement. The observer has disappeared from optics, but not the eye. Detached from the viewer, it is now re-absorbed into the mechanistic account and the empirical inquiry. Yet it is no longer the end of the visual process, merely an arbitrary point of reference, an un-privileged station in the natural process; "the eye of a newly deceased man . . . an ox or some other large animal" tells as much of its operations as a living human eye could. This is already a clear rejection of Aristotle's position that "sight is the substance of the eye . . . when seeing is removed the eye is no longer an eye."[107] Having detached eye and sight, Descartes proceeds to cut "through the membranes." He covers the dead eye with "some white body,

[104] Stephen Gaukroger, *Descartes*; Gaukroger, *Cartesian Logic* (Oxford, 1986); and Gaukroger "Descartes' Project for a Mathematical Physics" in *Descartes: Philosophy, Mathematics, Physics*, ed. Stephen Gaukroger (Sussex: Harvester Press, 1980); Daniel Garber, "Semel in vita" in his *Descartes Embodied: Reading Cartesian Philosophy through Cartesian Science* (Cambridge: Cambridge University Press, 2001), 221–56, and Garber, *Descartes' Metaphysical Physics* (Chicago: University of Chicago Press, 1992), 94–103.

[105] C.f. Smith, "What is the History of Medieval Optics Really About?" 194.

[106] Christoph Scheiner, *Rosa Ursina* (1630) BK 2, chap. XIII, 106–8. C.f. Lefèvre, *Inside the Camera Obscura*, 8.

[107] Aristotle *De anima* Bk 2, 1:412^{b}19–23.

thin enough to let daylight pass through it," and observes the images appearing on the cover. "The images . . . on a white cloth in a dark chamber are formed there in the same way and for the same reasons as on the back of the eye," Descartes concludes with "admiration and pleasure." But the implications are disconcerting: the eye is no longer a window, it is a screen; it is no longer *through* it that we observe, but *at* it.[108]

Descartes' skepticism was not *about* vision; it was visual skepticism. Descartes did not re-discover what was indeed noted since antiquity, that our vision was not to be trusted. Rather, he invented the eye of the mind, modeled on but completely independent from the eye of the flesh, and in this reversed the epistemological role of vision. From being the guarantor of our knowledge and a paradigm of direct acquaintance, vision became a metaphor for mediation. It was a paradoxical insight: by accepting that knowing is seeing and understanding how we see, Descartes was convinced that we may not know at all.

CONCLUSION

This then is the optical paradox. It is, in Erwin Panofsky's words, a Baroque realization of the radical implications of the Renaissance's "inherent conflicts"[109]: Keplerian confidence in distant images cast fundamental doubt on our sense of the immediate. The naturalization of vision leads to the estrangement of nature. Scientific observation entails the disappearance of the observer. Descartes' skepticism is an epistemological elaboration of this paradox.

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[108] René Descartes, *Discourse on Method*, trans. P. J. Olscamp (Indianapolis: Bobbs-Merrill, 1965), 91–93; 97.
[109] Erwin Panofsky, "What Is Baroque?" in *Three Essays on Style* (Cambridge, Mass.: MIT Press, 1995), 88.