A cartoon from *Puck* magazine (August 30, 1890). (Photo courtesy of Jack and Beverly Wilgus of Bright Bytes Studio.)

The Scientific Life Of the Camera Obscura

By Brian S. Baigrie

Technological innovation enjoys great currency in scholarly accounts of the rise of modern science, particularly for the light it sheds on those extraordinary periods of creativity known as scientific revolutions. Technology can be manipulated to bring about new discoveries: it makes results repeatable and hence exportable in standardized configurations to other destinations. When a research front has been thoroughly technologized, it offers scientists a veritable "discovery machine," stimulating novel techniques that further accelerate the pace of innovation. The scientific progress that results can be so breathtaking that what appears to scholars at a distance as revolutionary ferment is actually a massive acceleration in the production of knowledge.

When familiar instruments are manipulated to make discoveries, new techniques that accelerate the pace of innovation are sometimes the result. The electro-magnetic effect, first detected in 1820 by Hans

Christian Oersted (1777–1815) with a magnetic needle and a current passed through fine platinum wires, is an illustration of familiar technology being put to new and spectacular ends.[1] Oersted ushered in a new electrical age that led, in short order, to the electromagnet, the transformer, and the dynamo—the building blocks of the industrial revolution.

Our enthusiasm for new research technologies can make us forget the fact that, as often as not, the seeds of revolution are sown by scientists working with humble instruments that have been around for a very long time. For the same reason, bursts of innovation frequently stem not from any particular use to which these instruments are put, but rather from scientists thinking about them in unexpected ways. Instruments occasionally possess an intellectual dimension that far overshadows their intrinsic value, carrying with them the eclipse of an entire way of life and the dawn of a new, revolutionary narrative.

The intellectual significance of instruments is nowhere more apparent than in the role played by the humble *camera obscura* in the scientific revolution of the seventeenth century. When some of the light rays reflected from a bright subject pass through a pinhole in thin material, they do not scatter but cross and reform as an upside-down image on a flat surface held parallel to the hole. The camera obscura (from the Latin 'dark room') exploits this fact (Figure 1). If a small hole is made in the window cover of a darkened room on a bright day, an inverted image in full color and movement of the scene outside the window is produced on the opposite wall of the room.

The fact that a pinhole could form this type of image has been known since the very dawn of science. The ancient Chinese were aware of the fact as early as the fourth century BC. Outside China, the Arabian scholar Alhazen (Abu ali Al-Hassen ibn al Haytham) (c. 965–1038) first described it in about 1030. A clear description of the formation of images using a small hole in a darkened room is contained in the manuscripts of Leonardo da Vinci (1452–1519) in the fifteenth century.

The camera obscura has enjoyed two lives, one that has been fully documented by art historians, and a second, comparatively unknown, as an object of scientific speculation. In its first incarnation, the camera obscura served as a tool of visualization, first in the emergence of the naturalistic style of representation that historians identify with Renaissance art, and then in photography. Following the lead of Giovanni Battista della Porta (1538–1615), by the mid-sixteenth century, artists had begun to exploit the camera obscura as an aid to drawing and perspective. The first generation of camera obscura were always created in rooms in houses. By the seventeenth century, however, portable versions were being widely used by artists for sketching in the field. The device most commonly used for this purpose was the reflex box: after reflection by an inclined mirror, the lens formed

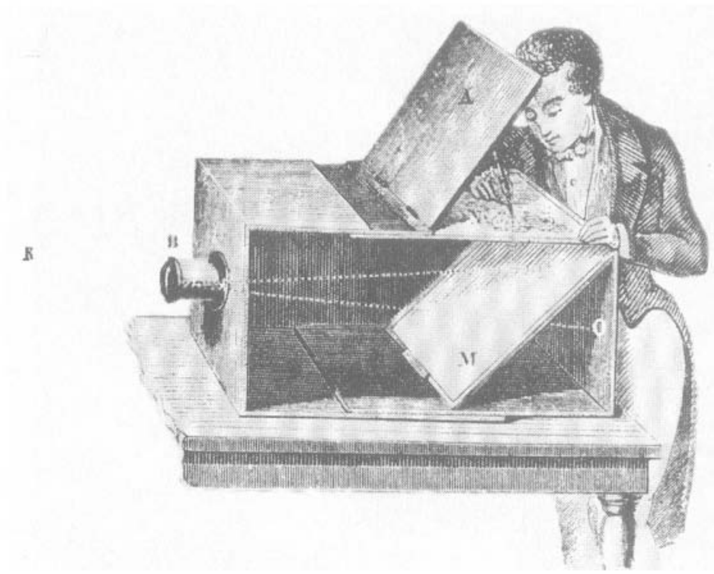

Figure 1. A tabletop camera obscura.

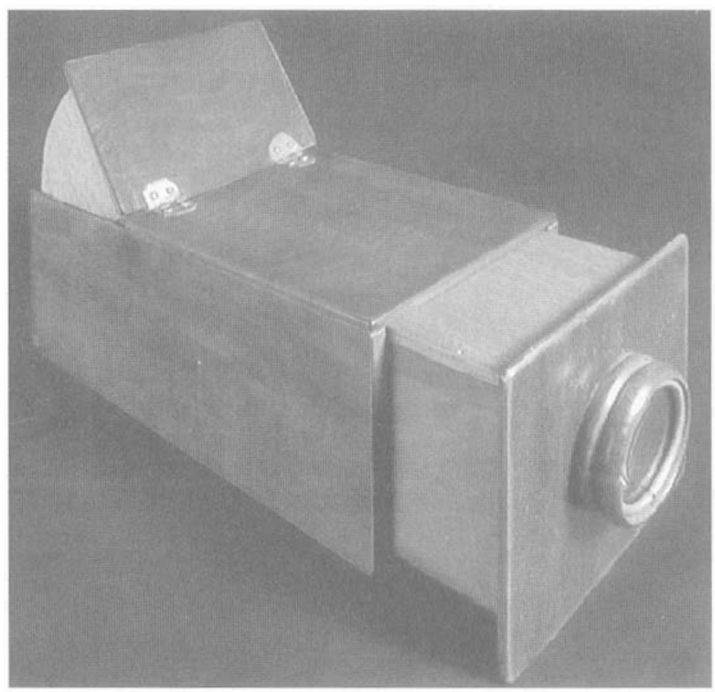

Figure 2. An English box camera obscura. Focus is achieved by sliding the inner section of the box in and out. (Photo courtesy of Jack and Beverly Wilgus of Bright Bytes Studio.)

an upright image on a sheet of translucent paper. Though there is evidence that many recognized artists used the camera obscura, few would acknowledge the practice because they felt that in some way it diminished their artistry.

By the time the first photographic experiments were taking place at the beginning of the nineteenth century, the camera obscura had evolved into three distinct forms. One was a darkened room with a lens and mirror in the roof. Furnished with improved lenses that could cast larger and sharper images, this type of camera obscura, which flourished at seaside resorts

[1] Oersted's privately circulated memoir of 1820 is titled *Experimenta circa effectum conflictus electrici in acum magneticum*. He was awarded the Copley Medal by the Royal Society and a large monetary prize by the Institut de France.

Figure 3. Johannes Kepler (1571–1630). (Photo courtesy of the Smithsonian Institute, Washington, DC, Dibner Library, Special Collections.)

and other picturesque sites, produced an image on a table. A second type was in the form of a portable tent: featuring a lens and mirror at the apex of the tent, it produced an image on a horizontal desk inside. The third form was the portable box camera obscura that produced an image on light-sensitive material. It was this type of camera obscura that eventually lead to the development of the photographic camera.[2]

The second life of the camera obscura began, in the manner of the vast majority of scientific instruments, as an aid to observation. The great observational astronomer Tycho Brahe (1546–1601) found that the camera obscura produced a wonderful image during eclipses. In 1600, however, when Brahe was using the camera obscura in lunar observations, he discerned that the lunar diameter as formed by the rays in the pinhole camera appeared smaller during a solar eclipse than at other times. Brahe's observation generated a curious intellectual puzzle that seemed to admit only two solutions: either the moon itself changed sizes or moved further away from the earth during the solar eclipse; or Brahe was somehow being deceived by the camera obscura.

This puzzle awakened the interest of Brahe's assistant, Johannes Kepler (1571–1630), now chiefly remembered for the three laws of planetary motion enshrined in Isaac Newton's celestial dynamics (Figure 3). The first solution presumed that the puzzle was astronomical in nature. Kepler rejected this out of hand. The puzzle, Kepler submitted in his *Ad vitellionem paralipomena* (1604), involved the optics of the visual images (which he called *pictures*) formed behind the small apertures in the pinhole camera.[3] The changing diameter of the moon was caused by the intersection of the optical mechanism with the rays of light. The deception detected by Brahe, Kepler reasoned, was built into the pinhole camera itself.

It was this thesis that transformed the camera obscura from a mere instrument into a scientific object of inquiry in its own right. It is true that scientists are often so taken with instruments that their interest in them transcends any connection with theory. Though instruments may come to enjoy a great deal of autonomy from theoretical concerns, their value as instruments is frequently tied to their ability to generate useful measurements. With Kepler's pioneering work in the science of vision, the camera obscura became an intellectual object in its own right.

An unpalatable consequence of Kepler's hypothesis was that naked-eye observation was somehow superior to instrument-mediated observation. This consequence was congenial to the Scholastic natural philosophy that dominated intellectual life in and around the universities. A central doctrine of Scholastic accounts of knowledge was that there is nothing in the mind which is not first in the senses. Equivocating the scientific with the sensible, these same scholars would soon oppose Galileo's startling telescopic observations with the common sense refrain that such things as Jupiter's moons and the craters of the moon are not available in ordinary sensation and so must be artifacts of Galileo's instrument. Anticipating this

Figure 4. A print from Frank Leslie's Popular Monthly (1877) showing a scene inside the Central Park camera obscura. (Photo courtesy of Jack and Beverly Wilgus of Bright Bytes Studio.)

[2] See Helmut Gernsheim, *The History of Photography from the Camera Obscura to the Beginning of the Modern Era*. London: Thames & Hudson.

[3] For a discussion of Kepler's involvement in the camera obscura, see Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century*. Chicago: The University of Chicago Press.

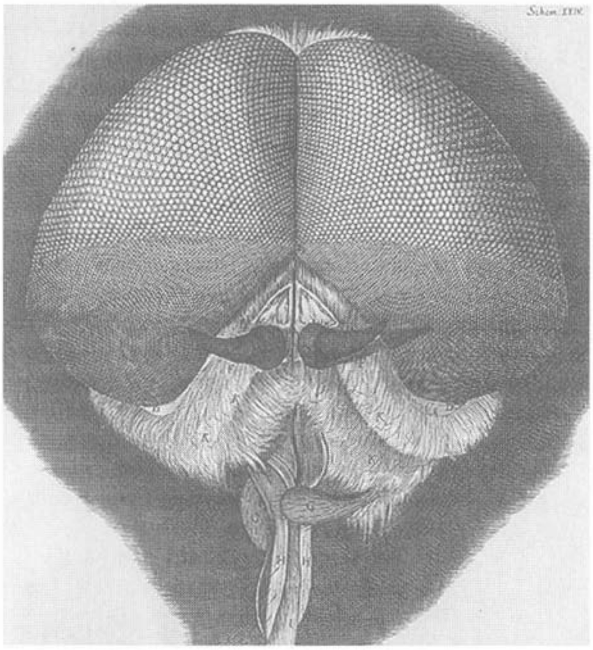

Figure 5. Illustration of the eyes of a grey drone fly, which appeared in *Micrographia* in 1665. (Photo courtesy of the Smithsonian Institute, Washington, DC, Dibner Library, Special Collections.)

objection, Kepler fatally undermined the Scholastic account of knowledge and the authority traditionally conferred on ordinary vision by pointing out that deception is also built into the human eye, which, he demonstrated to great effect, is an optical mechanism furnished with a lens that has focusing properties.

A startling consequence of Kepler's claim that our optical mechanism mediates the world is that the world must be seen differently through the eyes of other animals. Thanks to the Copernican system, natural philosophers were already furnished with a philosophical objection to the anthropocentrism of the received geocentric cosmology. With Kepler's pioneering work in vision science, the anti-anthropocentrism implicit in Copernicus' treatment of the earth as just another celestial body was now bolstered by science. As Kepler's views gathered momentum during the course of the seventeenth century, it is easy to see why natural philosophers became consumed with studying the eyes of other animals and in reconstructing the world as pictured by their optical mechanisms.

The most striking example of the anthropocentrism of the day was the celebrated illustration of the eye of a grey drone fly (Figure 5), which appeared in the enormously popular *Micrographia* (1665), composed by the English experimentalist Robert Hooke (1635–1703). Hooke numbered the hemispheres of the fly's eye at fourteen hundred. The sheer complexity of the fly's visual system reinforced Kepler's rejection of conventional wisdom, which placed a premium on unaided human observation. Indeed, the fact that the fly's visual mechanism was a more sophisticated contrivance than the human eye gave shape to an entirely new conception of sophistication in terms of minuteness of structure—a conception reflected in the enthusiasm for the new pocket watch that transformed business practices in the late seventeenth century, and that is still with us today in our quest to produce ever smaller and faster computers.

Kepler's demonstration that the human eye is a modified camera obscura—a picture-making machine—changed the practice of science forever. Mechanical analogy, and the mechanical models that are generated by analogous reasoning, are among the handful of tools in the scientist's toolkit. Kepler's demonstration was the first concrete scientific realization of an analogy between things that exist in a pure state of nature and mechanical contrivances fashioned by hammer and tongs.

The mechanization of the human eye proved to be the first in a long series of mechanical analogies that fill the pages of the sciences of the early modern period. In short order, the English anatomist William Harvey (1578–1657) argued that the heart is a mechanical pump, the principal function of which is to violently propel blood into the arterial system. Kepler applied his mechanistic hypothesis to one particular organ, the eye, leaving its functioning in relation to the entire system of the body untouched. The French natural philosopher René Descartes (1596–1650) took the additional step, in a number of scientific treatises, of treating the entire living animal body as an inanimate machine. By focusing exclusively on the one question that had guided Kepler in his optical research—what physical motions follow from each preceding motion—Descartes created a methodological template for the mechanistic style of explanation so characteristic of modern science.

Perhaps the most dramatic illustration of the importance of the mechanization of nature is furnished by the microscopist studies carried out by Antoni Leeuwenhoek (1632–1723). Reasoning that organisms are merely mechanical devices that transfer motion, Leeuwenhoek explicitly identified life and mobility.[4] This insight guided his discovery of parasitic protozoa in 1674, though Leeuwenhoek had no idea what they actually were.

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4. Leeuwenhoek, Antoni van. 1681. "A Letter of Mr. Leeuwenhoeck to Dr. G," *Philosophical Collections*, **2**, pp. 3–5.

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[4] See Leeuwenhoek's letter of 1681 (*Philosophical Collections*, **2**, p. 4): "the semen of a Cock about a year old, which had been kept alone in a coop for five days, I found exceeding full of those Animals, at least 50,000 in the bigness of a Sand... [they] seem'd to have life by their motion..." (Leeuwenhoek 1681:4).