LORRAINE DASTON AND PETER GALISON

The Image of Objectivity

The Talismanic Image

IN 1878 FRENCH PHYSIOLOGIST E. J. Marey, surveying the panoply of visual methods in the sciences, concluded: "There is no doubt that graphical expression will soon replace all others whenever one has at hand a movement or change of state—in a word, any phenomenon. Born before science, language is often inappropriate to express exact measures or definite relations." Others might cry out to salvage the "insights of dialectic," the "power of arguments," the "insinuations of elegance," or the "flowers of language," but their protestations were lost on Marey, who dreamed of a wordless science that spoke instead in high-speed photographs and mechanically generated curves; in images that were, as he put it, in the "language of the phenomena themselves."[1]

"Let nature speak for itself" became the watchword of a new brand of scientific objectivity that emerged in the latter half of the nineteenth century. At issue was not only accuracy but morality as well: the all-too-human scientists must, as a matter of duty, restrain themselves from imposing their hopes, expectations, generalizations, aesthetics, even ordinary language on the image of nature. Where human self-discipline flagged, the machine would take over. Wary of human intervention between nature and representation, Marey and his contemporaries turned to mechanically produced images to eliminate suspect mediation. They enlisted polygraphs, photographs, and a host of other devices in a near-fanatical effort to create atlases—the bibles of the observational sciences—documenting birds, fossils, human bodies, elementary particles, and flowers in images that were certified free of human interference.

This essay is an account of the moralization of objectivity in the late nineteenth and early twentieth centuries as reflected in scientific image making. We will use scientific atlases from diverse fields (anatomy, physiology, botany, paleontology, astronomy, X-rays, cloud-chamber physics) and from a span of several centuries (eighteenth to twentieth) to chart the emergence and nature of new conceptions of objectivity and subjectivity. We do not intend anything approaching a comprehensive survey of the genre and history of scientific atlases; rather our attention will be primarily focused on the latter half of the nineteenth century, when atlases proliferated in number and kind, purveying images of everything from spectra to embryos,[2] and when atlases became manifestos for the new brand of scientific objectivity. In order to highlight the novelty of this form of objectivity, we shall contrast it to the ideals and practices of earlier atlas makers.

What we will call "noninterventionist" or "mechanical" objectivity is only one of several elements that historical pressures have fused together into our current, conglomerate notion of objectivity. Modern objectivity mixes rather than integrates disparate components, which are historically and conceptually distinct. Each of these components has its own history, in addition to the collective history that explains how all of them came to be amalgamated into a single, if layered, concept. This layering accounts for the hopelessly but interestingly confused present usage of the term *objectivity*, which can be applied to everything from empirical reliability to procedural correctness to emotional detachment. As historians of objectivity, we will not be concerned with recent controversies over whether objectivity exists and, if so, which disciplines have it. We believe, however, that a history of scientific objectivity may clarify these debates by revealing both the diversity and contingency of the components that make up the current concept. Without knowing what we mean and why we mean it in asking such questions as "Is scientific knowledge objective?," it is hard to imagine what a sensible answer would look like.

In what follows we address the history of only one component of objectivity, but we believe that this component reveals a common pattern, namely the negative character of all forms of objectivity. Objectivity is related to subjectivity as wax to seal, as hollow imprint to the bolder and more solid features of subjectivity. Each of the several components of objectivity opposes a distinct form of subjectivity; each is defined by censuring some (by no means all) aspects of the personal. The history of the various forms of objectivity might be told as how, why, and when various forms of subjectivity came to be seen as *dangerously* subjective. Mechanical objectivity was indifferent to the subjectivity of, for example, personal idiosyncrasies; rather, it combatted the subjectivity of scientific and aesthetic judgment, dogmatic system building, and anthropomorphism. It took on a moral aspect because these aspects of subjectivity were thought amenable to control through self-restraint; it centered on the scientific image because images were thought least vulnerable to such subjective intrusions—protective charms against ambiguity, bad faith, and system building.

The problem for nineteenth-century atlas makers was not a mismatch between world and mind, as it had been for seventeenth-century epistemologists, but rather a struggle with inward temptation. The moral remedies sought were those of self-restraint: images mechanically reproduced and published warts and all; texts so laconic that they threaten to disappear entirely. Seventeenth-century epistemology aspired to the viewpoint of angels; nineteenth-century objectivity aspired to the self-discipline of saints. Although mechanical objectivity effaces some features of the scientist, it demands other traits; it has a positive as well as a negative sense. In its negative sense, this ideal of objectivity attempts to eliminate the mediating presence of the observer: some versions of this ideal rein in the judgments that select the phenomena, while others disparage the senses that register the phenomena, and still others ward off the theories and hypotheses that distort the phenomena. In its positive sense, mechanical objectivity requires painstaking care and exactitude, infinite patience, unflagging perseverance, preternatural sensory acuity, and an insatiable appetite for work. The phenomena never sleep and neither should the observer; neither fatigue nor carelessness excuse a lapse in attention that smears a measurement or omits a detail; the vastness and variety of nature require that observations be endlessly repeated.

What unites the negative and positive sides of mechanical objectivity is heroic self-discipline: on the one side, the honesty and self-restraint required to foreswear judgment, interpretation, and even the testimony of one's own senses; on the other, the taut concentration required for precise observation and measurement, endlessly repeated around the clock. It is a vision of scientific work that glorifies the plodding reliability of the bourgeois rather than the moody brilliance of the genius. It is also a profoundly moralized vision, of self-command triumphing over the temptations and frailties of flesh and spirit. Like almost all forms of moral virtuosity, it preaches asceticism, albeit of a highly specialized sort. The temptations and frailties had less to do with envy, lust, gluttony, and other standard sins than with seeing *as* rather than seeing *that*; with witting and unwitting tampering with the "facts." But in the view of late-nineteenth-century scientists, these professional sins were almost as difficult to combat as the seven deadly ones, and required a stern and vigilant conscience.

Mechanized science seems at first glance incompatible with moralized science, but in fact the two were closely related. While much is and has been made of those distinctive traits—emotional, intellectual, and moral—that distinguish humans from machines, it was a nineteenth-century commonplace that machines were paragons of certain human virtues. Chief among these virtues were those associated with work: patient, indefatigable, ever-alert machines would relieve human workers whose attention wandered, whose pace slackened, whose hand trembled. Scientists praised automatic recording devices and instruments in much the same terms. As the photograph promised to replace the meddling, weary artist, so the self-recording instrument promised to replace the meddling, weary observer. It was not simply that these devices saved the labor of human observers; they surpassed human observers in the laboring virtues: they produced not just more observations, but better observations. Of course, strictly speaking, no merit attached to these mechanical virtues, for their exercise involved neither free will nor self-command. But the fact that the machines had no choice but to be virtuous struck scientists distrustful of their own powers of self-discipline as a distinct advantage. Instead of freedom of will, machines offered freedom from will—from the willful interventions that had come to be seen as the most dangerous aspects of subjectivity. If the machine was ignorant of theory and incapable of judgment, so much the better, for theory and judgment were the first steps down the primrose path to intervention. In its very failings, the machine seemed to embody the negative ideal of noninterventionist objectivity, with its morality of restraint and prohibition.

In this essay, we argue that this form of scientific objectivity emerged only in the mid nineteenth century and is conceptually distinct from earlier attempts to be "true to nature" in its methods (mechanical), its morals (restrained), and its metaphysics (individualized). Although mechanical objectivity can be found in almost every scientific endeavor, we shall largely restrict our attention to atlases (and related volumes) for two reasons: first, the strong association between the visual and the factual made atlases prime bearers of the new objectivity; and second, the conflict between the mission of all atlases to characterize (not simply inventory) phenomena on the one hand, and the ban on interpretation on the other, shows how high a price scientists were prepared to pay for that objectivity. The remainder of the essay is divided into three parts. First, we use earlier, alternative approaches to creating pictures that were true to nature, but not objective in the mechanical sense, to pry apart the ideals of verisimilitude and objectivity. Second, we examine the attraction that techniques of mechanical reproduction held for advocates of the new objectivity, and their ultimate disappointment with these techniques. Third, we conclude with some reflections on how and why objectivity came to be moralized.

Truth to Nature

Historians and, especially, philosophers of science routinely use *objectivity* as a panhistorical honorific, awarding it to this or that discipline as it comes of scientific age but paying little attention to when objectivity itself developed, or to what served as its source. Before the several components of objectivity emerged and merged in the nineteenth and early twentieth centuries, other ideals guided scientific practice. Among these was the precept of truth to nature, and nowhere was this precept more revered than among scientific atlas makers, who believed their images to be the closest possible rendering of what truly is. The choice of which images best represented "what truly is" engaged atlas makers in ontological and aesthetic judgments that mechanical objectivity later forbade. In this section, we first explain the nature and functions of scientific atlases and then survey the various means by which eighteenth-century atlas makers reconciled these functions to their mandate to create images true to nature.

From the sixteenth century on, practitioners of the sciences of the eye have prepared editions of their designated phenomena in the form of atlases, profusely illustrated volumes of carefully chosen observables—bodily organs, constellations, flowering plants, instrument readings—depicted from a carefully chosen point of view.[3] The purpose of these atlases was and is to standardize the observing subjects and observed objects of the discipline by eliminating idiosyncrasies—not only those of individual observers but also those of individual phenomena. Because we moderns habitually oppose our brand of objectivity to the subjectivity of individuals, we fret most about idiosyncratic subjects: their "personal equations," their theoretical biases, their odd quirks. But idiosyncratic objects pose at least as great a threat to communal, cumulative science, for nature seldom repeats itself, variability and individuality being the rule rather than the exception. The atlas aims to make nature safe for science; to replace raw experience—the accidental, contingent experience of specific individual objects—with digested experience.

All sciences must deal with this problem of selecting and constituting "working objects," as opposed to the too plentiful and too various natural objects. This is a problem anterior to the problem of reference, and posterior to the problem of selecting domains of phenomena worthy of study. The problem of reference deals with how concepts adhere to the world. If working objects are not raw nature, they are not yet concepts, much less conjectures or theories; they are the materials from which concepts are formed and to which they are applied. The problem of selection deals with which phenomena are key to the essence of things. Working objects are constituted after this choice of phenomena has been made—after, for example, seventeenth-century mechanicians had selected pendula as more revealing of the essence of motion than air currents, or twentieth-century evolutionary biologists had selected banded snails as more revealing of the interplay between natural selection and random drift than chimpanzees. Working objects can be atlas images, type specimens, or laboratory processes—any manageable, communal representatives of the sector of nature under investigation. No science can do without such standardized working objects, for unrefined natural objects are too quirkily particular to cooperate in generalizations and comparisons.

Atlases supply working objects to the sciences of the eye. For initiates and neophytes alike, the atlas trains the eye to pick out certain kinds of objects as exemplary (e.g., this "typical" liver rather than that one with hepatitis) and to regard them in a certain way (e.g., using the Flamsteed rather than the Ptolemaic celestial projection). To acquire this expert eye is to win one's spurs in most empirical sciences; the atlases drill the eye of the beginner and refresh the eye of the old hand. In the case of atlases that present images from new instruments, such as the X-ray atlases of the early twentieth century, everyone in the field addressed by the atlas must begin to learn to "read" anew. Because atlases habituate the eye, they are perforce visual, even in those disciplines where other sensations play a significant role (e.g., texture in botany, which refines the lay *hairy* into as many distinct terms as Eskimos allegedly do *snow*). Whatever the amount and avowed function of the text in an atlas, which varies from long and essential to nonexistent and despised, the illustrations command center stage. Usually displayed in giant format, meticulously drawn and engraved, and expensively produced, they are the *raison d'être* of the atlases. Indeed, to call them "illustrations" at all is to belie their primacy, for it suggests that their function is merely ancillary, to illustrate a text or theory. Some early astronomical atlases do use the figures as genuine illustrations, to explicate rival cosmologies.[4] But in most atlases from the eighteenth century on, the pictures are the alpha and omega of the genre.

In addition to their primary function of standardizing objects in visual form, atlas pictures served other purposes in the natural sciences. In part, they served the cause of publicity for the scientific community, by preserving what is ephemeral and distributing what is rare or inaccessible to all who can purchase the volume, not just the lucky few who were in the right place at the right time with the right equipment.[5] In part, pictures served the cause of memory, for, as the atlas makers never tire of repeating, images are more vivid and indelible than words. And in part, especially for nineteenth-century authors, pictures served the cause of incorruptibility: they would check the impulse to infuse observation with a pet theory, and endure as facts for tomorrow's researchers long after today's theories and systems had gone the way of phlogiston.

Consider for example French pathologist Jean Cruveilhier's pioneering atlas, *Anatomie pathologique du corps humain* (1829–35). Cruveilhier was at pains to argue his colleagues out of their preference for verbal descriptions, however "graphic," of diseased organs. In contrast to normal anatomy, in which there exist abundant opportunities to observe this or that organ "a second, a third, a twentieth time," the opportunities for the pathologist are rare and fleeting: "A lost occasion may perhaps never recur." Even an observer with the eyes of a lynx and the memory of an elephant cannot "fix the fugitive features, if he does not engrave them as if in bronze, so as to be able to represent them at will, to put them into relation with analogous facts." Simply pickling the anomalous organ in alcohol is a poor substitute for a faithful drawing of a fresh cadaver, since changes of form and color "denature them" and in any case such a specimen "profits only a small number" of observers. Lacking the repetitive experience of normal anatomy, the pathologist is doubly aware of the psychological truth that a picture "constantly reproduces the same image," creating a vivid, indelible memory. Finally, the faithful drawing, like nature, outlives ephemeral theories—a standing reproach to all who would, whether "by their error or bad faith," twist a fact to fit a theory.[6] This last function of the atlas image as sentinel was new to the nineteenth century, and was a portent of the mechanical objectivity to come.

What was not new to nineteenth-century atlases was the dictum "truth to nature": there is no atlas in any field that does not pique itself on its accuracy, on its fidelity to fact. But in order to decide whether an atlas picture is an accurate rendering of nature, the atlas maker must first decide what nature is. All atlas makers must solve the problem of choice: Which objects should be presented as the standard phenomena of the discipline, and from which viewpoint? In the late nineteenth century, these choices triggered a crisis of anxiety and denial, for they seemed invitations to subjectivity, but in earlier periods atlas makers faced up to their task with considerably more confidence and candor. This is not to say that they abandoned themselves to subjectivity, in the pejorative sense of rendering specimens as their personal whims decreed. On the contrary, they were well nigh maniacal in their precautions to ensure the accuracy of their figures, according to their own lights. However, they did conceive the exercise of judgment in the selection of "typical," "characteristic," "ideal," or "average" images to be not only inevitable but laudable, the essence of the atlas maker's mission. In their view, whatever merit their atlases possessed derived precisely from these judgments, and from the breadth and depth of experience in their field upon which those judgments rested. Atlas makers committed to mechanical objectivity resisted interpretation; their predecessors, committed solely to truth to nature, relished it.

These early atlas makers, while proud of their interpretive skills, did not all interpret the notion of "truth to nature" the same way. The words *typical, ideal, characteristic,* and *average* are not precisely synonymous, even though they all fulfilled the same standardizing purpose. Examples from the earlier literature will make their differences on how to be true to nature more vivid. A schematic typology of earlier atlases will show that truth to nature was both a possible and variegated ideal long before the advent of mechanical objectivity. The categories and instantiating examples span the late seventeenth to the early nineteenth centuries, with a rough chronology that moves from types and ideals to characteristic individuals to individuals *tout court.* However, this chronology reflects a tendency rather than a clear-cut periodization, and several of the categories coexist in time. These alternative ways of being true to nature suffice to show that concern for accuracy does not necessarily imply concern for objectivity; further, the two concerns came into conflict when mechanical objectivity threatened to undermine the primary goals of atlases in representing nature.

In eighteenth-century atlases, "typical" phenomena were those that harkened back to some underlying *Typus* or "archetype," and from which individual phenomena could be derived, at least conceptually. The typical is rarely if ever embodied in a single individual; nonetheless, the researcher can intuit it (see the *Urpflanze* of fig. 1) from cumulative experience. As Goethe wrote of his archetype of the animal skeleton:

> Hence, an anatomical archetype [*Typus*] will be suggested here, a general picture containing the forms of all animals as potential, one which will guide us to an orderly description of each animal. . . . The mere idea of an archetype in general implies that no particular animal can be used as our point of comparison; the particular can never serve as a pattern [*Muster*] for the whole.[7]

This is not to say that the archetype wholly transcends experience, for Goethe claims that it is derived from and tested by observation. However, observations in search of the typical must always be made in series, for single observations made

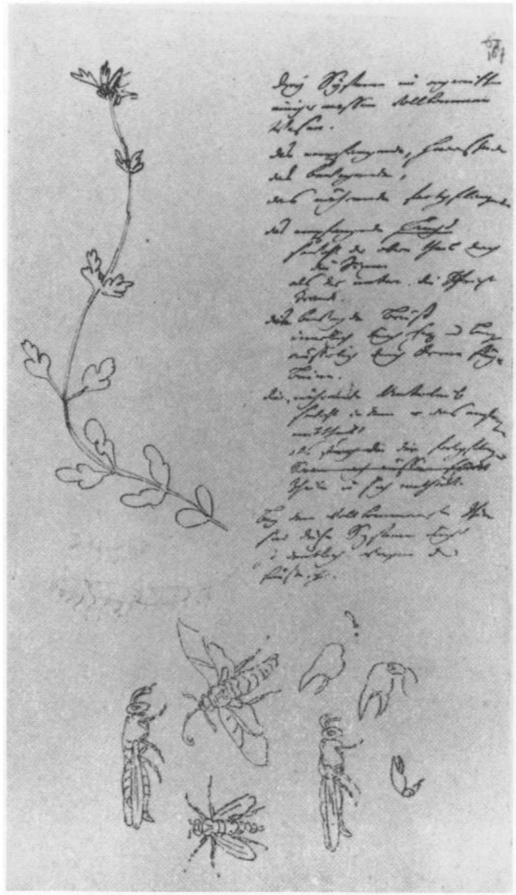


FIGURE 1. The *Urpflanze*, Goethe's sketch of the "*typus* of a higher plant and insect," meant to represent no plant in particular but rather the morphological prototype from which all higher plants can, in principle, be derived. Reproduced from K. Lothar Wolf et al., eds., *Goethe: Die Schriften zur Naturwissenschaft* (Weimar, 1947–1986), vol. 9a, *Zur Morphologie*, ed. Dorothea Kuhn, pl. 9.

by one individual are highly idiosyncratic: "For the observer never sees the pure phenomenon [*reine Phänomen*] with his own eyes; rather, much depends on his mood, the state of his senses, the light, air, weather, the physical object, how it is handled, and a thousand other circumstances."[8] Thus for Goethe, writing before the advent of mechanical objectivity, the act of "definition" required to distill the typical from the variable and accidental is not a slide into subjectivity but rather a precaution against it.

Typical images dominate the anatomical atlases of the seventeenth through mid nineteenth centuries, but not always in the unalloyed form celebrated by Goethe. Two important variants, which we shall call the "ideal" and the "characteristic," also stamp atlas illustrations of this earlier period. Briefly put, the "ideal" image purports to render not merely the typical but the perfect, while the "characteristic" image locates the typical in an individual. Both ideal and characteristic images standardize the phenomena, and the fabricators of both insisted upon pictorial accuracy. But the ontology and aesthetics underlying each contrasted sharply, as a few examples will show.

With the collaboration of Dutch artist and engraver Jan Wandelaar,[9] Bernhard Albinus, professor of anatomy at Leyden, produced several of the most influential anatomical atlases of the idealized sort, including the *Tabulae sceleti et musculorum corporis hominis* (1747). In the preface to this work, Albinus described his goals and working methods in considerable detail, and in terms that seem self-contradictory by the standards of mechanical objectivity: he is at once committed to the most exacting standards of visual accuracy in depicting his specimens, and to creating images of "the best pattern of nature" (see fig. 2). To the former end, he goes to lengths until then unheard of among anatomists to meticulously clean, reassemble, and prop up the skeleton, checking the exact positions of the hip bones, thorax, clavicles, and so on, by comparison with a very skinny man made to stand naked alongside the prepared skeleton. (This test cost Albinus some anxiety as well as time and trouble, for the naked man demanded a fire to ward off the winter chill, greatly accelerating the putrefaction of the skeleton.) Still worried lest the artist err in the proportions, Albinus erected an elaborate double

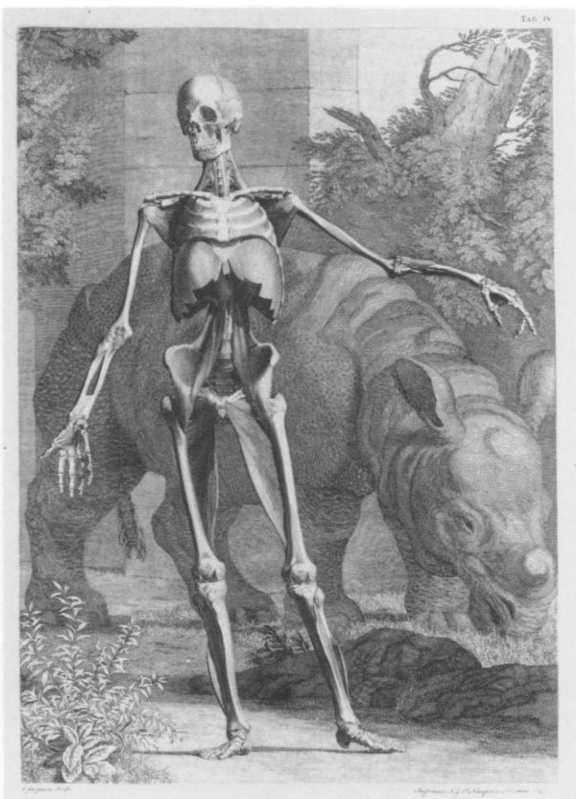


FIGURE 2. Albinus, "Fourth Muscular Table," in *Table of the Skeleton and Muscles of the Human Body* (London, 1749). The London publishers apparently had Wandelaar's original illustrations reengraved by several hands; this one is signed C. Grignion and G. Scotin. Albinus permitted his artist to make "ornaments" to fill up the page, preserve the light and shade of the figures, and to "make them [the tables] more agreeable." This two-and-a-half-year-old rhinoceros, viewed in 1742, was inserted into the background on these latter grounds: "We thought the rarity of the beast would render these figures of it more agreeable than any other ornament."

grid, one mesh at 4 rhenish feet from the skeleton and the other at 40, and positioned the artist precisely at that point where the struts of the grids coincided to the eye, drawing the specimen square by square, onto a plate Albinus had ruled with a matching pattern of "cross and streight [*sic*] lines." This procedure, suggested by Albinus's Leyden colleague, the physicist W. 'sGravesande, is strongly reminiscent of Alberti's instructions for drawing in perspective, and amounts to a kind of remote tracing of the object. The fixed viewpoint of the artist and the mapping of visual field onto plane of representation by means of the grids subject the artist to an exacting discipline of square-to-square correspondence in the name of naturalism. We are not surprised to read that Albinus, like the Renaissance practitioners of perspective, also prescribed how the finished engravings should be viewed as well as drawn.[10]

But we may be surprised to read that these remarkable figures, which occasioned three months of "an incredible deal of trouble to the ingraver," are not actually of the particular skeleton Albinus so painstakingly prepared. Having thus taken every ordinary and several extraordinary measures to ensure the integrity of object and subject, Albinus's pronouncements about just what it is the finished pictures are pictures of comes as a distinct shock to the modern reader. They are pictures of an ideal skeleton, which may or may not be realized in nature, and of which this particular skeleton is at best an approximation. Albinus is all too aware of the atlas maker's plight: nature is full of diversity, but science cannot be. He must choose his images, and his principle of choice is frankly normative:

> And as skeletons differ from one another, not only as to the age, sex, stature and perfection of the bones, but likewise in the marks of strength, beauty and make of the whole; I made choice of one that might discover signs of both strength and agility; the whole of it elegant, and at the same time not too delicate; so as neither to shew a juvenile or feminine roundness and slenderness, nor on the contrary an unpolished roughness and clumsiness; in short, all of the parts of it beautiful and pleasing to the eye. For as I wanted to shew an example of nature, I chused to take it from the best pattern of nature.[11]

Accordingly, Albinus selects a skeleton "of the male sex, of a middle stature, and very well proportioned; of the most perfect kind, without any blemish or deformity." (For Albinus it went without saying that a perfect skeleton was perforce male; his follower Samuel Soemmerring later constructed an "ideal"—and ideology-laden—female skeleton.)[12] But still the skeleton is not perfect enough, and Albinus does not scruple to improve nature by art: "Yet however it was not altogether so perfect, but something occurred in it less compleat than one could wish. As therefore painters, when they draw a handsome face, if there happens to be any blemish in it mend it in the picture, thereby to render the likeness the more beautiful; so those things which were less perfect, were mended in the figure, and were done in such a manner as to exhibit more perfect patterns; care being taken at the same time that they should be altogether just."[13]

"Perfect" and "just" (i.e., exact): these were Albinus's polestar and compass, and he saw no contradiction between the two. Albinus could hold both aims simultaneously because of a metaphysics and an attitude toward judgment and interpretation that contrasted sharply with those of the late nineteenth century. In effect, Albinus believed that universals such as his perfect skeleton had equivalent ontological warrant to particulars, and that the universal might be represented in a particular picture, if not actually embodied in a particular skeleton. That universal can only be known through minute acquaintance with the particular in all its details, but no image of a mere particular, no matter how precise, can capture the ideal. That requires judgment informed by long experience. Nor was anatomy anomalous in its idealizing tendencies. Until well into the nineteenth century, paleontologists reconstructed and "perfected their fossil specimens,"[14] a practice sharply criticized by their successors a few decades later, who prided themselves on "represent[ing] actual specimens with all their imperfections, as they *are*, not what they *may* have been."[15] Late-nineteenth-century anatomists and paleontologists believed that only particulars were real, and that to stray from particulars was to invite distortions in the interests of dubious theories or systems. Like all atlas makers, they still had to choose their images from nature's embarrassment of riches, but the choice now filled them with anxiety lest they succumb to the temptations of subjectivity. In contrast, Albinus and other idealizing atlas makers did not hesitate to offer pictures of objects they had never laid eyes upon, but in the interest of truth to nature rather than in violation of it.

Idealizers of Albinus's stamp were not unaware of what we might call the "naturalistic" alternative—that is, the attempt to portray this particular object just as it appeared, to the limits of verisimilar art. (Such objects were generally, though not always, deemed characteristic of a larger group.) Ludwig Choulant, the great nineteenth-century historian of anatomical illustration and champion of idealizers such as Albinus and Soemmerring, stated the naturalistic alternative only to reject it:

> Whenever the artist alone, without the guidance and instruction of the anatomist, undertakes the drawing, a purely individual and partly arbitrary representation will be the result, even in advanced periods of anatomy. Where, however, this individual's drawing is executed carefully and under the supervision of an expert anatomist, it becomes effective through its individual truth, its harmony with nature, not only for purposes of instruction, but also for the development of anatomic science; since this norm [*Mittelform*], which is no longer individual but has become ideal, can only be attained through an exact knowledge of the countless peculiarities of which it is the summation.[16]

There were eighteenth-century representatives of the naturalist alternative in anatomical illustration, but it was largely aesthetics rather than anxiety that determined their quite explicit choice. The British anatomist William Hunter's *The Anatomy of the Human Gravid Uterus* (1774), for example, opted for "the simple portrait, in which the object is represented exactly as it was seen" as opposed to

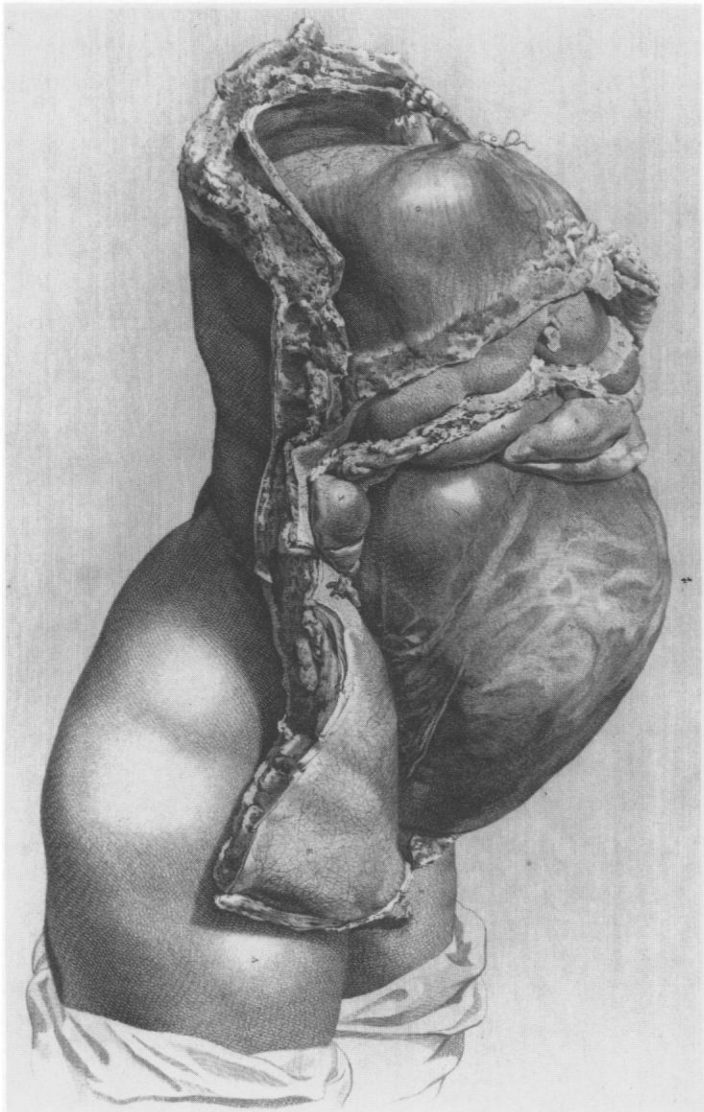


FIGURE 3. Plate 2 from William Hunter, *Anatomy of the Human Gravid Uterus* (Birmingham, 1774), depicting the womb of a woman who died suddenly during the ninth month of pregnancy. Hunter used thirteen different subjects in his atlas, at various stages in pregnancy. Although he emphasized their portrayal as individual objects, he clearly intended them to be characteristic of the anatomy of pregnant women in general.

"the representation of the object under such circumstances as were not actually seen, but conceived in the imagination" on grounds of "the elegance and harmony of the natural object." He asserted that a "simple portrait" bore "the mark of truth, and becomes almost as infallible as the object itself" but acknowledged that, "being finished from a view of one subject, [it] will often be somewhat indistinct or defective in some parts," whereas the figure "made up perhaps from a variety of studies after NATURE, may exhibit in one view, what could only be seen in several objects; and it admits of a better arrangement, of abridgement, and of greater precision."[17] There was not a whiff of distrust in Hunter's preference for the portrait of the individual object, for he admitted that considerations of precision may favor the ideal or typical alternative. Nor did he regard the aesthetic with suspicion, as being opposed to scientific accuracy. On the contrary, Hunter, like Albinus, considered the beauty of the depiction to be part and parcel of achieving that accuracy, not a seduction to betray it.

It would be a mistake to take Hunter at his word—that his figures did indeed represent the object "exactly as it was seen." As Ludmilla Jordanova has shown, Hunter's deeply unsettling figures, with their amputated limbs and preternaturally crisp outlines, participate in the artistic conventions of naturalism of the day and also in a none-too-subtle violence wrought upon the female cadaver (see fig. 3).[18] Like the photographs of the nineteenth century, Hunter's figures carry the stamp of the real only to eyes that have been taught the conventions (e.g., sharp outlines versus soft edges) of that brand of realism. Moreover, Hunter's specimens, like all anatomical "preparations," were already objects of art even before they were drawn, injected with wax or dyes to keep vessels dilated and "natural"-looking even after death.[19] Although Hunter claimed to have moved "not so much as one joint of a finger" of his specimens, he considered it part of truth to nature to inject the womb with "some spirits to raise it up, as nearly as I could guess, to the figure it had when the *abdomen* was first opened."[20] For our purposes, his naturalism is instructive because it shows, first, that scientific naturalism and the cult of individuating detail long antedated the technology of the photograph;[21] and, second, that naturalism need not be coupled with the anxiety of distortion and the rejection of aesthetics.

Even the naturalism of the camera obscura did not obviate the need for selective judgment and extended commentary on the part of the atlas maker. The English anatomist William Cheselden persuaded his two Dutch artists Vandergucht and Shinevoet to use "a convenient camera obscura to draw in" (see fig. 4) so that they could accomplish their figures for his *Osteographia* (1733) "with more accuracy and less labour." Yet the mechanical precision of the camera obscura was no substitute for the learned anatomist, who chose his specimens, carefully posed them in true-to-life stances (e.g., an arched cat skeleton facing off against a growling dog skeleton), and could vouch for every drawn line as well as every printed word: "The actions of all the skeletons both human and comparative, as well as the attitudes of every bone, were my own choice: and where particular parts needed to be more distinctly expressed on account of the anatomy, there I always directed; sometimes in the drawings with the pencil, and often with the needle upon the copperplate, and where the anatomist does not take this care, he will scarce have this work well performed."[22] The camera obscura, like the photograph that largely took its place in the nineteenth century, guaranteed an almost effortless accuracy, but eighteenth-century atlases required more than mere accuracy. What was portrayed was as important as how it was portrayed, and atlas makers had to exercise judgment in both cases, even as they tried to eliminate the wayward judgments of their artists with grids, measurement, or the camera obscura.

Atlases of "characteristic" images might be seen as a hybrid of the idealizing and naturalizing modes: although an individual object (rather than an imagined composite or corrected ideal) is depicted, it is made to stand for a whole class of similar objects. It is no accident that pathological atlases were among the first to use characteristic images, for neither the *Typus* of the "pure phenomenon" nor the ideal, with its venerable associations with health and normality,[23] could properly encompass the diseased organ. Nor could black-and-white engravings: Cruveilhier's exquisitely colored plates testify to the necessity of new dimensions of representation, as well as of greater specificity, in depicting the pathological. His subjects are individuated, poignantly so under the circumstances—"Benoît

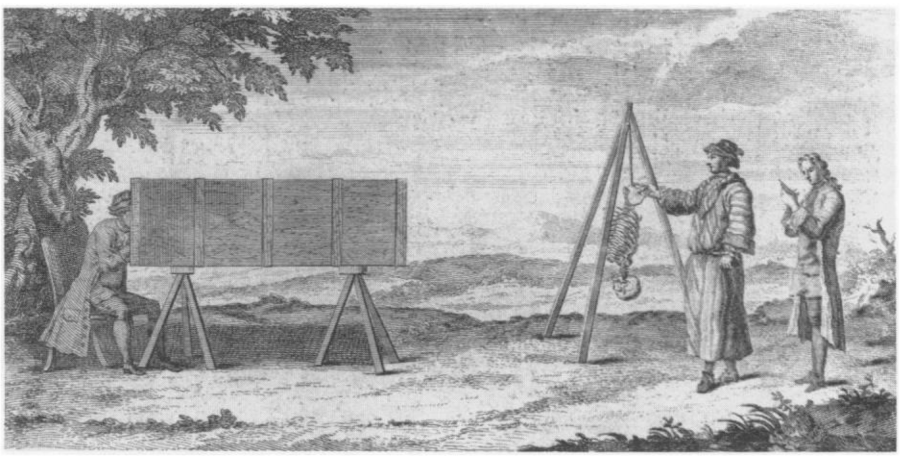


FIGURE 4. Title page illustration of William Cheselden, *Osteographia; or, The Anatomy of the Bones* (London, 1733), showing an artist seated before a camera obscura drawing a half-skeleton (which is suspended upside down, since the camera obscura image is inverted). The camera obscura, the camera lucida, tracing, and other mechanical means of rendering scientific images show that the photograph was an innovation in degree, not kind.

(Esther), laundress, 25 years old"—and Cruveilhier is voluble on the clinical details surrounding each sad case. Although he is, as we have seen, wary of systems and persuaded that pictures can do what words cannot, he does not share the view of later atlas makers that the text should be limited to terse captions, and that all speculation was *a fortiori* tabu. Cruveilhier not only infers diagnoses from visible signs; he does not scruple to hazard conjectures on the basis of his observations, preserved in his figures: "Several facts lead me to believe that the inflammation of the lymphatic vessels is primitive, and that that of the synovial [membrane] could only be the consequence."[24] These broader claims make sense only if the individual case figured and discussed is characteristic of a whole class of such ailments. For Cruveilhier, for all his warnings against systems, his figures are evidence mustered in the service of explanations and causal conjectures, not brute visual facts shorn of text, much less theory.

Atlases of characteristic images presented individual cases as exemplary and illustrative of broader classes and causal processes. For example, B. A. Morel's *Traité des dégénérescences physiques, intellectuelles, et morales de l'espèce humaine* (1857) insisted that constant causes "tend to create types of a determinate form," and that these pathologies would prove as "distinctive, fixed, and invariable" as normal types. Thus even people could be subsumed by type: two young girls (each illustrated) were "so perfectly similar in height and symptoms of their physical constitution and intellectual state, that one common description is equally applicable to both of them."[25] Individual depiction by no means precluded essentialist typologies, even in pathology. Botanists, zoologists, and paleontologists institutionalized the characteristic individual that stood for an entire species in the type specimen, usually the first individual discovered of that species: "By the 'type,' we understand that example of any natural group which possesses all the leading characters of that group."[26]

Even averaging, with its emphasis upon precise measurement of individual objects, could be made to serve the ends of essentialism. Gottlieb Gluge, professor of anatomy in Brussels and disciple of the statistician Adolphe Quetelet, delivered a paean to measurement in his *Atlas of Pathological Histology* (1853), inveighing against the errors of estimation by eye, and set about weighing organs to the hundredth of a gram. As usual in characteristic atlases, his subjects were individuated by description ("Male. Baker. Suicide"), and his measurements individuated them still further, by displaying the variability of even normal organ size. But also as usual in characteristic atlases, and in complete accordance with Quetelet's own brand of statistical essentialism,[27] these individuals nonetheless pointed beyond variability to an underlying type of which they were characteristic, setting strict limits to deviations: "Already, from the few investigations of this kind which have been made, an average is presented indicating the most frequent variations of the disease."[28]

The characteristic atlases of the mid nineteenth century mark a transition between the earlier atlases that had sought truth to nature in the unabashed depiction of the typical—be it *Typus*, ideal, characteristic exemplar, or average—and the later atlases that sought truth to nature through mechanical objectivity. Like the latter, the characteristic atlases presented figures of actual individuals, not of types or ideals that had not and/or could not be observed in a single instance. But like the former, these individuals still embodied types of whose reality the atlas maker was firmly convinced. The typical must now be instantiated in the individual, but the typical nonetheless exists, to be discerned by judgment and long acquaintance with the phenomena. Like the atlas makers of the late nineteenth century, the makers of characteristic atlases voiced uneasiness about the baleful effects of hypothesis and system, but they also expressed confidence that images would suffice to fend off such distortions, and saw no reason to subject themselves to a ban on interpretation. In effect, they recognized the existence of an enemy within, but they were not yet sufficiently alarmed to combat it with the asceticism of noninterventionist objectivity.

However, later atlas makers were considerably more anxious about the subjectivity implicit in judgments of typicality. Conflicts between truth to type and truth to the individual specimen brought this new anxiety over judgment into the open. For example, Walter Fitch, the prolific illustrator of Victorian floras, wryly warned of the dangers of excessive accuracy in an 1869 article addressed to would-be botanical artists:

> Owing to the great variation in form presented by some [orchid] species, if the artist render correctly any specimen put in his hands, he is liable to have his veracity called into question, and if any abnormal growth come his way, he had better not be rash enough to represent what may be regarded as impossible by some authority who has made Orchids his specialty. It might tend to upset some favourite theory, or possibly destroy a pet genus—an act of wanton impertinence which no artist endowed with a proper respect for the dicta of men of science would ever be wilfully guilty of![29]

Fitch's rueful advice was more than the artist's revenge against the overbearing supervision of the scientists, who had for generations peered over their illustrators' shoulders in schoolmasterish fashion. He also pointed an accusing finger just where the scientists themselves had begun to suspect their worst enemies lurked, namely within themselves. Long accustomed to monitor the vagaries of their artists, the atlas makers had begun to scrutinize themselves.

Fitch knew how easily a reasonable concern with typicality (he himself thought "some general knowledge of their [orchids'] normal structure" was essential to drawing these polymorphous flowers) could degenerate into an unreasonable partiality. In illustrations such as figure 5, he registers a transition between obligatory judgments of typicality to obligatory restraint from such judgments. In 1851, his patrons, the botanists Joseph Hooker, *père et fils*, were still capable of distinguishing "characteristic" from "faithful" figures of *Rhododendron arboreum, sm.*, while recommending both.[30] By 1869, however, the characteristic, and *a for-*

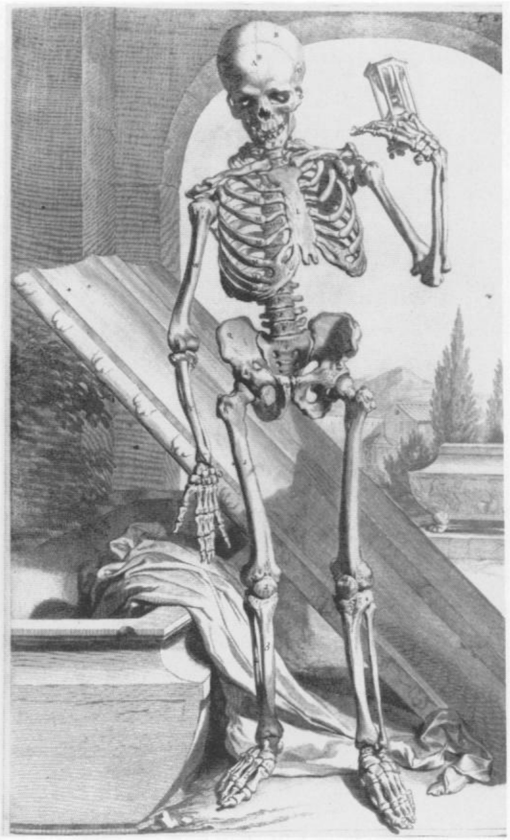
FIGURE 5. *Rhododendron argentum, Hook. fil.*, from Joseph Dalton Hooker, *The Rhododendrons of Sikkim-Himalaya* (2nd ed., London, 1849). That Hooker's drawings were actually composites of several blossoms is suggested by his remark apropos of this figure: "It [the species] seems to be shy of flowering, this season at least (1848); for it was [only with] difficulty that I could procure sufficient specimens to complete my drawing." In the later half of the nineteenth century, botanists, paleontologists, and other naturalists became increasingly distrustful of such composites, along with reconstructions and idealizations suspected of being vehicles for theory and interpretation. Hence, composite illustrations were largely replaced by renderings of concrete, individual "type specimens."

tiori the ideal, rendering could become an object of scientific suspicion, opening up, as Fitch only half-jokingly suggested, the possibility of bias and distortion. Similarly, paleontologists began in this same period to take a dim view of artists who "made up the great imperfections of the type-specimen with an ideal representation."[31] This is the climate in which images of individuals came to be preferred to those of types, and in which techniques of mechanical reproduction seemed to promise scientists salvation from their own worst selves.

Objectivity and Mechanical Reproduction

On first reflection, it might be thought that the shift from ideal types to individual depiction came about *because* of the introduction of photography. For "straight" photography is, above all, a signature of a particular scene, a specific and localized representation only awkwardly adaptable to a mosaic composition from different individuals. But as we have noted, resistance against the representation of an abstracted *Typus* or ideal began long before photographic evidence proliferated in the pages of medical atlases after the 1870s. Even when the photograph dominated atlas representation, it by no means stabilized the debate over objectivity. Quite the contrary—photographic depiction entered the fray along with X-rays, lithographs, photoengravings, camera obscura drawings, and ground glass tracings as attempts—never wholly successful—to extirpate human intervention between object and representation. Interpretation, selectivity, artistry, and judgment itself all came to appear as subjective temptations requiring mechanical or procedural safeguards.

Once again we can use our strategy of using the authors' invective against the subjective to unravel the different senses of subjectivity and its complement, objectivity. First, we discuss the subjectivity of the artist, how the scientist deployed mechanical means to police the artist, and the growing shift among atlas makers toward self-surveillance as well as surveillance of the artist. We next use the great X-ray debate to face directly the question of the photograph; we argue that while photography played a central role in the continuing development of mechanical objectivity, it neither created nor terminated the debate over how to depict. Finally, we come to the full-fledged establishment of mechanical objectivity as the ideal of scientific representation. What we find is that the image, as standard bearer of objectivity, is inextricably tied to a relentless search to replace individual volition and discretion in depiction by the invariable routines of mechanical reproduction. This mechanizing impulse is at once a part of the discourse of natural philosophy and a constituent of moral vision; the two were inseparable. Nothing in the works of Albinus or his contemporaries quite

FIGURES 6 AND 7. Godefridi Bidloo's "Zolaesque realism." Bidloo included far more than the dissected anatomical sections. Mixing allegorical poses and props with the auxiliary mechanisms of dissection (pins, nails, ropes, ties, and blocks), he achieved an effect that shocked readers in the late nineteenth and early twentieth centuries. These two prints are from his *Anatomia humani corporis* (Amsterdam, 1685), plates 30 (back dissection) and 87 (skeleton with hourglass).

prepares us for the fervor of self-denying moralism that animates the late-nineteenth-century briefs for mechanized scientific representation.

Consider William Anderson's 1885 "Introductory Address" to the Medical and Physical Society of St. Thomas's Hospital. His subject was the history of the relation of art to medical science, and his message was clear: medicine no longer could employ the great artists of the ages, as Vesalius had, but their services had in any case become obsolete. Scientific understanding had not only made artistic insight supererogatory, it had shown that the artist could prove to be a liability. The seventeenth-century Amsterdam anatomist Godfried Bidloo, for example, struck Anderson as "too naturalistic both for art and science, but the man who was usually almost Zolaesque in his superfluous realism could not always resist the temptation to pictorial allegory" (see figs. 6 and 7).[32] If even Bidloo had fallen prey to temptation, what was needed to restrain those impulses was a machine that would automatically and forcibly exclude such imposed meaning. John Bell, to whose 1810 *Anatomy of the Bones, Joints, and Muscles* Anderson granted artistic merit, was saved because "he was above all a man of science, and as he did not care to risk any sacrifice of accuracy by trusting the unaided eye of the draughtsman, he had each specimen drawn under the camera obscura."[33]

Drawing closer to the present, Anderson credited art with an unprecedented importance, but he did so only by redefining art from the fine arts of the past into any form of schematic illustration, diagram, photograph, or model. In this new sense, the artistic aids could "serve as a new language that speaks with strength and clearness where written or spoken words would convey their meaning slowly and imperfectly."[34] This new, science-directed art, of which photography was but a part, would scrutinize its subject "with the eye of the understanding," and by so doing might "provide us with a more useful presentation of anatomical or pathological facts than we could hope to gain from the pencil of Botticelli."[35]

The secret to the displacement of the titanic artists of the past, according to Anderson, lay in the control of the representational process itself by automatic means. Only in this way could "temptation" be avoided, whether these temptations originated (as in Bidloo's case) in artistry or, as in other cases, in systems of thought. In an age of science, mechanization could and would triumph over art:

> We have no Lionardo [*sic*] de Vinci, Calcar, Fialetti, or Berrettini, but the modern draughtsman makes up in comprehension of the needs of science all that he lacks in artistic genius. We can boast no engravings as effective as those of the broadsheets of Vesal, or even of the plates of Bidloo and Cheselden, but we are able to employ new processes that reproduce the drawings of the original object *without error of interpretation*, and others that give us very useful effects of colour at small expense.[36]

Such photomechanical elimination of the engraver cut one handworker out of the reproduction cycle and therefore, Anderson believed, contributed to the eradication of interpretation. Artists, even slavishly realistic ones, agreed that the artists' very presence meant that images were mediated. Jules Champfleury, an ally of Gustave Courbet and spokesman for the realist movement in France, insisted that "the reproduction of nature by man will never be a reproduction and imitation, but always an interpretation . . . since man is not a machine and is incapable of rendering objects mechanically."[37] Of course Champfleury lauded the artist's interpretive intervention, where Anderson lambasted it.

Policing of subjectivity by the partial application of photographic technology was widespread in the last decades of the nineteenth century, even where the actual use of photographs in the album was impractical, too expensive, too detailed, or even insufficiently detailed. For example, a quite common use of the photograph was to interpose it in the drawing stage of representation. Typical of such a strategy was the careful selection of photographs by the authors of *Johnston's Students' Atlas of Bones and Ligaments*. Only after such a selection did they turn the image over to an artist who traced the photograph as the basis for the final drawing.[38] Similarly, E. Ponfick's magnum opus of 1901, an atlas on medical surgical diagnostics, reassured the reader that both he and strict rules had confined the artist's actions. Outlines of organs were recorded on a plate of milk-glass mounted over the body; the image on glass was transferred to transparent paper; from the transparent paper the image was inscribed on paper destined for the full watercolor painting. "As I [Ponfick] observed the work of the artist constantly and carefully, remeasuring the distances and comparing the colours of the copy with those of the original section, I can justly vouch for the correctness of every line."[39]

Along the same lines, Johannes Sabotta, one of the great German anatomists of the turn of the century, advertised the use of photography in the preparation of his atlas—even though the images themselves were multicolor lithographs. "No woodcuts have been employed, since the failure of the latter method to produce illustrations true to life has been distinctly shown by several of the newer anatomical atlases. It leaves entirely too much to the *discretion* of the wood-engraver, whereas the photomechanical method of reproduction depends entirely upon the impression made upon the photographic plate by the original drawing." As a further control on the discretionary power of the illustrator, Sabotta had a photograph of the designated body section taken and enlarged to the size of the intended drawing.[40]

Sabotta followed much the same method when he turned to histology and microscopic anatomy in his 1902 treatise on that subject. Readers might worry that the samples were not representative of living tissue; the doctor reassured them that the vast majority came from two hanged men, several others from two additional victims of the gallows, so the "material" was still "fresh." It seems that the corpses were still warm with life (*noch lebenswarm*) some two-and-a-half hours after death. Again Sabotta had photographs made that were used as the basis for drawings. Here, however, he noted that precision (*Genauigkeit*) should not be pushed too far—for then every disturbing accidental feature of the preparation would enter the representation. Instead, some figures were actually made from two or three different preparations. Somewhat defensively, perhaps anticipating criticism, Sabotta reassured his readers that the combination was not made arbitrarily but with the careful repositioning of the camera to eliminate variation in perspective, and the photographic enlargements were cut and reassembled to reproduce a mosaic photograph against which the drawing would be judged. This, the author tells us, "would give the draughtsman [*dem Zeichner*] no possibility for subjective alterations."[41]

Sabotta's strategy thus crossed the categories of the characteristic, the *Typus*, and the ideal. By invoking specific photographs as controls on the mechanics of reproduction, he appears at first glance to follow the well-worn route to the characteristic—the individual depicted in striking detail meant to stand in for the class. But by amalgamating fractional parts of different microscopic individuals to construct the basis from which drawings would be made, Sabotta leaves the domain of the purely characteristic. Is the final drawing made from the mosaic an ideal—the picture of a perfect sample one might hope one day to find? Is it a picture of an ideal that might well not exist but represents a kind of limiting case? Or does Sabotta expect his routinized procedures to give rise to diagrams that would stand in for a *Typus*, lying altogether outside the collection of individuals past, present, and future, yet expressing an essential element of all of them? Such ontological questions are pushed aside; Sabotta's attention is devoted, instead, to the procedure of controlled reproduction as a means of squelching the subjectivity of interpretation. For Goethe, Albinus, and Hunter, the atlas maker bore an essential responsibility to resolve—one way or another—the problem of how single pictures could exemplify an entire class of natural phenomena. Sabotta's cobbled photographs form an apt metaphor for his uneasy authorial position

FIGURE 8. The synthetic criminal. By superimposing several projected images of malefactors, Francis Galton hoped to achieve a type that would be produced independently of any artist's subjective impulses. From Galton, "Composite Portraits," *Nature* 18 (1878): 97–100, 97.

between the older desire to perfect and the newer stricture to stand aside, to keep hands off the machine-generated image. By and large this fear of interpretation fueled a flight from the amalgamated image toward the individual; the very act of combining elements from different individuals appeared to late-nineteenth-century observers to leave far too much judgment to the artist. Some, however, would not give up so easily. Francis Galton shared none of Sabotta's slightly uncomfortable acceptance of the need for amalgamation. Galton, in collaboration with Herbert Spencer, enthusiastically embraced the possibility of simultaneously eliminating judgment *and* of capturing, in one image, the vivid image of a group. Indeed, Galton was persuaded that all attempts to exploit physiognomy to grasp underlying group proclivities were doomed to failure without a mechanized abstracting procedure. His remedy was disarmingly simple. Each member of the group to be synthesized had his or her picture drawn on transparent paper. By exposing a photographic plate to each of these images, a composite image would arise. Such a process would free the synthesis from the vagaries of individual distortion; even the time of plate exposure given to each individual could be adjusted on scientific grounds, such as degree of relatedness in the case of family averages. "A composite portrait," writes Galton,

> represents the picture that would rise before the mind's eye of a man who had the gift of pictorial imagination in an exalted degree. But the imaginative power even of the highest artists is far from precise, and is so apt to be biased by special cases that may have struck their fancies, that no two artists agree in any of their typical forms. The merit of the photographic composite is its mechanical precision, being subject to no errors beyond those incidental to all photographic productions.[42]

Galton's was a scheme that would go further than merely constraining the artist's depiction of an individual; the device would remove the process of abstraction from the artist's pen. No longer would even pattern recognition be left to the artists. Murderers or violent robbers could, for example, be brought into focus so that the archetypical killer could appear before our eyes (see fig. 8). The problem of judgment, for someone like Galton, arose with the artists.

Policing the artists—containing their predilection for "subjective alterations," "pictorial allegory," "Zolaesque . . . superfluous realism," artistic "discretion," or "bias" by "fancy"—was but the first moment in the construction of a vastly more encompassing set of restraints. Indeed, what characterized the creation of late-nineteenth-century pictorial objectivism was *self*-surveillance, a form of self-control at once moral and natural-philosophical. For in this period, the scientific authors came to see mechanical registration as a means of hemming in their *own* temptation to impose systems, aesthetic norms, hypotheses, language, even anthropomorphic elements on pictorial representation. What began as a policing of others now broadened into a moral injunction for the scientists, directed both at others *and* reflexively at themselves. Sometimes the control of the scientists' subordinates could be accomplished routinely by invoking the "personal equation," a systematic error-correction term that would be used to adjust each worker's results. In astronomy, for instance, one needed to record the precise time at which a star or planet crossed a wire in a viewing device. This was accomplished by pressing a button. But the procedure was more complicated than it looked, for

> a very slight knowledge of character will show that this will require different periods of time for different people. It will be but a fraction of a second in any case, but there will be a distinct difference, a constant difference, between the eager, quick, impulsive man who habitually anticipates, as it were, the instant when he sees star and wire together, and the phlegmatic, slow-and-sure man who carefully waits till he is quite sure that the contact has taken place and then deliberately and firmly records it. These differences are so truly personal to the observer that it is quite possible to correct for them, and after a given observer's habit has become known, to reduce his transit times to those of some standard observer.[43]

Adjusting for the more subtle interference by the scientist's own proclivity to impose interpretation, aesthetics, or theories was a more complex affair. But examples of the attempt abound, both in machine-dominated representational schemes that used some type of photography in one fashion or another, and in those that did not. The opthalmoscope, for example, provided the basis for a whole genre of atlases of the eye. One rather typical one, by Hermann Pagenstecher and Carl Centus in 1875, exhibits clearly the necessity and extraordinary difficulty of self-surveillance: "The authors have endeavoured, in these [pictures], to represent the object as naturally as possible. It cannot be hoped that they have always succeeded in this attempt: they are but too conscious, how often in its delineation the subjective idea [*subjective Anschauung*] of the investigator has escaped his hand."[44] Or elsewhere,

> They [the authors] have kept it purely *objective*, describing only the conditions before them, and endeavoring to exclude from it both their own views and the influence of prevailing theories. It would have been easy to extend it considerably, and to add theoretical and practical conclusions; but the authors considered this a thing to be carefully avoided, if their work was to possess more than a passing value and to preserve to the reader the advantages of unprejudiced view and unbiased judgment.[45]

Consider some of the ways in which the photograph—made by visible light or X-ray—was deployed. In his microscopic studies of nerve cells (1896), M. Allen Starr first described the object under investigation: "The method of Golgi has shown that each cell is an independent entity, its branches and subbranches of both varieties preserving their identity from origin to ending, interlacing . . . with those of other cells, as the branches of trees in a forest may interlace, but really as distinct and separable from each other as are those trees with their twigs and leaves." He then pointed to the inadequacy of artistic portrayal: "In the most

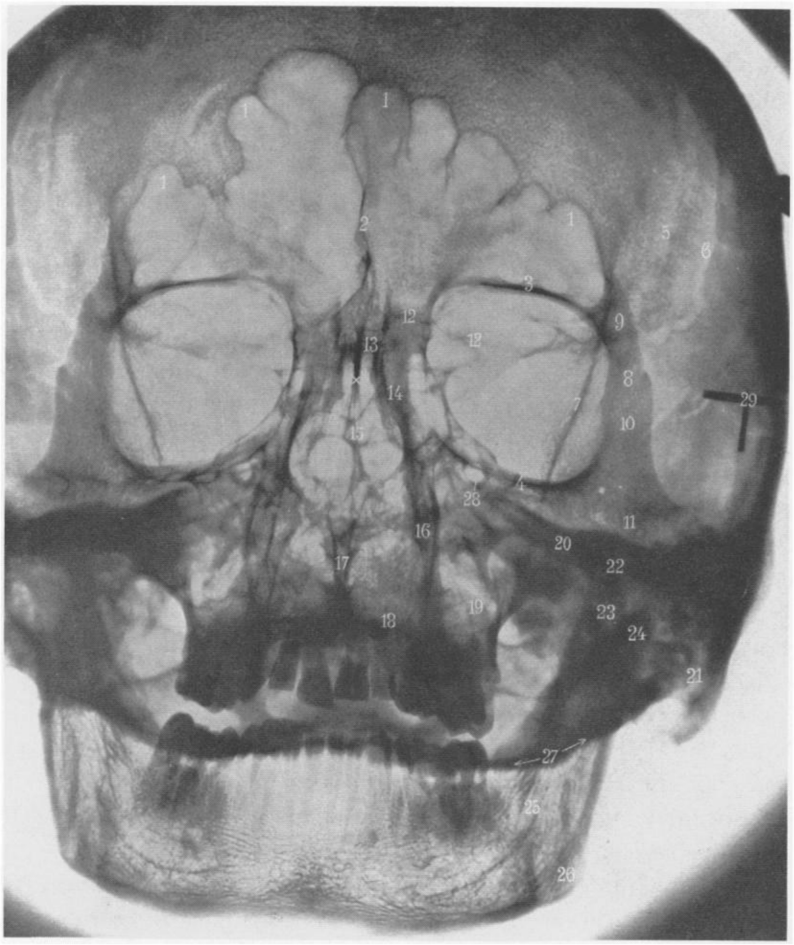


FIGURE 9. Skull X-ray from Rudolf Grashey, *Typische Röntgenbilder vom normalen Menschen* (Munich, 1939). Grashey transferred classification from author to reader by publishing a series of "wanted posters" (*Steckbriefe*) that illustrated the far reaches of the normal and thereby demarcated the normal from the pathological.

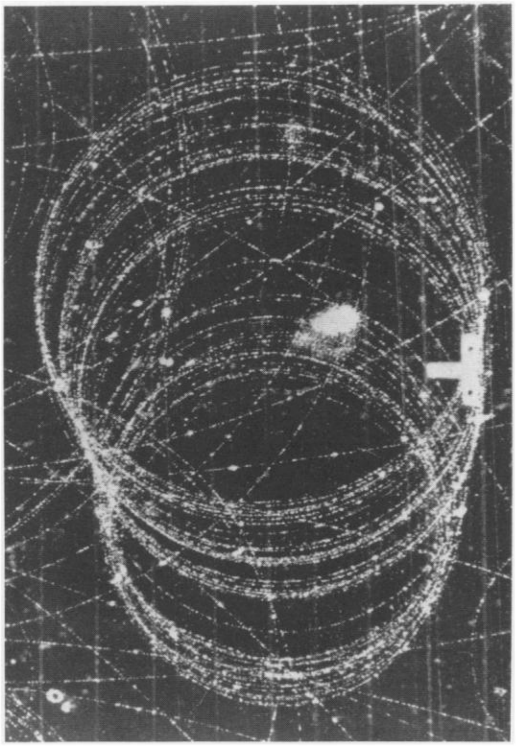
recent text-books of neurology and in the atlas of Golgi these facts have been shown by drawings and diagrams. But all such drawings are necessarily imperfect and involve a personal element of interpretation. It has seemed to me, therefore, that a series of photographs presenting the actual appearance of neurons under the microscope would be not only of interest but also of service to students."[46] By striving to eliminate "personal interpretation," Starr expunged the very virtue that someone like Albinus had lauded in the use of drawings and diagrams.

In X-ray photography, the drawing was never seen as a competitive form—the radiogram or "skiagram" took center stage as a new visual reality, invisible to human draftsmen in a way that even cells under a microscope were not. By the turn of the century, X-ray atlases proliferated (most widely in Germany, but also in the United States, France, and Britain) as is evident in the famous tomes by Rudolf Grashey, *Chirurgisch-Pathologische Röntgenbilder* and *Typische Röntgenbilder vom normalen Menschen* (fig. 9), the latter of which went through six printings between 1905 and 1939 and which continues to be a standard reference work in the field. Like his colleagues in anatomy, Grashey signaled his aversion to the artistic early in his volume: "I have vigorously avoided artistic aids; in those few cases where, because of the uneven covering of the emulsion [*Deckung*] on the negative, a few visible contours had to be added afterwards, I have explicitly so indicated."[47] But Grashey's caution before the pitfalls of artistic aids was only the beginning of a rather more sophisticated analysis of the precautions necessary in the use of the X-ray to produce reliable images. By 1905, when Grashey was completing his work on normal *Röntgenbilder*, it was clear that there were systematic mismatches between macroscopic anatomy and the X-ray image of the human body. There were elements of the body that did not produce image traces on the X-ray, and there were representational elements on the X-ray that did not correspond to identifiable characteristics under the anatomist's knife. As a result, the diagnostician had to learn—through a study of an atlas such as this—to qualify the mechanical procedure of X-raying with a knowledge of systematic deviations between anatomy and its Röntgen representation. Secondly, the atlas could, by the multiplication of examples, help to prepare the observer for the enormous variation of image that resulted from a movement of the X-ray tube or a rotation of the body part under scrutiny. Such a displacement of the camera, tube, or body could easily make certain contours disappear and other ones appear. Third, by collapsing a complex, three-dimensional form into two dimensions, the projective process itself could easily mislead. Macroscopic anatomy alone cannot rescue us here; only the systematic Röntgen photography of a skeleton, in which parts are marked with metal tags, can reveal the characteristic distortions produced in the dimension-reducing photographic process.

Finally, and most subtly, Grashey points to the immense difficulty of using individual photographs to demarcate the normal from the pathological. The problem is this: if one is committed, as was Grashey, to the mechanical registration of images of individuals, then how would one distinguish between variations within the bounds of the "normal" and variations that transgressed normalcy and entered into the territory of the pathological? Grashey's own solution was to elevate the most striking of such rare deviations (*augenfälligen selteneren Abweichungen*) to a place of honor (*Ehrenplatz*) in the Röntgen laboratory. They would then serve as boundary posts of the normal, guiding the diagnostician away from a false attribution of pathology when a patient arrived with a subjective difficulty. By 1900, the metaphysical position underlying Grashey's view was widespread and utterly different from the implicit metaphysics that had prevailed in the early nineteenth century. For Goethe, the depiction of the *Typus* did represent something in nature (though not apparent from this or that individual). For Albinus, the "true" representation of a subject referred to nature not only because it borrowed from several individuals but because it improved above any single one of them. For Hunter, the link to the general occurred through a particular individual, chosen precisely that it might represent (in both senses) a whole class. Different as they were, all three views took it for granted that a single representation could stand in for the myriad of variations found in nature.

Grashey and his contemporaries disagreed. For them, the link to the multitude of variants could not be contained in any single representation, be it ideal, typical, or characteristic. Instead, the most a picture could do was to serve as a signpost, announcing that this or that individual anatomical configuration stands in the domain of the normal. Many such instances were needed to convey the extent of the normal, as the normal spanned a space that even in principle could not be exhausted by individual representations, each differing from the rest. Thus when W. Gentner, H. Maier-Leibniz, and W. Bothe published their *Atlas of Typical Expansion Chamber Photographs*,[48] they included multiple examples of alpha particles ionizing a gas, beta particles scattering from different substances, and positrons annihilating electrons (see fig. 10). Each individual, it was hoped, would evoke a class of patterns in the mind of the reader. This is the essential point. While in the early nineteenth century, the burden of representation was supposed to lie in the picture itself, now it fell to the audience. The psychology of pattern recognition in the audience had replaced the metaphysical claims of the author. Mistrusting themselves, they assuaged their fear of subjectivity by transferring the necessity of judgment to the audience.

Paleontologists faced the same problem. It seems that at the turn of the twentieth century, students of British graptolites were confounded by conflicting descriptions of their fossils. According to one expert, the problem was that many of the best figures were "more or less unconsciously idealised" or inadequate in some other way. Better reproduction (see fig. 11) would defer responsibility by shifting the interpretive eye to the reader. It was, one author wrote,



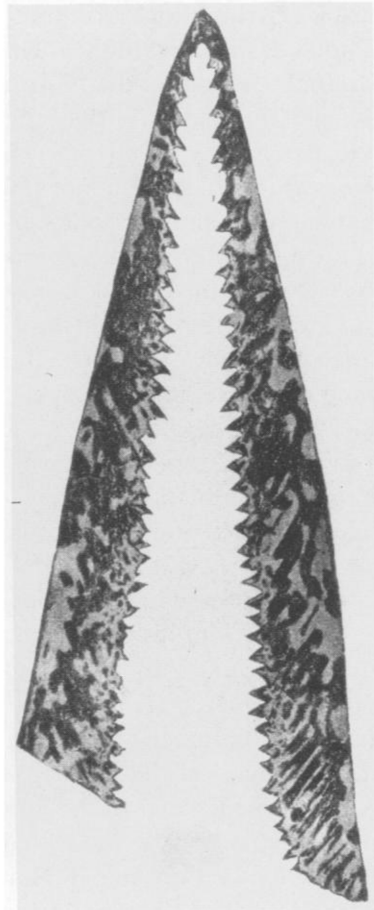


FIGURE 10. Cloud chamber photograph of an electron losing energy in a gas as it spirals within a magnetic field. Because the magnetic field is stronger in the center of the cloud chamber, the spirals slowly drift upwards. The reader is instructed to note 1) irregularities in the spacing of the spirals (attributed to multiple collisions of the electron with gas atoms) and 2) the sudden change in curvature around the seventeenth orbit (attributed to the emission of a photon by the electron). Readers were supposed to study these images and so to learn to separate the extraordinary from the ordinary. Source: W. Gentner, H. Maier-Leibnitz, and W. Bothe, *An Atlas of Typical Expansion Chamber Photographs* (New York, 1954), 51.

FIGURE 11. Graptolite. Like Grashey, the paleontologists hoped to shift responsibility from author to reader. By photographing graptolites, they hoped to avoid the "unconscious" alteration of images imposed by the author-illustrator. From Gertrude Lillian Elles and Ethel M. R. Wood, *A Monograph of British Graptolites* (London, 1901), detail from pl. 4.

obviously necessary to give such figures of the fossils themselves—by mechanical means if possible—as should agree with the originals in all respects, showing their imperfections as well as their perfections, that the reader might be in a position to judge of the fidelity of the descriptions by the figures themselves, and might also be able, should the need arise, to identify the actual fossil or type specimen represented on the plates.[49]

Casting a brief glance forward in time, we see that mid-twentieth-century atlas makers took exactly this path. Consider the frank admission of the necessity of the capacity to recognize patterns in this excerpt from the preface to an atlas of electroencephalography published in 1941:

This book has been written in the hope that it will help the reader to see at a glance what it has taken others many hours to find, that it will help to train his eye so that he can arrive at diagnoses from subjective criteria. Where complex patterns must be analyzed, such criteria are exceedingly serviceable. For example, although it is possible to tell an Eskimo from an Indian by the mathematical relationship between certain body measurements at a glance and can often arrive at a better differentiation than can be obtained from any single quantitative index or even from a group of indices. It would be wrong, however, to disparage the use of indices and objective measurements; they are useful and should be employed wherever possible. But a "seeing eye" which comes from complete familiarity with the material is the most valuable instrument which an electroencephalographer can possess; no one can be truly competent until he has acquired it.[50]

For the electroencephalographer, the acquisition of the "seeing eye" permitted the recognition of distillation of the pathological from the normal. For the particle physicist, exploiting the cloud chamber or the emulsion method, the seeing eye separated the novel from the known. P. M. S. Blackett put it succinctly in the foreword to one of the most successful of the particle atlases, published in 1952:

An important step in any investigation using [the visual techniques] is the interpretation of a photograph, often of a complex photograph, and this involves the ability to recognise quickly many different types of sub-atomic events. To acquire skill in interpretation, a preliminary study must be made of many examples of photographs of the different kinds of known events. Only when all known types of event can be recognised will the hitherto unknown be detected.[51]

Neither electroencephalographer nor particle physicist could simply point to a picture and instruct the reader to find identical occurrences in the pictorial output of their own instruments. Earlier generations of atlas makers chose "truth to nature" as their slogan: their pictures would depict the designated phenomena as they were, as they ought to be, or as they existed beneath the variation of mere appearances. Byt the late nineteenth century, however, the atlas makers no longer could make such unproblematic claims for the general applicability of their images, and by the early twentieth century, they had shifted responsibility to the reader.

Caught between the infinite complexity of variation and their commitment to the representation of individuals, the authors must cede to the psychological.

Selection and distillation, previously among the atlas writer's principle tasks, now were removed from the authorial domain and laid squarely in that of the audience. Such a solution preserved the purity of individual representation at the cost of acknowledging the essential *role* of the readers' response: the human capacity to render judgment, the electroencephalographers cheerfully allow, is "exceedingly serviceable." For Grashey, the problem occurs in the shadows of bone, not ink tracings, but the weight of nature's diversity is similarly felt: "One must know these variations," Grashey insisted. "We need an all-points bulletin issued for them. A series of pictures in this atlas is devoted in part to spreading widely wanted posters [*Steckbrief*] for them."[52]

Grashey's police metaphor was entirely appropriate. Not only was the history of late-nineteenth-century photography thoroughly bound up with the history of crime control, the X-ray photograph itself was increasingly finding its way into court.[53] As it did, the difficulties surrounding scientific evidence and legal evidence merged. For Grashey, the problems were diagnostic, and could be attacked with compensating techniques like any other form of scientific instrumental error. For others, however, instrumental problems rapidly exploded into juridical disputes with profound professional and pecuniary consequences for the clinician using them. At issue was, once again, the shifting border between judgment and mechanization, between the possibility (or necessity) of human intervention and the routinized, automatic functioning of the technology. The disputes over photographic evidence show that new photomechanical techniques shifted rather than eliminated the suspected sources of subjectivity. Of all the audiences who addressed the "medico-legal" concept of evidence, perhaps the most active (and distressed) was the assembly of clinical surgeons, who saw in the new X-ray photography a potential legal weapon that could be turned against them in malpractice suits.

The resulting fracas, recorded in (among other places) the *American Journal of the Medical Sciences*, captures the distorting characteristics of photographs as evidence in both senses—legal and scientific. Above all, critics challenged the vulnerability of the image to changes in the relative location of the camera, the X-ray tube, and the object under investigation. A Dr. Ames lamented that "I have to my sorrow learned that the ray has many tricks, and we cannot always believe what we see, or rather fail to see, and a picture, to tell the truth, must have the plate, the object to be photographed, and the tube in proper relation during the exposure."[54] Insisting on the same point, a New York doctor wanted sworn witnesses in court to attest to the exact placement of the instruments and patient.[55] The interwoven character of scientific and legal evidence is reiterated by another doctor, who warned his colleagues that they should not forget that "the X-ray operator either by wilfulness or negligence in fastening the plate and making the exposure may exaggerate any existing deformity and an unprejudiced artist should be insisted upon."[56]

For some of the clinicians, the very form of X-ray photography was a threat because the photographic medium fairly radiated authority, even while practitioners of the art frequently confronted its deceptiveness. In part the ability of X-rays to penetrate where ordinary vision could not bestowed on the medium an aura of superhuman power. But in addition, by its very nature, X-ray technology was parasitic on the widespread assumption that the photograph does not lie. How could it, designed as it was to eschew the dangers of subjective intervention? So while a moderate clinician might want to use the new device as a supplement to other practices, the image of the X-ray appeared (in court at least) to preempt and displace all other forms of knowledge. One doctor commented plaintively that "usefulness and infallibility are not identical. In a thing which purports to be a representation analogous to a photograph, showing only what exists and nothing else, the claim of infallibility, of exact accuracy, is sure to be made by some lawyers and listened to approvingly by some judges and juries."[57]

The doctor was right. By 1900, the photograph did wield a powerful ideological force as the very symbol of neutral, exquisitely detailed truth. Even if people by then knew better, there remained in the photograph an ineradicable glow of veracity. Edgar Allan Poe's homage to the daguerreotype seems to capture the dream of such perfect transparency: "If we examine a work of ordinary art, by means of a powerful microscope, all traces of resemblance to nature will disappear—but the closest scrutiny of the photographic drawing discloses only a more absolute truth, more perfect identity of aspect with the thing represented."[58] What sustained Poe's dream of perfect identity was faith, not technology. One of the greatest of mid-twentieth-century electron microscopists was blunt on the subject: even when the scientist knows crispness and truth are not coextensive, the photographic dream is still compelling.

> Perhaps it is more an article of faith for the morphologist, than a matter of demonstrated fact, that an image which is sharp, coherent, orderly, fine-textured and generally aesthetically pleasing is more likely to be true than one which is coarse, disorderly and indistinct. Like other matters of faith, this may not withstand logical analysis but it has proven to be operationally sound and has been responsible for much of the progress that has been made in descriptive cytology at the electron microscope level. To accept any other guiding principle is to encourage carelessness and technical ineptitude.[59]

Or, as Charles Rosen and Henri Zerner put it, "It is not that a photograph has more resemblance than a handmade picture (many have much less, and what could be more *like* something than a successfully painted trompe l'oeil?), but that our belief guarantees its authenticity. . . . We tend to trust the camera more than our own eyes."[60] Against this deeply ingrained trust, though in different ways, both the expert and advocate Grashey and the rather defensive doctors were in the same position: both sought to challenge the manifest transparency of the meaning of the X-ray photograph. But while the medics wanted above all to check the hasty conclusions of an alleged jury of peers, Grashey hoped to reestablish transparency through the systematic control of the modalities of distortion.

A more radical critique than that advanced by the frightened surgeons came from those who doubted that the X-ray photograph, or any photograph for that matter, could ever become a stable piece of evidence. Photographs lied. And in the climate of infatuation with X-rays, several doctors found it essential to puncture the inflated claims made for the medium. One respondent pointed to the obscurity of photomicrographs should they be presented without interpretation; just so, he added, with X-rays.[61] Here the encryption of information takes place in the technology itself: just as photomicrography had previously introduced new visual conventions (over and above straight photography) into pictorial representation, so now X-rays did the same. As one blunt commentator put it: "Everybody knows that a skiagraph may be easily made to tell untruths and that a like unstable veracity may attach to skiagrams."[62] Precisely because of their conclusion that photographs did *not* carry a transparent meaning, the American Surgical Association unanimously counseled its members to use their medical knowledge and learn to read what might otherwise be misleading. In an environment where interpretations were going to be rife, sometimes arbitrary, and frequently extremely dangerous to their professional existence, surgeons had to join the ranks of the experts to defend themselves.[63]

For these doctors, danger lurked in the imposition of individual interpretation; the photograph promised freedom from the single will, but in and of itself was insufficiently powerful to wrest control from an individual photographer, doctor, or lawyer. The photograph, in other words, did not end the debate over objectivity; it entered the debate. One response was to demand witnesses to the production of the image, another to require experts to mediate between picture and the public, and the third was to recommend that the surgeons themselves learn the techniques necessary to eliminate their dependence on intermediate readers. A fourth criticism was less hopeful, and advocated a rejection of the method itself rather than more stringent controls. As one doctor commented, "Knowledge obtained by long experience and positive indications is far more valuable than any representation visible alone to the eye."[64]

The clinicians' fear of evidence "visible alone to the eye" reminds us both of the commonalities and differences between the position of researchers and doctors. Both groups had a profound fear of a willful interpretation made without law—where the law could be laid down through laboratory procedure, solemn witnesses, or the physical laws of automatic enregistration. But while medical doctors worried about deception from without, scientific researchers' anxiety centered around the more insidious threat from within. Consequently, while the doctors could still look to judgment as an aid against the deception of skewed figures, the researchers came to fear their own judgments as another, more dangerous form of interpretation.

By the late 1920s, polemics against the danger of individual judgment had reached a crescendo. Erwin Christeller, a research scientist, used his *Atlas der Histotopographie gesunder und erkrankter Organe* to caution the scientist against producing his own drawings—tempting as that might be.[65] Instead, he counseled handing the task to technicians who could produce pictures without passing through the stage of using a model; the procedure could be made "fully mechanical and as far as possible, forcibly guided by this direct reproduction procedure of the art department." Such forcible self-restraint from intervention removed the possibility of the scientist's own systematic beliefs or commitments from blocking the passage from eye to hand. This desire to extricate everyone, even himself, from the exertion of judgment extended to Christeller's counsel to his fellow anatomists: turn over your manuscript to the publisher with your original anatomical preparations so the latter can be reproduced "purely mechanically" (*rein mechanisch*).[66] At the same time the scientist's control was necessary to block

FIGURE 12. Tattered tissue. By *not* omitting the fibrous edges of his sections, Erwin Christeller made visually explicit his abstinence from intervention—the figure therefore wore its authenticity, so to speak, on its sleeve. This particular figure depicts a low-grade tumor in the passageway between the stomach and the beginning of the small intestine (polypoid adenoma of the pylorus). Source: Christeller, *Atlas der Histotopographie gesunder und erkrankter Organe* (Leipzig, 1927), table 39, fig. 79.

others' inclinations or ignorance from interfering with the production of images. "I do not want to neglect to mention that through the whole conduct of the printing process, I maintained continuous control of the photographers and color engravers, even giving them detailed instructions and putting at their disposal my own instruments."[67]

Once so policed, and presumably only then, could the photographic process be elevated to a special epistemic status, putting it in a category of its own. As Christeller put it: "It is obvious that drawings and schemata have, in many cases, many virtues over those of photograms. But as means of proof and objective documentation to ground argumentation [*Beweismittel und objektive Belege für Begrunde*] photographs are far superior."[68] The photographic superiority was inextricably attached to the removal of individual judgment. With respect to color, for example, Christeller thought that no method was perfect: drawings, however, carried with them an inalienable subjectivity. Photograms, by contrast, were tarnished not by subjectivity but only by the crudeness imposed by the limited palette of the color raster. Given the choice, the author clearly favored the crude but mechanical photographic process. Accuracy had to be sacrificed on the altar of objectivity.

So riveted was Christeller by the ideology of mechanization that he was determined to leave imperfections in the photograph as a literal mark of objectivity:

> With the exception of the elimination of any foreign bodies [such as] dust particles or crack lines, no corrections to the reproductions have been undertaken, so that the technically unavoidable errors are visible in some places. For example, there are small intrusions [*Überschlagstellen*] of the fibrous tissue fringes on the edge of the sections; [there is also an] absence of soft tissue components. . . . [I displayed these imperfections because] I believed it my obligation also, at the same time, to display with great objectivity the limits of the technique.[69]

The tattered tissue edge served for Christeller the role of the deliberate and humbling fault in a Persian carpet. But while the carpet maker seeks to avoid the hubris of attempted perfection, Christeller's torn tissue samples, such as the ones displayed in figure 12, were put forward as a testimony to objectivity, to the disciplined self-denial of the temptation to perfect. Their presence in the atlas was a rebuke to the aestheticized improvement of the ideal.

Such a rejection of subjective temptation permeated atlases of the time. In Alexander Bruce's *Topographical Atlas of the Spinal Cord* (1901), the author spared no effort to regularize the presentation of each picture, enlarging each by precisely the same amount, and reproducing the photographs by photogravure. "Every care," he insisted, "has been taken to secure that each figure should be an accurate, unsophisticated representation of its corresponding section, and it has been thought advisable to leave the Plates to speak for themselves, and not to interfere with them by lines or marks to indicate the position of cells or other structures."[70] Just as "sophistication" could corrupt an individual, so such artifacts

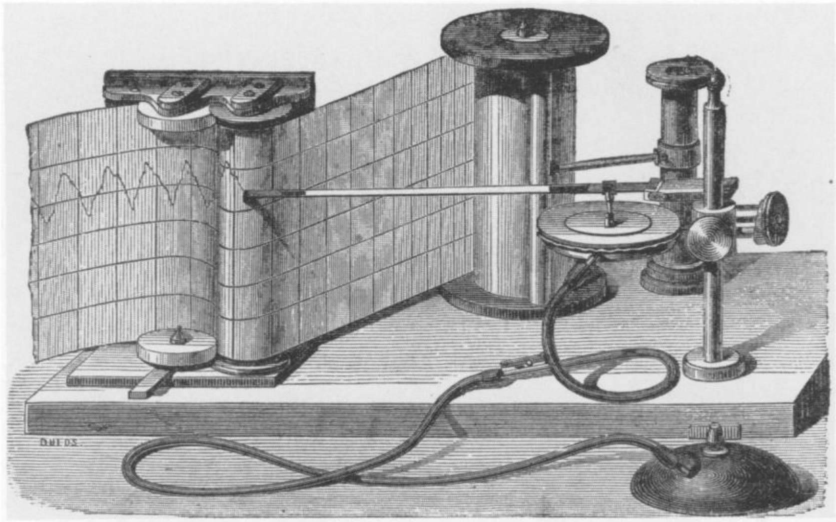


FIGURE 13. Portable polygraph. This device was designed to measure, *inter alia*, the pulse of the heart, the pulse of the arteries, respiration, and muscular contraction. For E. J. Marey, these and other automatically produced figures were doubly important: first, they transcended the divisiveness and incompleteness of language, and second, they captured, without interpretation, what the human senses never could. From Marey, *La Methode graphique dans les sciences experimentales* (Paris, 1878), 457.

of custom could spoil the honest plainness of an unmolested plate. Left to their own devices the plates could and would "speak for themselves," untranslated and untrammeled by human intervention. If this meant deleting the lines or marks that might aid the reader in understanding the plate and relating what was seen to other samples, so be it: the cost of interference was too high to pay. For both Bruce and Christeller the search for objectivity was not merely surface commentary; it penetrated into fundamental decisions about laboratory procedure and representational strategy.

The moral narrative surrounding this mechanical construction of pictorial objectivity took many forms. As we have argued, pictures (properly constructed) served as talismanic guards against frauds and system builders, aesthetes and idealizers. But picture-producing instruments carried a positive as well as negative moral weight; they could do things that humans could not, and avoid what humans could not help but do. Joined with the virtues of machines in general, writers like the French physiologist Marey saw in the imaging instrument (see fig. 13) the possibility of realizing both an ideal of scientific work and a more general ideal of a universal pictorial language. Here Marey transcended the standard atlas rhetoric about pictures and languages by extending the mystique of the visual to the dense symbolic presentation of functions and graphs. But the primary impact of what Marey called inscription instruments (*appareils inscripteurs*) was this: by automating the registration of different types of force (through electrical currents, weight, temperature), researchers could reform the very essence of scientific research and evidence. "The graphical method translates all these changes in the activity of forces into an arresting form that one could call the language of the phenomena themselves, as it is superior to all other modes of expression."[71] Such a language was, for Marey, universal in two senses. Graphical representation could cut across the artificial boundaries of natural languages to reveal nature to all people, and graphical representation could cut across disciplinary boundaries to capture phenomena as diverse as the pulse of a heart and the downturn of an economy. Pictures became more than merely helpful tools; they were the words of nature itself.

Sometimes the "words" of such mathematical pictures were warnings: in research, the false correlation of variables would be reined in by the sudden, unmistakable appearance of "incoherent" graphical curves. A legitimate advance would be rewarded by the opposite—a graphical version of a numerical law that would be "arresting" (*saissisante*) and "luminous" (*lumineuse*). Like his anatomical contemporaries, Marey set the graphical representation the job of policing not only technicians but the scientific authors themselves—here, to admonish the scientist to go no further.

As oracles speaking nature's own language, the inscription instruments acquired a second, even more far-reaching function. They could actually *become* the ideal observers science had always sought: "Patient and exact observers, blessed with senses more numerous and more perfect than our own, they work by themselves for the edification of science; they accumulate documents of an unimpeachable fidelity, which the mind easily grasps, making comparisons easy and memory enduring."[72] Echoing these same themes, the French popularizer of science Gaston Tissandier celebrated the mechanical observer, both more exact and exacting than its human counterpart. Who, he asks, could resist "a certain emotion" of awe at seeing the topography of the moon reproduced photographically, with mathematical exactitude. The camera would neither tire at the microscope, nor fail in the repetitious but essential readings of thermometers and barometers. "That which man cannot do, the machine can accomplish," Tissandier proclaimed.[73] In the eighteenth century, mechanical aids had offered assistance in the production of images that would be "true to nature." With Marey and his contemporaries, the machine-made image replaced the variegated ideals of truth to nature with a moral order of objective representation.

We use the term *moral* here quite deliberately, to emphasize the two-sided goal of using mechanization to achieve "truth to nature." True, the rhetoric of ever-increasing precision is used to celebrate the technical progression from camera lucida to photographic reproduction. But as many atlas writers indicated, photochemical, mechanical reproduction was not always or even usually the means to make an image that readers would automatically find most similar to a bird, a dissected corpse, or a cell.[74] Burdened with detail not found in the reader's own specimens, produced in black and white, often blurred to boot, there were many cases where the photograph was unable to provide the audience with a guide equal to that offered by an illustrator. What the photograph (along with tracings, smoked glass, camera lucida, and other mechanical devices) offered was a path to truthful depiction of a different sort, one that led not by precision but by automation—by the exclusion of the scientist's will from the field of discourse. On this view any sacrifice of resemblance was more than justified by the immediacy of the machine-made images of nature that eliminated the meddlesome intervention of humans: authenticity before mere similarity. The search for this rendition of objective representation was a moral, as much as a technical, quest.

Objectivity Moralized

Although mechanical objectivity was nominally in the service of truth to nature, its primary allegiance was to a morality of self-restraint. When forced to choose between accuracy and moral probity, the atlas makers often chose the latter, as we have seen: better to have bad color, ragged tissue edges, and blurred boundaries than even a suspicion of subjectivity. The discipline earlier atlas makers had imposed on their artists had been in the interests of truth to nature (construed as variously as nature itself), but they had deemed judgment and selection essential to the portrayal of the truly typical or characteristic. Later atlas makers, as fearful of themselves as of their artists, eschewed the typical *because* judgment and selection were needed to detect it, and judgment and selection bordered on the dread subjectivity of interpretation.

Nonetheless, no atlas maker could dodge the responsibility of presenting figures that would teach the reader how to recognize the typical, the ideal, the characteristic, the average, or the normal. To do so would have betrayed the mission of the atlas itself. A mere collection of unsorted individual specimens, portrayed in all their intricate peculiarity, would have been positively subversive. Caught between the charybdis of interpretation and the scylla of irrelevance, some atlas makers worked out a precarious compromise. They would no longer present typical phenomena, or even individual phenomena characteristic of a type. Rather, they would present a scatter of individual phenomena that would stake out the range of the normal, leaving it to the reader to accomplish intuitively what the atlas maker no longer dared to do explicitly: to acquire an ability to distinguish at a glance the normal from the pathological, the typical from the anomalous, the novel from the unknown.

Not only did mechanical objectivity prune the ambitions of the atlas; it also transformed the ideal character of the atlas maker. At the very least, the atlas maker of yore had been a person qualified by wide experience and sober judgment to select and present an edition of interpreted phenomena for the guidance of other anatomists, botanists, entomologists, and so on. An exalted few had been atlas makers of genius, capable of intuiting universal truth from flawed particulars, even when scientific knowledge was meager: Choulant praised Vesalius not only for his scientific methods but also for his "eye artistically trained," which led him to anatomical truth by "pursuing beauty in all the works of nature."[75] As might be expected, the genial image fit best when art and science self-consciously converged, as in the case of the idealizing anatomists and botanists. But even atlas makers of lesser gifts and less idealizing tendencies were emphatically present in their works, selecting and preparing their specimens, alternately flattering and bullying their artists, negotiating with the publisher for the best engravers, all with the aim of publishing atlases that were a testimony to their knowledge and judgment. Knowledge and judgment were, after all, their title to authority and authorship; otherwise any greenhorn or untutored artist could publish a scientific atlas. Failure to discriminate between essential and accidental detail; failure to amend a flawed or atypical specimen; failure to explain or comment upon the significance of an image—all of these would have been taken as signs of incompetence, not virtuous restraint, by the earlier atlas makers.

However, already in the early decades of the nineteenth century scientists in diverse fields, and of very diverse methodological and theoretical persuasions, began to fidget uneasily about the perils within, especially judgment and imagination. Scientists sometimes sought, not always with success, to discipline these "inner enemies," as Goethe called them,[76] by rules of method, measurement, and work discipline.[77] But more often discipline came from within, confronting the "inner enemies" on their own territory. It is this internal conflict that imparted to mechanical objectivity its high moral tone. Imagination and judgment were suspect not primarily because they were personal traits, but rather because they were "unruly" and required discipline. Moreover, lack of sufficient discipline pointed to character flaws—self-indulgence, impatience, partiality for one's own prettiest ideas, sloth, even dishonesty—which were best corrected at their source, by assuming the persona of one's own sharpest critic, even in the heat of discovery. The British physicist Michael Faraday described this supreme act of self-discipline in the language of the mortification of the spirit: "The world little knows how many of the thoughts and theories which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realized."[78] Self-discipline or self-control was of course the cardinal Victorian virtue, celebrated by the homely sage Samuel Smiles as "the primary essence of character. . . . The most self-reliant, self-governing man is always under discipline; and the more perfect the discipline, the higher will be his moral condition." Scientists figured prominently among Smiles's heroes: Faraday "was a man of excitable and even fiery nature; but, through high self-discipline, he had converted the fire into a central glow and motive power of life"; Alexander von Humboldt "pursu[ed] his scientific labors during the night or in the early morning, when most other people were asleep"; the mark of the successful scientist was "sedulous attention and painstaking industry."[79] Science now demanded self-discipline, grafted to a titanic will.

For the scientific atlas makers of the later nineteenth century, the machine aided where the will failed. At once a powerful and polyvalent symbol, the machine was fundamental to the very idea of mechanical objectivity. First, the capacity of a machine to turn out thousands of identical objects linked it with the standardizing mission of the atlas, which aimed, after all, both to standardize and to reproduce phenomena. The machine also provided a new model for the scale and perfection to which standardization might strive. Echoes of the popular fascination with the ubiquity and standardized identity of manufactured goods crop up elsewhere in the scientific literature of this period. James Clerk Maxwell, following John Herschel, used them as a metaphor for atoms too similar to be distinguished.[80] The Physikalisch-Technische Reichsanstalt in the then-recently unified Germany sought to impose the same level of standardization on scientific wares that the Customs Agency (*Zoll-Verein*) had set for commercial wares,[81] and international commissions all over Europe and North America convened to establish standard units of electricity and other physical quantities.[82] Rudolf Virchow caught some of the cultural luster associated with standardization when he extolled "geistige Einheit" to the 1871 meeting of Deutscher Naturforscher und Ärtzte shortly after German unification: "The task of the future, now that external unity of the Reich has been established, is to establish the inner unity . . . the true unification of minds, putting the many members of the nation on a common intellectual footing."[83]

Second, the machine, in the form of new scientific instruments, embodied a positive ideal of the observer: patient, indefatigible, ever alert, probing beyond the limits of the human senses. Once again, scientists took their cue from popular rhetoric on the wonder-working machine. Charles Babbage, mathematician and muse of manufacturing, rhapsodized over the advantages of mechanical labor for tasks that required endless repetition, great force, or exquisite delicacy. Scientist that he was, Babbage was especially enthusiastic about the possibilities of using machines to observe, measure, and record, for they could counteract several 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."[84] Just as manufacturers admonished their workers with the example of the more productive, more careful, more skilled machine, scientists admonished themselves with the example of the more attentive, more hardworking, more honest instrument.

Third, and most significant for our purposes, the machine, now in the form of techniques of mechanical reproduction, held out the promise of images uncontaminated by interpretation. This promise was never actually made good—neither camera obscura nor smoked-glass tracings nor photograph could rid the atlases of judgment altogether. 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 an observer and an artist, miraculously free from the inner temptation to theorize, anthropomorphize, beautify, or otherwise interpret nature. What the human observer could achieve only by iron self-discipline, the machine achieved willy-nilly—such, at least, was the hope, often expressed and just as often dashed. Here constitutive and symbolic functions of the machine blur, for the machine seemed at once a means to, and symbol of, mechanical objectivity.

In this last interplay of machine and objectivity, the scientific image commanded center stage. As we have seen, mechanical objectivity encompassed all of science in its injunctions, admonishing the theorist and experimenter trafficking in words as well as the atlas maker trafficking in images. However, the atlas image held a privileged position in the morality of mechanical objectivity, first as its enforcer and then as its purest realization. Cruveilhier had hoped that images would stand watch against the temptation to build systems in the air; his successors ruefully acknowledged images alone were not proof against the intrusions of the subjective, but they hoped in their turn that *mechanically produced* images would be. The late-nineteenth-century scientific armamentarium of machines that spewed out images, both of visible objects and of invisible forces, was a testimony to the atlas makers' hope and ingenuity.

One type of mechanical image, the photograph, became the emblem for all aspects of noninterventionist objectivity: "The photograph has acquired a symbolic value, and its fine grain and evenness of detail have come to imply objectivity; photographic vision has become a primary metaphor for objective truth."[85] This was not because the photograph was necessarily truer to nature than handmade images—many paintings bore a closer resemblance to their subject matter than early photographs, if only because they used color—but rather because the camera apparently eliminated human agency. Nonintervention, not verisimilitude, lay at the heart of mechanical objectivity, and this is why mechanically produced images captured its message best. Images had always been considered more direct than words, and mechanical images that could be touted as nature's self-portrait were more immediate still. Thus images were not just the products of mechanical objectivity; they were also its prime exemplars.

But mechanical objectivity, with its strong ascetic overtone, also tapped roots deeper and older than the machine age. Self-discipline came hard, and the struggle against the inner enemies took on, explicitly, an aura of stoic nobility. Ernest Renan, the French apostle of science, chose the language of Christian asceticism and self-sacrifice to describe the creed of the modern scientist. Praising the "painstaking, humble, laborious" work required to write scientific monographs, Renan recognized the temptation, "sweeter and more flattering to vanity," to pluck prematurely the fruit of generalization and theory. It was the very strength of this temptation, all the stronger for the more gifted scientist, that conferred moral dignity upon resistance:

> A profound scientific virtue is needed to brake that fatal inclination and to deny oneself that headlong haste, when the whole of human nature clamors for the definitive solution. The heroes of science are those who, capable of a more elevated viewpoint, can forbid themselves all premature philosophical thought . . . when all the instincts of their nature would have carried them off to fly to the high peaks.[86]

Though others may have hesitated before Renan's frankly Christian language, his moral and religious view of the scientific life permeated late-nineteenth-century visions. Pledged to depict the true objects of their world, scientists demanded of themselves a sleepless vigilance against the several temptations of theorizing, aestheticizing, and pouring evidence into preconceived molds. The rallying calls to ascetic self-discipline began in the early decades of the nineteenth century and grew ever more urgent. They are the birth cries of mechanical objectivity.

Asceticism can take on a dizzying diversity of forms, even when confined to the Christian tradition.[87] Just as the characteristic asceticism of medieval women was stamped with their special daily concerns, stalwart against the temptations of food rather than power,[88] so the asceticism of nineteenth-century scientists dealt with the sins peculiar to their tribe. St. Augustine had reproached himself with lust and pride; nineteenth-century scientists reproached themselves with anthropomorphism and interpretation. The language of self-command, of heroism spoken through clenched teeth and born of not boldness but its opposite, was remarkably similar. This resemblance was not lost on several nineteenth-century writers: Renan trumpeted science as the "courage de s'abstenir," and as the religion for the modern age. He self-consciously described the plight of the self-effacing researcher in "the phrase of the Evangelist, to lose one's soul in order to save it."[89] James Martineau detected an affinity between science and religion "in a common distrust of everything internal, even of the very faculties . . . by which the external is apprehended and received."[90]

Sociologists of religion tell us that moral virtuosity never exists without an appreciative audience, and nineteenth-century scientific asceticism was no exception. Despite the formulaic professions of humility unto self-effacement, scientific asceticism was far from modest in its aims. Like the priests whose celibacy, fasting, and vigils purified them for direct contact with the godhead and made them fit vessels for divine truth and worldly power, the self-restraint of the scientists purified them for direct contact with nature and made them fit vessels for natural truth and worldly power. Noninterventionist objectivity was the professional ethos of scientists, but it was not for scientific consumption only. By ringing the changes on the resonant cultural themes of self-purification through self-abnegation, scientists persuaded themselves and others of their worthiness to assume priestly functions in an ever more secularized society. Sometimes this ambition to become the new clerisy was laid bare for all to see, as in the cases of Renan and Claude Bernard in France, T. H. Huxley and John Tyndall in Britain, and Ernst Haeckel in Germany.[91] Sometimes such perceived arrogance triggered predictable resistance.

The trope of scientific humility must be read in light of this resistance. When French physiologist Claude Bernard harped on the modesty instilled by experiment, he was countering charges that a new scientific dogmatism had become as imperious and constricting as medieval scholasticism: "The experimenter's mind differs from the metaphysician's or the scholastic's in its modesty, because experiment makes him, moment by moment, conscious of both his relative and his absolute ignorance. In teaching man, experimental science results in lessening his pride more and more." For Bernard, pride takes on the specifically scientific meaning of metaphysical intervention, for "man is by nature metaphysical and proud. He has gone so far as to think that the idealistic creations of his mind, which correspond to his feelings, also represent reality." Against such perversities of human nature, even experiment is an insufficient check, for it is always possible to distort the results.[92] The external check of experiment must be supplemented by the internal check of self-restraint; the scientist "must never answer for her [nature] nor listen partially to her answers by taking, from the results of an experiment, only those which support or confirm his hypothesis."[93] Humility and self-restraint, the one imposed from without and the other from within, thus define the pride-breaking morality of the scientists.

Morality is the salient word here, and with it comes an apparent paradox. How could it be that the very objectivity that seemed to insulate science from the moral—the creed that takes the fact/value distinction as its motto—simultaneously lay claim to moral dignity of the highest order? This apparent contradiction is an artefact of the negative quality of objectivity. It is an ethos of restraint, both external restraints of method and quantification and internal restraints of self-denial and self-criticism. Otherwise put, objectivity is a morality of prohibitions rather than exhortations, but no less a morality for that. Among those prohibitions are bans against projection and anthropomorphism, against the insertion of hopes and fears into images of and facts about nature: these are all subspecies of interpretation, and therefore forbidden. Seen from the standpoint of mechanical objectivity alone, there is nothing to distinguish these forms of socially charged interpretation from other forms not so charged, such as system building. It took an additional political awareness, more particularly an acute awareness of ideology in the Marxist sense, to separate these particular forms of intervention from the others, and to convert nonintervention into a doctrine of "value-free" or "neutral" science.[94]

This vector pointing toward the further development of the ideals and practices of objectivity should serve as a reminder that the emergence of mechanical objectivity in the latter half of the nineteenth century by no means exhausts the history of modern objectivity as a whole. Other key elements of that history are still missing. For example, we have shown how scientific atlas makers came to brand judgment and interpretation as subjective, but not how the "subjective" per se came to be used exclusively as an epithet in science. As late as 1865, Bernard could classify mathematics among the "subjective truths . . . flowing from principles of which the mind is conscious, and which bring it the sensation of absolute and necessary evidence," in contrast to "the objective or outer world truth" that would never attain certainty.[95] Nor can we explore, in the compass of this article, how mechanical objectivity became fused with other varieties of objectivity, such as the metaphysical element that makes objectivity synonymous with truth, or the aperspectival element that identifies objectivity with the escape from any and all perspectives. Each of these elements has a distinct history, as well as partaking of a collective history binding them into a single concept.

Because so much recent philosophical attention has been directed to aperspectival objectivity, it is tempting to collapse all of objectivity into the view from nowhere.[96] This temptation to simplify by conflation should be resisted, for the highest expressions of objectivity in one mode may seem worthless when judged by the standards of another mode. The photograph that was the essence and emblem of mechanical objectivity carried no metaphysical cachet: at best it was an accurate rendering of sensory appearances, which are notoriously bad guides to the "really real." Nor would it have passed muster with the aperspectival objectivity that eradicates all that is personal, idiosyncratic, perspectival. The photographic "look" was in fact radically perspectival—as many of our X-ray users never ceased to lament. We can fully understand why photographs wear the halo of objectivity only when we recognize that the kind of objectivity that beatifies them is mechanical objectivity, and not its metaphysical or aperspectival kin. The moral of our story is that objectivity is a multifarious, mutable thing, capable of new meanings and new symbols: in both a literal and figurative sense, scientists of the late-nineteenth-century created a new image of objectivity.

Notes

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1. E.J. Marey, *La Méthode graphique dans les sciences expérimentales et particulièrement en physiologie et en médecine* (Paris, 1878), iii–vi. On Marey, see François Dagognet, *Etienne-Jules Marey: La Passion de la trace* (Paris, 1987); on the "objectification" of clinical medicine in general, see Stanley Joel Reiser, *Medicine and the Reign of Technology* (Cambridge, 1978). On the role of inscriptions to mobilize allies and to secure polemical and rhetorical aims, see Bruno Latour's "Visualization and Cognition: Thinking with Eyes and Hands," *Knowledge and Society* 6 (1986): 1–40, especially his notion of "immutable mobiles." This article also contains further references to articles relating to inscription in contemporary debates within the sociology of science.
2. See, for example, Josef M. Eder, *Atlas typischer Spektra* (Vienna, 1928); or Wilhelm His, *Anatomie menschlicher Embryonen: Atlas Tafel I–VIII* (Leipzig, 1880). One publisher alone, Lehmann Verlag, issued a series of seventeen atlases in medicine, and a much larger run of smaller hand atlases.
3. The word *atlas* was first used by Gerard Mercator in 1596 for his map of the world: see *Gerard Mercator's Map of the World*, with an introduction by B. Van 'T Hoff (Rotterdam, 1961), 17. The term spread to astronomical maps by the early eighteenth century: see the titles in Deborah J. Warner, *The Sky Explored: Celestial Cartography, 1500–1800* (New York, 1978). Because of the oversize format of these works, the word *atlas* came in the eighteenth century to designate a very large size (34″×26.5″) of drawing paper: E.J. Labarre, *Dictionary and Encyclopaedia of Paper and Paper-Making* (2nd ed., London, 1952), 10–11. The term was apparently transferred to all illustrated scientific works in the mid nineteenth century, when figures were printed separately from explanatory texts, in large format supplements—hence *atlases*, deriving from their size: e.g., text in octo, atlas in folio. As text and figures merged into a single volume, often oversize, *atlas* came to refer to the entire work, and *atlases* to the whole genre of such scientific picture books. We shall use the term retrospectively to refer to all such works, even those earlier ones which may not use the word *atlas* in the title.
4. See for example Johann Gabriel Doppelmayr, *Atlas coelestis* (Norimbergae, 1742); or Andreas Cellarius, *Harmonia macrocosmica seu atlas universalis et novus* (Amsterdam, 1666).
5. On the problem of limited access to experimental results and the solution of "virtual witnessing," see Steven Shapin and Simon Schaffer, *The Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, N.J., 1985).
6. Jean Cruveilhier, *Anatomie pathologique du corps humain*, 2 vols. (Paris, 1829–35), 1:i–ii.
7. Johann Wolfgang Goethe, "Erster Entwurf einer allgemeinen Einleitung in die vergleichende Anatomie, ausgehend von der Osteologie" (1798; 1893), in Dorothea Kuhn and Rike Wankmüller, eds., *Goethes Werke*, 14 vols. (7th ed., Munich, 1975), 13:172; trans. (slightly modified) from Douglas Miller, ed. and trans., *Goethe: Scientific Studies* (New York, 1988), 118.
8. Johann Wolfgang Goethe, "Erfahrung und Wissenschaft" (1792; 1823), in *Werke*, 13:24; trans. in Miller, *Goethe*, 24.
9. On Wandelaar and other illustrators of this period, see individual entries in Hans

Vollmer, ed., *Allgemeines Lexicon der bildenden Künstler von Antike bis zur Gegenwart*, 36 vols. (Leipzig, 1927). Many of the eighteenth-century atlas illustrators were Dutch or Dutch-trained; on the Dutch tradition of descriptive art, see Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago, 1983).

10. Bernhard Siegfried Albinus, *Tables of the Skeleton and Muscles of the Human Body* (London, 1749), sig. cr.
11. Ibid., sig. br.
12. Londa Schiebinger, "Skeletons in the Closet: The First Illustrations of the Female Skeleton in Eighteenth-Century Anatomy," *Representations* 14 (1986): 42–82.
13. Albinus, *Tables*, sig. br.
14. See for example James Sowerby, *The Mineral Conchology of Great Britain* (London, 1813), 101, 156, and passim; Daniel Sharpe, *Description of the Fossil Remains of Mollusca Found in the Chalk of England* (London, 1854), plate 11, figs. 1a and 1b. For idealizing-cum-theoretical tendencies in geological illustrations of the late eighteenth and early nineteenth centuries, see Martin Rudwick, "The Emergence of a Visual Language for Geological Science, 1760–1840," *History of Science* 14 (1976): 149–95, 171.
15. Henry Bowman Brady, *A Monograph of Carboniferous and Permian Forominifera* (London, 1876), 7.
16. Ludwig Choulant, *History and Bibliography of Anatomic Illustration* (1852), ed. and trans. Mortimer Frank (Chicago, 1920), 23.
17. William Hunter, *The Anatomy of the Human Gravid Uterus* (Birmingham, 1774), preface, n.p.
18. See Ludmilla J. Jordanova, "Gender, Generation, and Science: William Hunter's Obstetrical Atlas," in W. F. Bynum and Roy Porter, eds., *William Hunter and the Eighteenth-Century Medical World* (Cambridge, 1985), 385–412, especially her perceptive contrast of the treatment of the female cadaver and that of the fetus in Hunter's atlas.
19. On preparing the cadaver for illustration, see Robert Herrlinger and Marilene Putscher, *Geschichte der medizinischen Abbildung*, 2 vols. (Munich, 1972), 2:49.
20. Hunter, *Anatomy*, plate 2, n.p.
21. On artistic anticipations of "photographic" vision, see Peter Galassi, *Before Photography: Painting and the Invention of Photography* (New York, 1981).
22. William Cheselden, *Osteographia; or, The Anatomy of the Bones* (London, 1733), "To the Reader," n.p.
23. Georges Canguilhem, *On the Normal and the Pathological* (1966), trans. Carolyn R. Fawcett (Dordrecht, 1978).
24. Cruveilhier, *Anatomie*, vol. 1, book 17, p. 5.
25. B. A. Morel, *Traité de dégénérescences physiques, intellectuelles, et morales de l'espèce humaine: Atlas de XII planches* (Paris, 1857), 5, 19, 12.
26. Henry Woodward, *A Monograph of the British Fossil Crustacea Belonging to the Order Merostomata* (London, 1866), 2; see also O. C. Marsh, "The Value of Type Specimens and Importance of Their Preservation," *American Journal of Science* 6 (1898): 401–9, 401; and Charles Schuchert, "Catalogue of the Type of Specimens of Fossil Invertebrates in the Department of Geology, United States National Museum," *Bulletin of the United States National Museum*, no. 53, part 1 (Washington, 1905), 9–12.
27. On statistical essentialism in Quetelet and others, see Theodore M. Porter, *The Rise of Statistical Thinking* (Princeton, N.J., 1986).
28. Gottlieb Gluge, *Atlas of Pathological Histology*, trans. Joseph Leidy (Philadelphia, 1853), 6.

29. Walter Fitch, "Botanical Drawing," *Gardeners' Chronicle* (1869); reprinted in Wilfrid Blunt, *The Art of Botanical Illustration* (London, 1950), 276.
30. Joseph Dalton Hooker, *The Rhododendron of Sikkim-Himalaya*, ed. W. Hooker (2nd ed., London, 1849), n.p.
31. John Lycett, *A Monograph of the British Fossil Trigoniae* (London, 1875), 134.
32. William Anderson, "An Outline of the History of Art in Its Relation to Medical Science," introductory address delivered at the Medical and Physical Society of St. Thomas's Hospital, 1885, *Saint Thomas's Hospital Reports* 15 (1886): 151–81, 170.
33. Ibid., 172. 34. Ibid., 175. 35. Ibid., 179–80.
36. Ibid., 175.
37. Quoted in Linda Nochlin, *Realism* (Harmondsworth, Eng., 1971), 36.
38. Charles W. Cathcart and F. M. Caird, *Johnston's Students' Atlas of Bones and Ligaments* (Edinburgh, 1885), preface, n.p.
39. E. Ponfick, *Topographischer Atlas der medezinisch-chirurgischen Diagnostik* (Jena, 1901), "Methode" (i.e., methodological preface), n.p.
40. Johannes Sabotta, *Atlas and Text-Book of Human Anatomy* (Philadelphia, 1909), 13 (emphasis added).
41. Johannes Sabotta, *Atlas und Grundriss der Histologie und mikroskopischen Anatomie des Menschen* (Munich, 1902), vi–vii.
42. Francis Galton, "Composite Portraits," *Nature* 18 (1878): 97–100, 97.
43. W. Walter Maunder, *The Royal Observatory Greenwich: A Glance at Its History and Work* (London, 1900), 176–77. We would like to thank Simon Schaffer for bringing this quotation to our attention; also see his article, "Astronomers Mark Time: Discipline and the Personal Equation," *Science in Context* 2 (1988): 115–45.
44. Hermann Pagenstecher and Carl Centus, *Atlas der pathologischen Anatomie der Augapfels* (Wiesbaden, 1875), vii, emphasis added.
45. Ibid., vii–viii, emphasis added.
46. M. Allen Starr, *Atlas of Nerve Cells* (New York, 1896), v–vi.
47. Rudolf Grashey, *Chirurgisch-Pathologische Röntgenbilder*, vol. 2 (Munich, 1924), from first preface, iii–iv.
48. W. Gentner, H. Maier-Leibniz, and W. Bothe, *An Atlas of Typical Expansion Chamber Photographs* (New York, 1954).
49. Gertrude L. Elles and Ethel M. R. Wood, *A Monograph of British Graptolites* (London, 1901), 2.
50. Frederic A. Gibbs and Erna L. Gibbs, *Atlas of Electroencephalography* (Cambridge, Mass., 1941), preface, n.p.
51. P. M. S. Blackett, foreword to G. D. Rochester and J. G. Wilson, *Cloud Chamber Photographs of the Cosmic Radiation* (New York, 1952), vii.
52. Rudolf Grashey, *Typische Röntgenbilder vom normalen Menschen* (Munich, 1939), v.
53. For a Foucauldian analysis of the role of photography as a means of social control, see John Tagg, *The Burden of Representation* (Amherst, Mass., 1988), and references therein.
54. Dr. Ames, cited in the "Report of the Committee of the American Surgical Association on the Medico-Legal Relations of the X-Rays," *American Journal of the Medical Sciences* 120 (1900): 7–36, 22.
55. Ibid., 29; citation to Dr. Samuel Lloyd, *Journal of the American Medical Association*, 7 May 1898, 1111.
56. R. Harvey Reed, "The X-Ray from a Medico-Legal Standpoint," *Journal of the American Medical Association*, 35 (1898): 1013–19, 1018.

57. Ames, "Report on Medico-Legal Relations," 11.
58. Cited in Richard Rudisill, *Mirror Image: Influence of the Daguerreotype on American Society* (Albuquerque, N.M., 1971); itself cited in Allan Sekula, "On the Invention of Photographic Meaning," in Victor Burgin, *Thinking Photography* (Houndmills, Eng., 1982), 86–87.
59. Don W. Fawcett, "Histology and Cytology," in *Modern Developments in Electron Microscopy*, ed. B. M. Siegel (New York, 1964).
60. Charles Rosen and Henri Zerner, *Romanticism and Realism* (New York, 1984), 108.
61. Dr. T. S. K. Morton, in Ames, "Report on Medico-Legal Relations," 24.
62. *Lancet* (1899), cited in ibid., 33. *Skiagram* (from Greek *skia*, "shadow") was a term from 1795 to 1805 for an image made by a shadow cast on photosensitized medium. *Skiagram*, *skiagraph*, and *radiogram* seem to have been used interchangeably.
63. Ames, "Report on Medico-Legal Relations," 36 (among eight conclusions unanimously adopted as expressing views of the American Surgical Association).
64. Reed, "Medico-Legal Standpoint," 1016.
65. Erwin Christeller, *Atlas der Histotopographie gesunder und erkrankter Organe* (Leipzig, 1927).
66. Ibid., 18. 67. Ibid. 68. Ibid.
69. Ibid., 19.
70. Alexander Bruce, *A Topographical Atlas of the Spinal Cord* (London, 1901), preface, n.p.
71. Marey, *Methode graphique*, iii. 72. Ibid., viii–ix.
73. Gaston Tissandier, *Les Merveilles de la photographie* (Paris, 1874), 226, 254–55, and 264.
74. The debate over the role of photographic versus hand-drawn representation continues. As John Law shows in his article, "Lists, Field Guides, and the Descriptive Organization of Seeing: Birdwatching as an Exemplary Observational Activity," *Human Studies* 11 (1988): 271–303. One opponent of photographic representation writes: "A drawing can do much more than a photograph to emphasize the field marks. A photograph is a record of a fleeting instant; a drawing is a composite of the artist's experience. The artist can edit out, show field marks to best advantage, and delete unnecessary clutter. He can choose position and stress basic color and pattern unmodified by transitory light and shade. . . . Whereas a photograph can have a living immediacy a good drawing is really more instructive" (279–81). On the opposing side, the Audubon Society guide advocated photographic realism: "Photographs add a new dimension in realism and natural beauty. Fine modern photographs are closer to the way the human eye usually sees a bird and, moreover, they are a pleasure to look at" (286).
75. Choulant, *History*, 30.
76. Johann Wolfgang Goethe, "Der Versuch als Vermittler von Objekt und Subjekt" (1792; 1823), in *Werke*, 13:14–15; trans. in Miller, *Goethe*, 14.
77. See Zeno J. Switjtink, "The Objectification of Measurement," in Lorenz Krüger et al., eds., *Probabilistic Revolution*, vol. 1, *Ideas in History* (Cambridge, Mass., 1987), 261–85; Simon Schaffer, "Astronomers Mark Time . . . ," *Science in Context* 2 (1988): 115–46; Richard Yeo, "Scientific Method and the Rhetoric of Science in Britain, 1830–1917," in J. A. Schuster and Yeo, eds., *The Politics and Rhetoric of Scientific Method* (Dordrecht, 1986), 259–97.
78. Quoted in Karl Pearson, *The Grammar of Science* (London, 1892), 38.
79. Samuel Smiles, *Character* (New York, 1880), 165, 167, 175; *Life and Labor* (Chicago, 1891), 58; *Self-Help* (New York, 1915), 144. We are grateful to Simon Schaffer for drawing our attention to Smiles's views on scientists.

80. James Clerk Maxwell, "Atom," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (New York, 1965), 445–84.
81. David Cahan, *An Institute for Empire: The Physikalisch-Technische Reichanstalt, 1871–1918* (Cambridge, 1989).
82. Simon Schaffer, "A Manufactury of Ohms: The Integrity of Victorian Values" (Unpublished MS).
83. Rudolf Virchow, address, *Tageblatt der 44, Versammlung Deutscher Naturforscher und Ärtzte* (Rostock, 1871), 77.
84. Charles Babbage, *On the Economy of Machinery and Manufactures* (4th ed., London, 1835), 54.
85. Rosen and Zerner, *Romanticism*, 108.
86. Ernest Renan, *L'Avenir de la science* (Paris, 1890), 235.
87. Peter Brown, *The Body and Society: Men, Women, and Sexual Renunciation in Early Christianity* (New York, 1988), xvii.
88. Caroline Walker Bynum, *Holy Feast and Holy Fast: The Religious Significance of Food to Medieval Women* (Berkeley, 1987).
89. Renan, *Avenir*, 235.
90. Quoted in Frank Miller Turner, *Between Science and Religion: The Reaction to Scientific Naturalism in Late Victorian England* (New Haven, 1974), 2.
91. Ibid., 9.
92. Claude Bernard countenanced the interventions and hypotheses of the experimenter, but he strictly distinguished the role of the experimenter from that of the observer who records the results. Bernard even flirted with the idea that the latter function might best be performed by "an uneducated man, knowing nothing of theory"; *An Introduction to the Study of Experimental Medicine* (1865), trans. Henry Copley Green (New York, 1957), 38.
93. Ibid., 28, 27, 22–23.
94. Robert N. Proctor, *Value-Free Science?: The Origins of an Ideal* (Cambridge, Mass., forthcoming). See also Max Weber, "'Objektivität' sozialwissenschaftlicher und sozialpolitischer Erkenntnis" (1904), in Johannes Winckelmann, ed., *Gesammelte Aufsätze für Wissenschaftslehre* (3rd ed., Tübingen, 1968), 146–214.
95. Bernard, *Introduction*, 28–29; compare British physiologist Thomas Henry Huxley, *Autobiographies*, ed. Gavin de Beer (Oxford, 1983), 95–96.
96. Thomas Nagel, *The View from Nowhere* (Oxford, 1986). Nagel gives as his source Bernard Williams's notion of "pure" or "absolute inquiry" as developed in *Descartes: The Project of Pure Inquiry* (Harmondsworth, Eng., 1978), but its most lyrical philosophical exponent was Charles Sanders Pierce; see for example his "A Critical Review of Berkeley's Idealism" (1871), in Philip Wiener, ed., *Values in a Universe of Chance: Selected Writings of C. S. Pierce* (New York, 1958), 81–83.