were skills hemmed, even policed, by the supervising scientist. Alfred Donné, a Parisian professor of medicine, not only praised the daguerreotypes made by Léon Foucault for Donné's 1844–45 microscopy atlas of bodily fluids but also listed Foucault as his coauthor on the title page. An effective illustrator came to embody an essential component of a composite scientific self—that part of the self capable of amplifying the moral "no" that nature whispered against the scientist's much-loved hypothesis. Increasingly in search of mechanical objectivity, scientists demanded images, machines, and illustrators that would not budge even to obey the scientist's own misdirected will.

This form of image-based scientific objectivity emerged only in the mid-nineteenth century. It appeared piecemeal, haltingly at first and then more intensively, positioned against idealizing, truth-to-nature images that themselves never died out completely. Like the spring melt of an ice-bound northern river, the change begins with a crack here and there; later come the explosive shears that throw off sheets of ice, echoing through the woods like shotgun blasts, followed eventually by a powerful rush of water that should not, for all its drama, obscure the myriad local changes that preceded it. Objectivity entered the practical domain of scientific atlas making slowly, throughout the 1840s, then gained momentum, until it could be found almost everywhere in the rush of the 1880s and 1890s.

Mechanical objectivity is strikingly distinct from earlier attempts to depict nature rightly in its methods (mechanical), ethics (restrained), and metaphysics (individualized). Although mechanical objectivity can be found in other scientific endeavors of the period, for the same reasons given earlier, we largely restrict our attention to atlases (along with various kinds of scientific handbooks). Here we see images of record designed to last for generations, concrete visual practices rather than oratory alone, and a long historical baseline that offers a window onto the joined shift of scientific ethos and epistemic virtues. Atlases in the age of objectivity taught simultaneously what there was and how scientists must restrain themselves in order to know. Although the ambition of objective vision never entirely replaced seeing as truth-to-nature, the atlases of mechanical objectivity stood for a new and powerful alternative form of scientific vision—blind sight.

By the late nineteenth century, mechanical objectivity was firmly installed as a guiding if not *the* guiding ideal of scientific representation across a wide range of disciplines. Ethics and epistemology fused as atlas makers strove to supervise not only their artists but also themselves. The image, the standard bearer for objectivity as it had been for truth-to-nature, marched before a relentless army attempting to replace willful depiction with mechanical reproduction. This mechanizing impulse was present at once in scientific technique and as moral vision; indeed, the two were inseparable. Nothing in the works of William Cheselden, Bernhard Siegfried Albinus, or Carolus Linnaeus quite prepares us for the fervor of self-denying ethics that animated the late nineteenth-century brief for mechanized representation. Image, author, and technique joined to create a new form of scientific sight.

Before proceeding to the broader category of automatic image production, we must address the form of automatic reproduction of the mid-nineteenth century that looms so large in retrospect: photography. Was the rush for objectivity simply due to a fascination with the new medium? Tempting as this simple explanation may be, the evidence militates against it. Far from being the unmoved prime mover in the history of objectivity, the photographic image did not fall whole into the status of objective sight; on the contrary, the photograph was also criticized, transformed, cut, pasted, touched up, and enhanced. From the very first, the relationship of scientific objectivity to photography was anything but simple determinism. Not all objective images were photographs; nor were all photographs considered *ipso facto* objective.

Photography as Science and Art

Photography was not one but several inventions. Developed in the 1820s and 1830s using different media and different methods, this family of techniques produced strikingly different visual results. Louis-Jacques-Mandé Daguerre, who had previously earned his living in Paris by painting illusionist panoramas, produced a method of chemically fixing an image from a camera obscura on a highly polished silver plate (or a copper plate coated in silver); the resulting image was a unique object, remarkable for its sharp-edged rendering of minute detail.[10] Working independently of Daguerre, the British polymath William Henry Fox Talbot experimented with paper treated with salt and silver nitrate, against which he pressed various flat objects, such as leaves and lace (and, later, camera obscura projections) to obtain a negative reminiscent of a watercolor or silhouette. Talbot initially called his invention "photogenic drawing"; he hoped it would replace the camera lucida for maladroit draftsmen like himself and perhaps also provide a way of reproducing paintings more cheaply and faithfully than engraving.[11] Talbot's countryman and friend the astronomer and physicist Sir John Herschel also saw the potential of photography as a means of making and copying pictures, but his chief interest in the process, to which he contributed numerous chemical improvements in correspondence with Talbot, was its potential to create a scientific instrument for the investigation of the properties of light, such as the detection of ultraviolet light (which was invisible to the naked eye). From the outset, scientific photography partook of this variety of means and ends.[12] (See figures 3.4 and 3.5.)

But scientific photography was only one species of nineteenth-century photography, and objective photography was in turn only one variety of scientific photography.[13] Starting with Herschel's experiments on ultraviolet light, photography was ingeniously deployed to make visible phenomena otherwise invisible to the human eye: light polarization, bullets streaking through the air, birds in flight.[14] In these cases, photographers used their images as instruments of scientific discovery. Photography could also be used to reproduce known phenomena, especially in the field of natural history, with an extraordinary density of detail, extending the precision of lithography.[15] The Swiss-born American naturalist Alexander Agassiz hoped photography would "give figures with an amount of detail which the great expense of engraving or lithographing would usually make impossible, even were it mechanically practicable."[16] (See figure 3.6.) In the service of discovery or detail, scientific photography need not lay claim to mechanical objectivity; sometimes quite the contrary. Our focus here is on that subspecies of scientific photography that did make such claims.

Both artists and scientists were quick to appreciate that photography could be used for registering details, but they split over its usefulness for promoting mechanical objectivity. In his sensational

Fig. 3.4. Arrangement of Fossil Shells. Louis-Jacques-Mandé Daguerre, 1837–1839, Conservatoire National des Arts et Métiers, Paris, daguerreotype (© Musée des arts et métiers-CNAM, Paris/Photo Studio, CNAM). The daguerreotype method exposed a polished silver plate coated with a layer of silver iodide to light in a camera, producing a latent image on the plate itself that became visible when the plate was fumed with mercury. This image, one of Daguerre's earliest, displays the remarkable finish and detail that fascinated contemporaries. But it could not be reproduced, except by engraving the daguerreotype itself, thereby destroying it. (Please see Color Plates.)

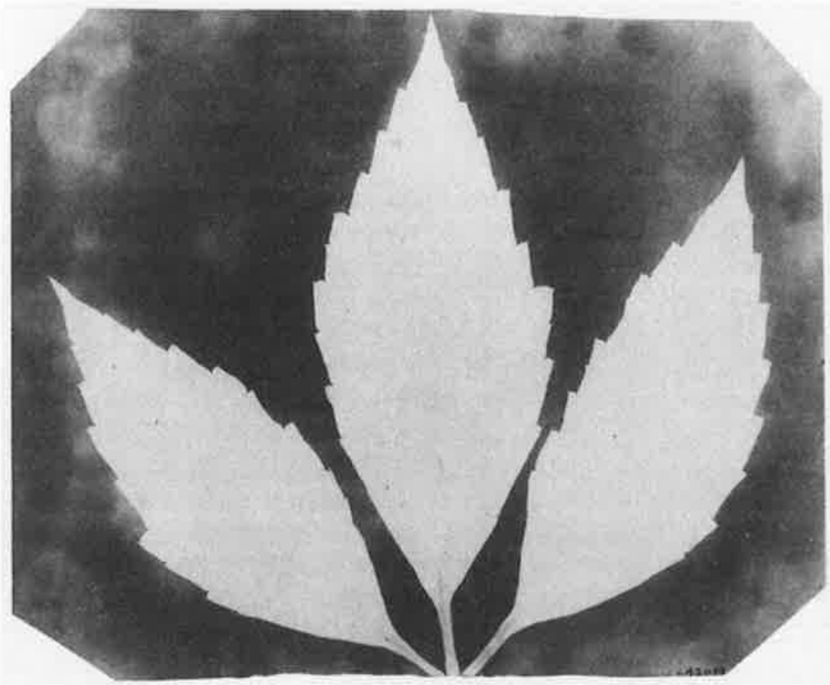


Fig. 3.5. Three Leaves. Photogram, William Henry Fox Talbot, 1839, Fox Talbot Museum, Lacock, England (courtesy of the British Library). This photogenic drawing negative resulted from the exposure to sunlight of paper impregnated with light-sensitive silver chloride. It is, in fact, a photogram: the leaves have been pressed directly against the paper under glass and exposed for about a quarter of an hour, turning the silver chloride into metallic silver. The resulting image could then be used, by repeating the process, to create a "positive" in which light and dark areas were reversed. Because of the long exposure times required by the process, images were often indistinct.

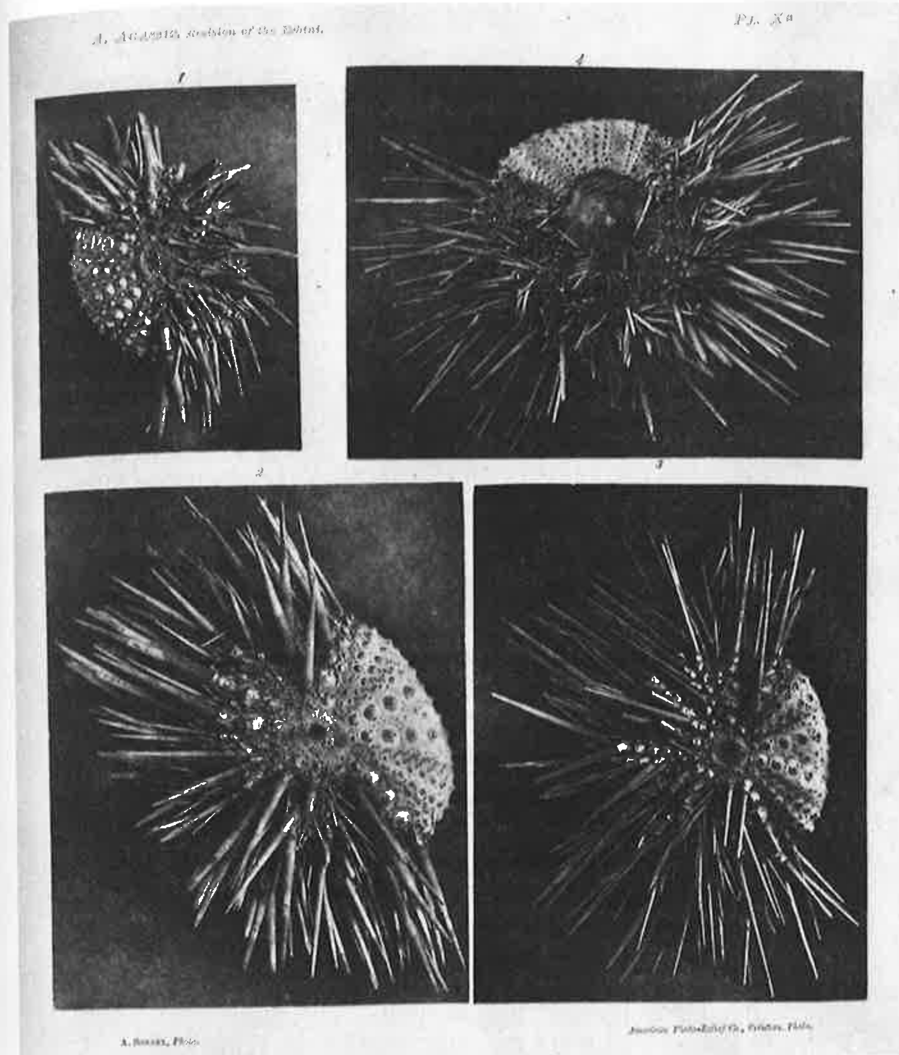


Fig. 3.6. Echinoderms in Detail. *Echinometra viridis* (fig. 1, *upper left*) and *Echinometra subangularis* (figs. 2–4), Woodburytypes, Alexander Agassiz, *Revision of the Echini* (Cambridge: Cambridge University Press, 1872–1874), pl. 10 (Museum of Comparative Zoology, Harvard University. Photograph © President and Fellows of Harvard College). Agassiz was among the first to use novel techniques like the Woodburytype and Albertype to mechanically reproduce photographic images for scientific publications. His survey of echini specimens held in collections throughout the world was illustrated with both lithographs and photographs, the latter made by Auguste Sonrel, who had also been Louis Agassiz's (Alexander's father) scientific illustrator and lithographer. The polished style that made Sonrel's natural-history lithographs famous was continued in the new medium. Here, scientific photography aimed at the near-effortless registration of detail, not at objectivity.

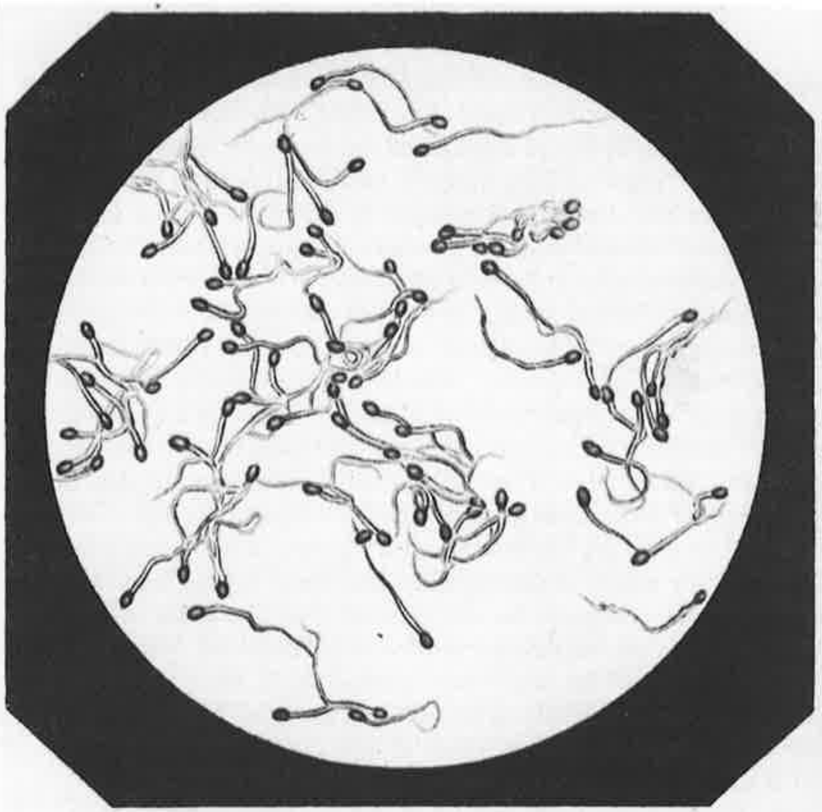
public presentation of Daguerre's invention to a joint public session of the Académie des Sciences and the Académie des Beaux-Arts in Paris on August 19, 1839, the French astronomer and physicist François Arago exclaimed over the possibilities the new medium offered as a scientific recording device and light detector; quoting the painter Paul Delaroche, he also envisioned photographs as a means of perfecting "certain conditions of art, so that they become for painters, even the most clever, a subject of observation and studies." Though scientists might want photography to provide them with a hands-off epistemology, and artists might be after photography's soft light, chiaroscuro, and richness of tone, there were those on both sides of the divide who admired the photograph's ability to render each and every tiny detail effortlessly. Arago imagined how useful the new invention would have been to the Napoleonic expedition to Egypt in order to record "the millions and millions of hieroglyphics" covering temples; Delaroche marveled at the "unimaginably exquisite finish" of daguerreotypes.[17]

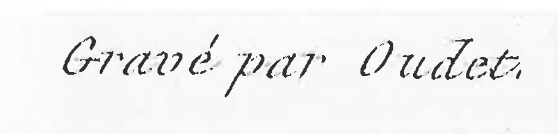
Because photography was at first conceived as a substitute for drawing and engraving, it was imagined as a marvel of saved artistic labor. "It is so natural," remarked Talbot, apropos of his "photogenic drawings," "to associate the idea of *labour* with great complexity and elaborate detail of execution, that one is more struck at seeing the thousand florets of an *Agrostis* [blossom] depicted . . . than one is by the picture of a large and simple leaf of an oak . . . but in truth the difficulty is the same."[18] Reviewers of Talbot's *Pencil of Nature* (1844–1846) compared one of the calotype images (images made on photosensitized high-quality writing paper) favorably to a seventeenth-century Dutch painting of a domestic scene. Apparently to allay skepticism, Talbot inserted slips in some copies of his book: "The plates of the present work are impressed by the agency of Light alone, without any aid whatever from the artist's pencil. They are the sun-pictures themselves, and not, as some persons have imagined, engravings in imitation."[19] The capacity to freeze detail with negligible labor remained a lauded feature of nineteenth-century photography for scientific illustration – and of photography as a new, better way to reproduce artwork.[20]

Very soon, however, another argument was advanced in favor of photography as a distinctly *scientific* medium. The automatism of the

photographic process promised images free of human interpretation – *objective* images, as they came to be called.[21] The multiple inventors of photography had all emphasized the wondrous spontaneity of the images, "impressed by nature's hand," in Talbot's phrase.[22] Automatism and objectivity converged in one of the earliest scientific atlases to boast of its use of photographic images, Donné's *Cours de microscopie complémentaire des études médicales* (*Course in Microscopy to Complement Medical Studies*, 1844–1845). Alongside drawings of microscopic views of blood, milk, semen, and other bodily fluids, Donné included photographs "exactly representing the objects as they appear, and independently of all interpretation; to achieve this result, I did not want to trust either my own hand or even that of a draftsman, always more or less influenced by the theoretical ideas of the author; profiting from the marvelous invention of the daguerreotype, the objects are reproduced with rigorous fidelity, unknown until now, by means of photographic processes." Donné hoped his images would extinguish the oft-repeated objection of his medical colleagues that the microscope showed only "illusions." Who could resist this wonder? An object that "painted itself, fixed itself upon the plate without the help of art, without the least contribution of the hand of man, by the sole effect of light, and always identical in the least details."[23] (See figures 3.7 and 3.8.)

In contrast to the argument from detail, the argument from objectivity undercut the artistic claims of photography. The Salon of 1859, the first official Parisian art exhibition to include photographs, divided critics. Charles Baudelaire railed against slavishly naturalistic landscapes and the still more slavish artistic photography, deploring an art so lacking in self-respect as to "prostrate itself before external reality." To "copy nature" was to forsake not only the imagination but also the individuality Baudelaire and other Romantic critics believed essential to great art: "The artist, the true artist, must never paint except according to what he sees or feels. He must be *really* faithful to his own nature." Photography might be admirable in the hands of the naturalist or the astronomer, but the "absolute material exactitude" sought by science was inimical to art.[24] Reviewing the same exhibition, Louis Figuier (a professor at the Ecole de Pharmacie in Montpellier and science journalist and popularizer) defended photography as art, citing the photographer's individual style and "sentiment." No



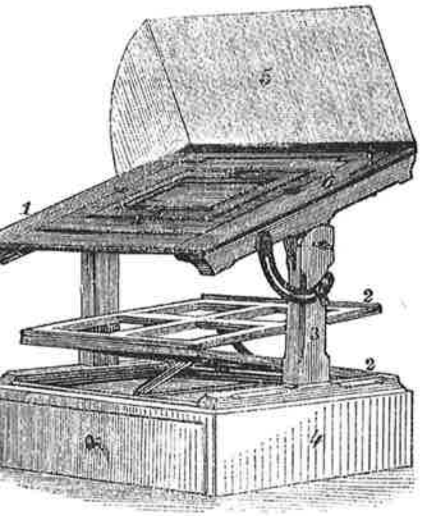


Figs. 3.7, 3.8. Mechanical Objectivity Before Mechanical Reproduction. Bat spermata, Alfred Donné and Léon Foucault, *Cours de microscopie complémentaire des études médicales: Anatomie microscopique et physiologie des fluides de l'économie* (Paris: Baillère, 1844–1845), atlas, pl. 15, fig. 62 (*top*), magnified detail (*bottom*). This figure is labeled as "taken by means of a microscope daguerreotype by L. Foucault," but it is, in fact, a lithograph based on the daguerreotype, since the latter could not be mechanically reproduced. The magnified detail shows the signature of the lithographer Oudet. Until the 1880s, however, lithographs or wood engravings (see fig. 3.12) copied from photographs were often assumed to carry the latter's imprimatur of objectivity.

one, Figuier was certain, could mistake the full-blooded work of a French photographer for the wan images of the English. How could such originality be reduced to a "simple mechanism"?[25]

Opposed as Baudelaire and Figuier were on whether photography qualified as art, they agreed entirely on the criterion for defining art. Genuine art must bear the stamp of the maker's individuality and imaginative interpretation; no "mechanical" copy of nature could qualify. This was the same criterion that scientists invoked to distinguish artistic from scientific images, albeit with reversed valuation. By the 1860s, the term "mechanical photography" was being used in opposition to aesthetic photography (for example, in portraiture).[26] It was a sign of the new opposition of science and art that the mixing of genres of objective (scientific) and subjective (artistic) photography could provoke scandal, as when it was revealed that the California photographer Eadweard Muybridge, who as a commercial photographer would have routinely retouched his landscapes, had done the same for his famous photographs of a galloping horse, touted as a scientific rebuttal to artistic misconceptions.[27] Whereas photography trade journals and handbooks were full of advice on how to retouch photos and the best way to secure copyright protection for artistic property (see figure 3.9), self-consciously "mechanical" photography eschewed all such aesthetic interventions.[28] The mechanical, objective photograph had allegedly been traced by "nature's pencil" alone, and nature was entirely artless.

Were such claims anything more than rhetorical flourishes? Historians of photography point out the considerable skill and judgment required to make a photograph; nature emphatically does not paint itself by itself.[29] Historians of art call attention to the aesthetic context that shaped the making and seeing of photographs, even scientific and medical ones.[30] Historians of science note that nineteenth-century photographers and scientists and their audiences were perfectly aware that photographs could be faked, retouched, or otherwise manipulated.[31] (See figures 3.10 and 3.11.) Almost any article of the period on how to make a photograph for scientific purposes gives pages of detailed, difficult instructions; it required effort and artifice to persuade nature to imprint its image. In what sense, then, could these images be described by atlas makers as objective and mechanical?



Figs. 3.9, 3.10, 3.11. Artful Photography. Retouching apparatus, Alois von Reiter, "Retouchirpult für Negativs," *Photographische Correspondenz* 2 (1865), pp. 17–18 (*top*); girl in winter clothes and retouched snowfall, H. Collischon, 1897, from Timm Starl, *Im Prisma des Fortschritts: Zur Fotografie des 19. Jahrhunderts* (Marburg, Germany: Jonas Verlag, 1991), p. 52 (*bottom left and right*). Professional journals for photographers often featured devices like this one for retouching negatives – in this case, by directing light to the desired spot on the negative by means of a mirror. Portraits could be "improved" and special effects added, as in the case of the artificial snowfall shown here. Late nineteenth-century commercial photographers – and their customers – were fully aware that photographs could be manipulated.

When nineteenth-century scientists called for objective photographs to supplement, correct, or replace subjective drawings, they did not, in the first instance, fear imposture, except perhaps in cases such as inquiries into spiritualism.[32] Rather, they worried about a far more subtle source of error, one more authentically subjective and specifically scientific: the projection of their own preconceptions and theories onto data and images. Therefore, the fact that photographs may require filters, sophisticated lenses, special preparation of the object, long exposure time, or darkroom manipulation was irrelevant to the issue of objective or indexical depiction, so long as none of these operations colluded in the scientist's wishful thinking. Often, a division of labor in which technicians supposedly ignorant of the theoretical stakes made and developed the photographs was proposed as a precaution. Even in the late nineteenth century, after photogravure techniques made it possible to reproduce photographs cheaply and accurately, scientific drawings still survived. Photographs were preferred for subject matter that might arouse skepticism – because it was rare or spectacular or controversial. Manuals on scientific photography recommended that ethnographers use photographs rather than drawings, because European artistic conventions might otherwise distort non-European bodies: "The draftsman, whatever might otherwise have been his talent, did not know how to see and always drew people of the white race whom he later colored in black or red."[33] (See figure 3.12.) Similarly, the persistent visual ambiguities of microscopy demanded photographic illustration, to forestall the observer's tendency "to insert involuntarily his hypothetical explanation into the depiction."[34] A photograph was deemed scientifically objective because it countered a specific kind of scientific subjectivity: intervention to aestheticize or theorize the seen.

The term "mechanical" must also be understood in context, a task made more difficult by the pervasive conflation of two conceptually and historically distinct processes via the single phrase "mechanical reproduction."[35] In one sense, the phrase refers to the automatic production of an image without the interventions of an artist. In another sense, it refers to the "automatic" multiplication of images (which could be lithographs or engravings as well as photographs) so that they could be accurately, widely, and inexpensively

Fig. 3.12. "Polynesian Types." Wood engraving, E. Hamy, "Polynésiens et leur extinction," *La nature* 3 (1875), pp. 161–63. Highly illustrated popular science journals like *La nature* used a range of reproductive media, including lithographs, engravings, and – in order to reproduce photographs for mass print runs – wood engravings like this one, done after a photograph by Commander Miot. *La nature* typically turned to wood-engraved photographs (as opposed to lithographed drawings) when the object was exotic (as in this case), singular (for example, conjoined twins), or spectacular (for example, a solar eclipse).

disseminated. Although photographs became prototypical of the first sense of mechanical, they did not fall under the second until the 1880s, when new techniques, such as the Woodburytype and half-tone photolithography, made mass printings of photographs practicable.[36] Earlier published photographs had to be either printed by hand from the negative or reproduced through woodcut, engraving, or lithography. Look closely at the "microphotograph" printed in Donné's 1845 atlas (figure 3.7): it is, in fact, an engraving, signed by the engraver Oudet. Indeed, "photographs" in the scientific and the popular press were often wood engravings from photographs (as in figure 3.12), carrying the assurances that they had not been retouched.[37] As the science popularizer Gaston Tissandier wrote in 1874, only with the means to insure "the inalterability and the indefinite multiplication" of photographs would Daguerre's mechanical art be complete.[38]

When the term "mechanical" was applied to photographs prior to *circa* 1880, it referred to the process by which light imprinted an image on specially prepared metal, paper, or glass. Because the image was likened to a drawing or engraving, the absent human hand implied by the word "mechanical" was that of the artist, not the photographer. Fixated upon the delineation of the image itself, early photographers and their audiences compared photography to drawing. Even if aided by a camera obscura or a camera lucida, the draftsman must still trace the projected image onto paper – no easy task, as Talbot had discovered to his chagrin. However arduous preparing the apparatus, composing the picture, operating the camera, and developing the image were, the process was (in the particular cultural context of the time) perceived as requiring negligible labor compared to the task of putting pencil to paper. This was why the image counted as "mechanical."

"Mechanical" had long referred to an inferior brand of human labor executed with the hands, not the head (Shakespeare's "rude mechanicals"). As the Industrial Revolution transformed work in nineteenth century, "mechanical" retained its pejorative, manual associations, but now referred dismissively to actual machines and the workers who tended them, suggesting they were repetitive, mindless, automatic.[39] Eighteenth-century scientific atlas makers had longed for artists talented enough to render kangaroos and crystals truthfully and elegantly but pliant enough to bow to the naturalist's judgment: the clever but docile servant. Nineteenth-century atlas makers derived their image-making ideals from the factory rather than the atelier. As the British mathematician and political economist Charles Babbage put it apropos of the calculation of logarithms, what was wanted was a mechanical "substitute for one of the lowest operations of the human intellect."[40] It was, he thought, but a short step from unlettered drudges to unthinking machines.[41] Haunted by anxieties about their own subjective representations, scientists discovered the ethical-epistemic consolations of the mechanical image, in which, by a supreme act of self-effacing will – or by deploying procedures and machines that bypassed the will – they could ensure that no intelligence would disturb the image.

Automatic Images and Blind Sight

Scientific photography held out a promise of automaticity, although it clearly could not do without real human hands and heads. Conversely, there were numerous forms of procedural, mechanical reproduction (such as tracing or even highly supervised wood-engraving) that were not photographic. Most important, however, the ethical-epistemic stance that scientists began to take after the 1830s increasingly insisted on a ferocious devotion to depicting what was seen on the surface, not what was deduced or interpreted. This emphasis was not simply the reflection of this or that bit of the history of photography. In short, the photographic and the mechanical were *not* coextensive, and the shift from depiction that celebrated intervention to one that disdained it did not come about *because* of photography.

For the scientific atlas makers of the late nineteenth century, the machine was both a literal and a guiding ideal. Machines assisted where the will failed, where the will threatened to take over, or where the will pulled in contradictory directions. Machine-regulated image making was a powerful and polyvalent symbol, fundamental to the new scientific goal of objectivity.

First, the machine's ability to turn out thousands of identical objects linked it with the standardizing mission of the atlas. The machine provided a new model for the perfection toward which working objects of science might strive. Echoes of the popular fascination with the ubiquity and standardized identity of manufac-

tured goods crop up throughout nineteenth-century scientific literature. Following Herschel, James Clerk Maxwell even used the mass production of identical bullets as a metaphor for atoms too similar to be distinguished.[42] The identical form of bullets suggested a maker – and for Maxwell the identical form of atoms pointed to a Maker. Though often lost on moderns who fetishize the handmade, there was, in the nineteenth century, an aesthetic pleasure in identical objects.

Second, as it took the form of new scientific instruments, the machine embodied a positive ideal of the observer, but one that contrasted sharply with the eighteenth-century genius of observation. The machine was patient, indefatigable, ever alert, probing beyond the limits of the human senses. Once again, scientists took their cue from popular rhetoric on the wonder-working machine. Babbage rhapsodized about the advantages of mechanical labor for tasks that required endless repetition, great force, or exquisite delicacy. He was especially enthusiastic about the possibilities of using machines to observe, measure, and record, for they counteracted all-too-human weaknesses: "One great advantage which we may derive from machinery is from the check which it affords against the inattention, the idleness, or the dishonesty of human agents."[43] Just as manufacturers admonished their workers with the example of the more productive, more careful, more skilled machine, scientists admonished *themselves* with the more attentive, more hard-working, more honest instrument.

Third, and most significant for our purposes, the machine seemed to offer images uncontaminated by interpretation. This promise was never actually fulfilled – neither the camera obscura nor smoked-glass tracings nor the photograph could altogether rid the atlases of interpretation. Nonetheless, the scientists' continuing claim to such judgment-free representation is testimony to the intensity of their longing for the perfect, "pure" image. In this context, the machine stood for authenticity: it was at once observer and artist, free from the inner temptation to theorize, anthropomorphize, beautify, or interpret nature. What the human observer could achieve only by iron self-discipline, the machine effortlessly accomplished – such, at least, was the hope. Here the machine's constitutive and symbolic functions blur, for the machine seemed at once a means to and a symbol of mechanical objectivity.