Contents

Chapter One

Epistemologies of the Eye

Blind Sight

Scientific objectivity has a history. Objectivity has not always defined science. Nor is objectivity the same as truth or certainty, and it is younger than both. Objectivity preserves the artifact or variation that would have been erased in the name of truth; it scruples to filter out the noise that undermines certainty. To be objective is to aspire to knowledge that bears no trace of the knower—knowledge unmarked by prejudice or skill, fantasy or judgment, wishing or striving. Objectivity is blind sight, seeing without inference, interpretation, or intelligence. Only in the mid-nineteenth century did scientists begin to yearn for this blind sight, the "objective view" that embraces accidents and asymmetries, Arthur Worthington's shattered splash-coronet. This book is about how and why objectivity emerged as a new way of studying nature, and of being a scientist.

Since the nineteenth century, objectivity has had its prophets, philosophers, and preachers. But its specificity—and its strangeness—is most clearly seen in the everyday work of its practitioners: literally seen, in the essential practice of scientific image-making. Making pictures is not the only practice that has served scientific objectivity: an armamentarium of other techniques, including inference statistics, double-blind clinical trials, and self-registering instruments, have been enlisted to hold subjectivity at bay.[1] But none is as old and ubiquitous as image making. We have chosen to tell the history of scientific objectivity through pictures drawn from the long tradition of scientific atlases, those select collections of images that identify a discipline's most significant objects of inquiry.

Look, if you will, at these three images from scientific atlases: the first, from an eighteenth-century flora; the second, from a late nineteenth-century catalogue of snowflakes; the third, from a mid-twentieth-century compendium of solar magnetograms (see figures 1.1, 1.2, and 1.3). A single glance reveals that the images were differently made: a copperplate engraving, a microphotograph, an instrument contour. The practiced eye contemporary with any one of these images made systematic sense of it. These three figures constitute a synopsis of our story. They capture more than a flower, a snowflake, a magnetic field: each encodes a technology of scientific sight implicating author, illustrator, production, and reader.

Each of these images is the product of a distinct code of epistemic virtue, codes that we shall call, in terms to be developed presently, truth-to-nature, mechanical objectivity, and trained judgment. As the dates of the images suggest, this is a historical series, and it will be one of the principal theses of this book that it is a series punctuated by novelty. There was a science of truth-to-nature before there was one of objectivity; trained judgment was, in turn, a reaction to objectivity. But this history is one of innovation and proliferation rather than monarchic succession. The emergence of objectivity as a new epistemic virtue in the mid-nineteenth century did not abolish truth-to-nature, any more than the turn to trained judgment in the early twentieth century eliminated objectivity. Instead of the analogy of a succession of political regimes or scientific theories, each triumphing on the ruins of its predecessor, imagine new stars winking into existence, not replacing old ones but changing the geography of the heavens.

There is a deep historical rhythm to this sequence: in some strong sense, each successive stage presupposes and builds upon, as well as reacts to, the earlier ones. Truth-to-nature was a precondition for mechanical objectivity, just as mechanical objectivity was a precondition for trained judgment. As the repertoire of epistemic virtues expands, each redefines the others. This is not some neat Hegelian arithmetic of thesis plus antithesis equals synthesis, but a far messier situation in which all the elements continue in play and in interaction with one another. Late twentieth-century scientists could and did still sometimes strive for truth-to-nature in their images, but they did not, could not, simply return to the ideals and practices of their eighteenth-century predecessors. The meaning of truth-to-nature had been recast by the existence of alternatives, which in some cases figured as competitors. Judgment, for example, was understood differently before and after objectivity: what was once an act of practical reason became an intervention of subjectivity, whether defensively or defiantly exercised.

In contrast to the static tableaux of paradigms and epistemes, this is a history of dynamic fields, in which newly introduced bodies reconfigure and reshape those already present, and vice versa. The reactive logic of this sequence is productive. You can play an eighteenth-century clavichord at any time after the instrument's revival around 1900 — but you cannot hear it after two intervening centuries of the pianoforte in the way it was heard in 1700. Sequence weaves history into the warp and woof of the present: not just as a past process reaching its present state of rest — how things came to be as they are — but also as the source of tensions that keep the present in motion.

This book describes how these three epistemic virtues, truth-to-nature, objectivity, and trained judgment, infused the making of images in scientific atlases from roughly the early eighteenth to the mid-twentieth century, in Europe and North America. The purview of these virtues encompasses far more than images, and atlases by no means exhaust even the realm of scientific images.[2] We have narrowed our sights to images in scientific atlases, first, because we want to show how epistemic virtues permeate scientific practice as well as precept; second, because scientific atlases have been central to scientific practice across disciplines and periods; and third, because atlases set standards for how phenomena are to be seen and depicted. Scientific atlas images are images at work, and they have been at work for centuries in all the sciences of the eye, from anatomy to physics, from meteorology to embryology.

Collective Empiricism

All sciences must deal with the problem of selecting and constituting "working objects," as opposed to the too plentiful and too various natural objects. Working objects can be atlas images, type specimens, or laboratory processes — any manageable, communal representative of the sector of nature under investigation. No science can do without such standardized working objects, for unrefined natural objects

Fig. 1.1. Truth-to-Nature. *Campanula foliis hastatis dentatis*, Carolus Linnaeus, *Hortus Cliffortianus* (Amsterdam: n.p., 1737), table 8 (courtesy of Staats- und Universitätsbibliothek Göttingen). Drawn by Georg Dionysius Ehret, engraved by Jan Wandelaar, and based on close observation by both naturalist and artist, this illustration for a landmark botanical work (still used by taxonomists) aimed to portray the underlying type of the plant species, rather than any individual specimen. It is an image of the characteristic, the essential, the universal, the typical: truth-to-nature.

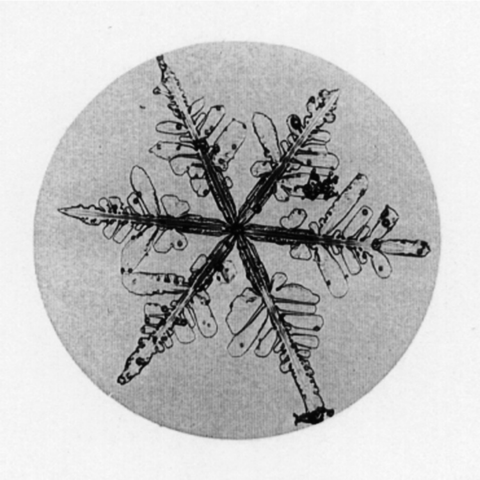


Fig. 1.2. Mechanical Objectivity. Snowflake, Gustav Hellmann, with microphotographs by Richard Neuhauss, *Schneekrystalle: Beobachtungen und Studien* (Berlin: Mückenberger, 1893), table 6, no. 10. An individual snowflake is shown with all its peculiarities and asymmetries in an attempt to capture nature with as little human intervention as possible: mechanical objectivity.

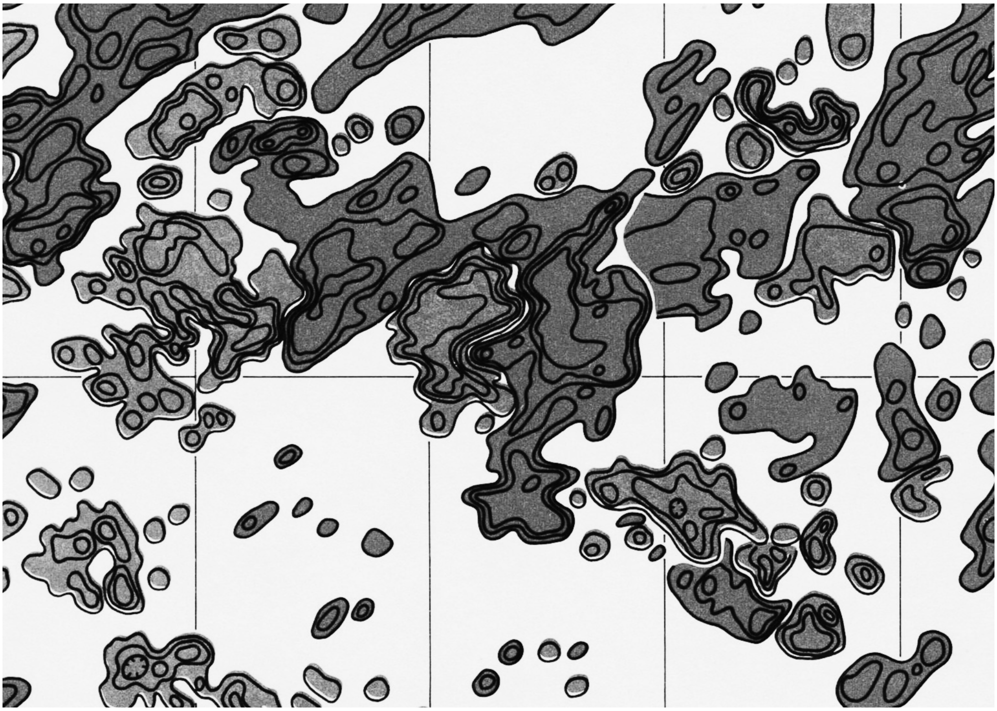


Fig. 1.3. Trained Judgment. Sun Rotation 1417, Aug.–Sept. 1959 (detail), Robert Howard, Václav Bumba, and Sara F. Smith, *Atlas of Solar Magnetic Fields*, August 1959 – June 1966 (Washington, DC: Carnegie Institute, 1967) (courtesy of the Observatories of the Carnegie Institution of Washington, DC). This image of the magnetic field of the sun mixed the output of sophisticated equipment with a "subjective" smoothing of the data — the authors deemed this intervention necessary to remove instrumental artifacts: trained judgment. (Please see Color Plates.)

are too quirkily particular to cooperate in generalizations and comparisons. Sometimes these working objects replace natural specimens: for example, a 1795 report on the collection of the vellum paintings of plants and animals at the Muséum d'Histoire Naturelle in Paris explained how such images could "reanimate, by this means, plants that blossomed . . . by chance [once] in fifty or a hundred years, like the agave that flowered last year; the same goes for the animals that often pass but rarely in our climes and of which one sees sometimes only one individual in centuries."[3] Even scientists working in solitude must regularize their objects. *Collective empiricism*, involving investigators dispersed over continents and generations, imposes still more urgently the need for common objects of inquiry.

Atlases are systematic compilations of working objects. They are the dictionaries of the sciences of the eye. For initiates and neophytes alike, the atlas trains the eye to pick out certain kinds of objects as exemplary (for example, this "typical" healthy liver rather than that one with cirrhosis) and to regard them in a certain way (for example, 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 bacteriological atlases of the late nineteenth century and the x-ray atlases of the early twentieth century, everyone in the field addressed by the atlas must begin to learn to "see" anew. Whatever the amount and avowed function of the text in an atlas, which varies from long and essential to nonexistent or despised, the illustrations command center stage. Usually displayed in giant format, meticulously drawn and reproduced, and expensively printed, they are the *raison d'être* of the atlas. To call atlas images "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, pictures are the alpha and the omega of the genre.

Not only do images make the atlas; atlas images make the science. Atlases are the repositories of images of record for the observational sciences. The name "atlas" derives from Gerardus Mercator's world map, *Atlas sive cosmographicae meditationes de fabrica mvndi et fabricati figvra* (*Atlas, or Cosmographical Meditations on the Fabric of the World*, 1595) (the title was an allusion to the titan Atlas of Greek mythology, who bore the world on his shoulders). By the late eighteenth century, the term had spread from geography to astronomy and anatomy ("maps" of the heavens or the human body), and, by the mid-nineteenth century, "atlases" had proliferated throughout the empirical sciences.[5] Even if older works did not bear the word "atlas" in their titles, they were explicitly included in the lineage that later atlas makers were obliged to trace: every new atlas must begin with an explanation of why the old ones are no longer adequate to their task, why new images of record are necessary. These genealogies define what counts as an atlas in our account. Whether atlases display crystals or cloud chamber traces, brain slices or galaxies, they still aim to "map" the territory of the sciences they serve. They are the guides all practitioners consult time and time again to find out what is worth looking at, how it looks, and, perhaps most important of all, how it should be looked at.

These reference works may be as small as a field guide that slips into a naturalist's pocket, but they tend toward the large, even the gigantic. Many are oversized volumes (an "atlas folio" is a book twenty-three to twenty-five inches tall), and some are too large and heavy to be comfortably handled by a single person. John James Audubon's *Birds of America* (1827–38) was printed as a double elephant folio (twenty-seven inches by thirty-nine inches); James Bateman's *Orchidaceae of Mexico and Guatemala* (1837–43) weighed over thirty-eight pounds. (See figures 1.4 and 1.5.) The ambitions of the authors rival the grand scale of their books. Atlas makers woo, badger, and monopolize the finest artists available. They lavish the best quality ink and paper on images displayed in grand format, sometimes life-size or larger. Atlases are expensive, even opulent works that devour time, nerves, and money, as their authors never tire of repeating. Atlas prefaces read like the trials of Job: the errors of earlier atlases that must be remedied; the long wait for just the right specimens; the courting and correcting of the artist; the pitched battle with the cheapskate publisher; the penury to which the whole endless project has reduced the indefatigable author. These pains are worth taking because an atlas is meant to be a lasting work of orientation for

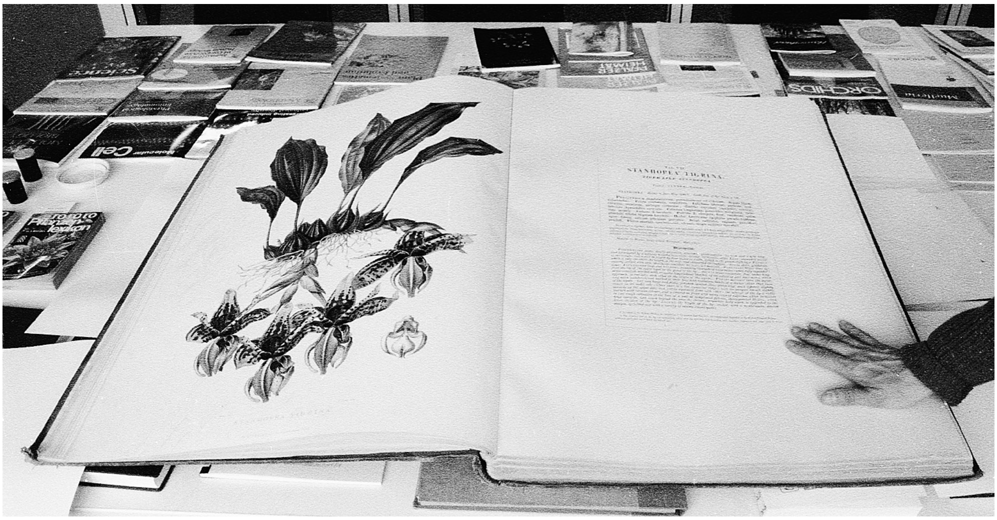
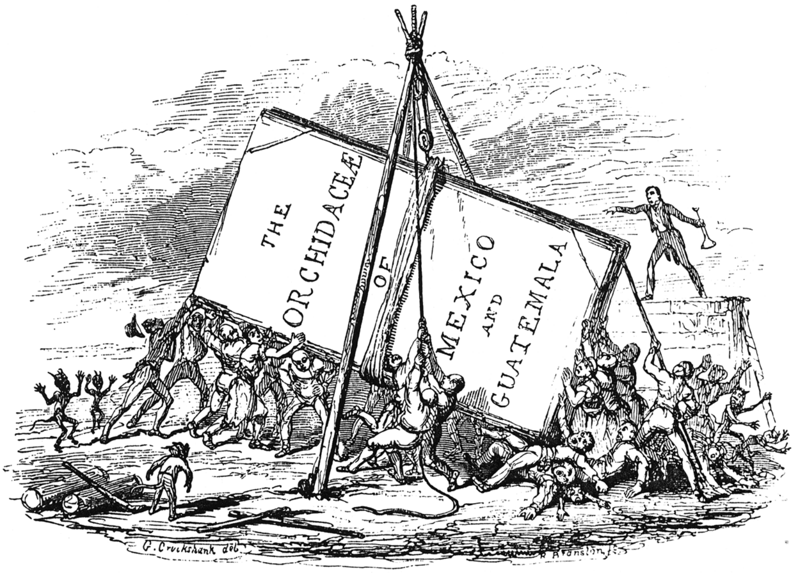


Fig. 1.4. Double Elephant, *Stanhopea tigrina*. James Bateman, *The Orchidaceae of Mexico and Guatemala* (London: Ridgway, 1837–1843), pl. 7, drawn by Augusta Withers and lithographed by M. Gauci (Botanical Garden, Berlin). The opulently produced flora makes full use of the double elephant folio page to display the hand-colored images of the orchids but allows the accompanying text (a mere 8.5 by 11 inches) to float like an island on the facing page. The hand and surrounding normal-sized books give some idea of the scale of this expensive, enormous, and unwieldy volume, produced in a format to set off the images to maximal effect. Photograph by Kelley Wilder. (Please see Color Plates.)



Μεγα βιβλιον μεγα κακον.

Fig. 1.5. "Big Book, Great Evil." James Bateman, *The Orchidaceae of Mexico and Guatemala* (London: Ridgway, 1837–1843), p. 8, drawn by George Cruikshank (Botanical Garden, Berlin). The Victorian cartoonist Cruikshank's vignette pokes fun at the elephantine dimensions of Bateman's atlas. A team of laborers struggles to hoist the volume with a pulley; the Greek caption is reinforced by the jeering demons looking on from the left. Since the cartoon was commissioned by Bateman himself, it probably expresses his own attitude of mingled enthusiasm and self-irony toward his magnum opus.

generations of observers. Every atlas is presented with fanfare, as if it were the atlas to end all atlases. Atlases aim to be definitive in every sense of the term: they set the standards of a science in word, image, and deed — how to describe, how to depict, how to see.

Since at least the seventeenth century, scientific atlases have served to train the eye of the novice and calibrate that of the old hand. They teach how to see the essential and overlook the incidental, which objects are typical and which are anomalous, what the range and limits of variability in nature are. Without them, every student of nature would have to start from scratch to learn to see, select, and sort. Building on the work of others would be difficult or impossible, for one could never be sure that one's predecessors and correspondents were referring to the same thing, seen in the same tutored way. Only those who had learned at the master's side would be visually coordinated. Science would be confined, as it was for many centuries, before the advent of printing made the wide dissemination of such atlases practicable, to local traditions of apprenticeship. Images like these were far from merely decorative. They made collective empiricism in the sciences possible, beyond the confines of a local school.

Making and using an atlas is one of the least individual activities in science. Atlases are intrinsically collective. They are designed for longevity: if all goes well, they should serve generations within a scientific community. Many are themselves the fruit of scientific collaborations, drawing their images from a multitude of authors or author-groups. Almost all depend on a close working relationship between scientist and illustrator. But the contributions of atlases go further: atlases make other collaborations possible, including the loose collaborations that permit dispersed observers to exchange and accumulate results. Early atlases were often written in Latin to assure maximum diffusion; after the demise of Latin as the lingua franca of the learned world, bilingual and trilingual editions were produced for the same reason. The atlas is a profoundly social undertaking, but because the term "social" carries so many and such varied connotations, it would be more precise to say that the atlas is always — and fundamentally — an exemplary form of collective empiricism: the collaboration of investigators distributed over time and space in the study of natural phenomena too vast and various to be encompassed by a solitary thinker, no matter how brilliant, erudite, and diligent.

Atlas makers create one sliver of the world anew in images — skeletons, stellar spectra, bacteria. Atlas users become the people of a book, which teaches them how to make sense of their sliver-world and how to communicate with one another about it. Certain atlas images may become badges of group identity, nowadays emblazoned on T-shirts and conference logos, in earlier decades and centuries etched in memory like icons. Dog-eared and spine-cracked with constant use, atlases enroll practitioners as well as phenomena. They simultaneously assume the existence of and call into being communities of observers who see the same things in the same ways. Without an atlas to unite them, atlas makers have long claimed, all observers are isolated observers.

In this book, we trace the emergence of epistemic virtues through atlas images — by no means the only expression of truth-to-nature or objectivity or trained judgment, but nonetheless one of the most revealing. By examining volumes of images of record (including atlases, handbooks, surveys, and expedition reports), abstractions like objectivity become concrete and visible, reflections of changing scientific ambitions for right depiction.

The history we propose raises a flock of questions: What exactly are epistemic virtues? How do lofty norms like truth, objectivity, and judgment connect with on-the-ground scientific conduct? Why try to track an entity as abstract as epistemology via the concrete details of a drawing or a photograph? And, above all, how can objectivity have a history? In the remainder of this introductory chapter, we will try to make this counterintuitive brand of history plausible, tackling the last, most burning question first.

Objectivity Is New

The history of scientific objectivity is surprisingly short. It first emerged in the mid-nineteenth century and in a matter of decades became established not only as a scientific norm but also as a set of practices, including the making of images for scientific atlases. However dominant objectivity may have become in the sciences since *circa* 1860, it never had, and still does not have, the epistemological field to itself. Before objectivity, there was truth-to-nature; after the advent of objectivity came trained judgment. The new did not always edge out the old. Some disciplines were won over quickly to the newest epistemic virtue, while others persevered in their allegiance to older ones. The relationship among epistemic virtues may be one of quiet compatibility, or it may be one of rivalry and conflict. In some cases, it is possible to pursue several simultaneously; in others, scientists must choose between truth and objectivity, or between objectivity and judgment. Contradictions arise.

This situation is familiar enough in the case of moral virtues. Different virtues — for example, justice and benevolence — come to be accepted as such in different historical periods. The claims of justice and benevolence can all too plausibly collide in cultures that honor both: for Shylock in *The Merchant of Venice*, a man's word is his bond; Portia replies that the quality of mercy is not strained. Codes of virtue, whether moral or epistemic, that evolve historically are loosely coherent, but not strictly internally consistent. Epistemic virtues are distinct as ideals and, more important for our argument, as historically specific ways of investigating and picturing nature. As ideals, they may more or less peacefully, if vaguely, coexist. But at the level of specific, workaday choices — which instrument to use, whether to retouch a photograph or disregard an outlying data point, how to train young scientists to see — conflicts can occur. It is not always possible to serve truth and objectivity at the same time, any more than justice and benevolence can always be reconciled in specific cases.

Here skeptics will break in with a chorus of objections. Isn't the claim that objectivity is a nineteenth-century innovation tantamount to the claim that science itself begins in the nineteenth century? What about Archimedes, Andreas Vesalius, Galileo, Isaac Newton, and a host of other luminaries who worked in earlier epochs? How can there be science worthy of the name without objectivity? And how can truth and objectivity be pried apart, much less opposed to each other?

All these objections stem from an identification of objectivity with science *tout court*. Given the commanding place that objectivity has come to occupy in the modern manual of epistemic virtues, this conflation is perhaps not surprising. But it is imprecise, both historically and conceptually. Historically, it ignores the evidence of usage and use: when, exactly, did scientists start to talk about objectivity, and how did they put it to work? Conceptually, it operates by synecdoche, making this or that aspect of objectivity stand for the whole, and on an *ad hoc* basis. The criterion may be emotional detachment in one case; automatic procedures for registering data in another; recourse to quantification in still another; belief in a bedrock reality independent of human observers in yet another. In this fashion, it is not difficult to tote up a long list of forerunners of objectivity — except that none of them operate with the concept in its entirety, to say nothing of the practices. The aim of a non-teleological history of scientific objectivity must be to show how all these elements came to be fused together (it is not self-evident, for example, what emotional detachment has to do with automatic data registration), designated by a single word, and translated into specific scientific techniques. Moreover, isolated instances are of little interest. We want to know when objectivity became ubiquitous and irresistible.

The evidence for the nineteenth-century novelty of scientific objectivity starts with the word itself. The word "objectivity" has a somersault history. Its cognates in European languages derive from the Latin adverbial or adjectival form *obiectivus/obiective*, introduced by fourteenth-century scholastic philosophers such as Duns Scotus and William of Ockham. (The substantive form does not emerge until much later, around the turn of the nineteenth century.) From the very beginning, it was always paired with *subiectivus/subiective*, but the terms originally meant almost precisely the opposite of what they mean today. "Objective" referred to things as they are presented to consciousness, whereas "subjective" referred to things in themselves.[6] One can still find traces of this scholastic usage in those passages of the *Meditationes de prima philosophia* (*Meditations on First Philosophy*, 1641) where René Descartes contrasts the "formal reality" of our ideas (that is, whether they correspond to anything in the external world) with their "objective reality" (that is, the degree of reality they enjoy by virtue of their clarity and distinctness, regardless of whether they exist in material form).[7] Even eighteenth-century dictionaries still preserved echoes of this medieval usage, which rings so bizarrely in modern ears: "Hence a thing is said to *exist* OBJECTIVELY, *objectivè*, when it exists no otherwise than in being known; or in being an Object of the Mind."[8]

The words *objective* and *subjective* fell into disuse during the seventeenth and eighteenth centuries and were invoked only occasionally, as technical terms, by metaphysicians and logicians.[9] It was Immanuel Kant who dusted off the musty scholastic terminology of "objective" and "subjective" and breathed new life and new meanings into it. But the Kantian meanings were the grandparents, not the twins, of our familiar senses of those words. Kant's "objective validity" (*objektive Gültigkeit*) referred not to external objects (*Gegenstände*) but to the "forms of sensibility" (time, space, causality) that are the preconditions of experience. And his habit of using "subjective" as a rough synonym for "merely empirical sensations" shares with later usage only the sneer with which the word is intoned. For Kant, the line between the objective and the subjective generally runs between universal and particular, not between world and mind.

Yet it was the reception of Kantian philosophy, often refracted through other traditions, that revamped terminology of the objective and subjective in the early nineteenth century. In Germany, idealist philosophers such as Johann Gottlieb Fichte and Friedrich Schelling turned Kant's distinctions to their own ends; in Britain, the poet Samuel Taylor Coleridge, who had scant German but grand ambitions, presented the new philosophy to his countrymen as a continuation of Francis Bacon; in France, the philosopher Victor Cousin grafted Kant onto Descartes.[10] The post-Kantian usage was so new that some readers thought at first it was just a mistake. Coleridge scribbled in his copy of Henrich Steffens's *Grundzüge der philosophischen Naturwissenschaft* (*Foundations of Philosophical Natural Science*, 1806): "Steffens has needlessly perplexed his reasoning by his strange use of Subjective and Objective—his S[ubjectivity] = the O[bjectivity] of former Philosophers, and his O[bjectivity] = their S[ubjectivity]."[11] But by 1817 Coleridge had made the barbarous terminology his own, interpreting it in a way that was to become standard thereafter: "Now the sum of all that is merely OBJECTIVE, we will henceforth call NATURE, confining the term to its passive and material sense, as comprising all the phaenomena by which its existence is made known to us. On the other hand the sum of all that is SUBJECTIVE, we may comprehend in the name of the SELF or INTELLIGENCE. Both conceptions are in necessary antithesis."[12]

Starting in the 1820s and 1830s, dictionary entries (first in German, then in French, and later in English) began to define the words "objectivity" and "subjectivity" in something like the (to us) familiar sense, often with a nod in the direction of Kantian philosophy. In 1820, for example, a German dictionary defined *objektiv* as a "relation to an external object" and *subjektiv* as "personal, inner, inhering in us, in opposition to objective"; as late as 1863, a French dictionary still called this the "new sense" (diametrically opposed to the old, scholastic sense) of word *objectif* and credited "the philosophy of Kant" with the novelty. When the English man of letters Thomas De Quincey published the second edition of his *Confessions of an English Opium Eater* in 1856, he could write of "objectivity": "This word, so nearly unintelligible in 1821 [the date of the first edition], so intensely scholastic, and consequently, when surrounded by familiar and vernacular words, so apparently pedantic, yet, on the other hand, so indispensable to accurate thinking, and to wide thinking, has since 1821 become too common to need any apology."[13] Sometime *circa* 1850 the modern sense of "objectivity" had arrived in the major European languages, still paired with its ancestral opposite "subjectivity." Both had turned 180 degrees in meaning.

Skeptics will perhaps be entertained but unimpressed by the curious history of the word "objectivity." Etymology is full of oddities, they will concede, but the novelty of the word does not imply the novelty of the thing. Long before there was a vocabulary that captured the distinction that by 1850 had come to be known as that between objectivity and subjectivity, wasn't it recognized and observed in fact? They may point to the annals of seventeenth-century epistemology, to Bacon and Descartes.[14] What, after all, was the distinction between primary and secondary qualities that Descartes and others made, if not a case of objectivity versus subjectivity *avant la lettre*? And what about the idols of the cave, tribe, marketplace, and theater that Bacon identified and criticized in *Novum organum* (*New Organon*, 1620): don't these constitute a veritable catalogue of subjectivity in science?

These objections and many more like them rest on the assumption that the history of epistemology and the history of objectivity coincide. But our claim is that the history of objectivity is only a subset, albeit an extremely important one, of the much longer and larger history of epistemology — the philosophical examination of obstacles to knowledge. Not every philosophical diagnosis of error is an exercise in objectivity, because not all errors stem from subjectivity. There were other ways to go astray in the natural philosophy of the seventeenth century, just as there are other ways to fail in the science of the twentieth and early twenty-first centuries.

Take the case of the primary-secondary quality distinction as Descartes advanced it in the *Principia philosophiae* (*Principles of Philosophy*, 1644). Descartes privileged size, figure, duration, and other primary qualities over secondary qualities like odor, color, pain, and flavor because the former ideas are more clearly and distinctly perceived by the mind than the latter; that is, his was a distinction among purely mental entities, one kind of idea versus another — what nineteenth-century authors would (and did) label "subjective."[15] Or Bacon's idols: only one of the four categories (the idols of the cave) applied to the individual psyche and could therefore be a candidate for subjectivity in the modern sense (the others refer to errors inherent in the human species, language, and theories, respectively). Bacon's remedy for the idols of the cave had nothing to do with the suppression of the subjective self, but rather addressed the balance between opposing tendencies to excess: lumpers and splitters, traditionalists and innovators, analysts and synthesizers.[16] His epistemological advice — bend over backward to counteract one-sided tendencies and predilections — echoed the moral counsel he gave in his essay "Of Nature in Men" on how to reform natural inclinations: "Neither is the ancient rule amiss, to bend nature as a wand to a contrary extreme, whereby to set it right; understanding it where the contrary extreme is no vice."[17]

The larger point here is that the framework within which seventeenth-century epistemology was conducted was a very different one from that in which nineteenth-century scientists pursued scientific objectivity. There is a history of what one might call the nosology and etiology of error, upon which diagnosis and therapy depend. Subjectivity is not the same kind of epistemological ailment as the infirmities of the senses or the imposition of authority feared by earlier philosophers, and it demands a specialized therapy. However many twists and turns the history of the terms *objective* and *subjective* took over the course of five hundred years, they were always paired:

there is no objectivity without subjectivity to suppress, and vice versa. If subjectivity in its post-Kantian sense is historically specific, this implies that objectivity is as well. The philosophical vocabulary of mental life prior to Kant is extremely rich, but it is notably different from that of the nineteenth and twentieth centuries: "soul," "mind," "spirit," and "faculties" only begin to suggest the variety in English, with further nuances and even categories available in other vernaculars and Latin.

Post-Kantian subjectivity is as distinctive as any of these concepts. It presumes an individualized, unified self organized around the will, an entity equivalent to neither the rational soul as conceived by seventeenth-century philosophers nor the associationist mind posited by their eighteenth-century successors. Those who deployed post-Kantian notions of objectivity and subjectivity had discovered a new kind of epistemological malady and, consequently, a new remedy for it. To prescribe this post-Kantian remedy — objectivity — for a Baconian ailment — the idols of the cave — is rather like taking an antibiotic for a sprained ankle.

Although it is not the subject of this book, we recognize that our claim that objectivity is new to the nineteenth century has implications for the history of epistemology as well as the history of science. The claim by no means denies the originality of seventeenth-century epistemologists like Bacon and Descartes; on the contrary, it magnifies their originality to read them in their own terms, rather than tacitly to translate, with inevitable distortion, their unfamiliar preoccupations into our own familiar ones. Epistemology can be reconceived as ethics has been in recent philosophical work: as the repository of multiple virtues and visions of the good, not all simultaneously tenable (or at least not simultaneously maximizable), each originally the product of distinct historical circumstances, even if their moral claims have outlived the contexts that gave them birth.[18]

On this analogy, we can identify distinct epistemic virtues — not only truth and objectivity but also certainty, precision, replicability — each with its own historical trajectory and scientific practices. Historians of philosophy have pointed out that maximizing certainty can come at the expense of maximizing truth; historians of science have shown that precision and replicability can tug in opposite directions.[19] Once objectivity is thought of as one of several epistemic virtues, distinct in its origins and its implications, it becomes easier to imagine that it might have a genuine history, one that forms only part of the history of epistemology as a whole. We will return to the idea of epistemic virtues below, when we take up the ethical dimensions of scientific objectivity.

The skeptics are not finished. Even if objectivity is not coextensive with epistemology, they may rejoin, isn't it a precondition of all science worthy of the name? Why doesn't the mathematical natural philosophy of Newton or the painstaking microscopic research of Antonie van Leeuwenhoek qualify as a chapter in the history of objectivity? They will insist that scientific objectivity is a transhistoric honorific: that the history of objectivity is nothing less than the history of science itself.

Our answer here borrows a leaf from the skeptics' own book. They are right to assert a wide gap between epistemological precept and scientific practice, even if the two are correlated. Epistemology (of whatever kind) advanced in the abstract cannot be easily equated with its practices in the concrete. Figuring out how to operationalize an epistemological ideal in making an image or measurement is as challenging as figuring out how to test a theory experimentally. Epistemic virtues are various not only in the abstract but also in their concrete realization. Science dedicated above all to certainty is done differently — not worse, but differently — from science that takes truth-to-nature as its highest desideratum. But a science devoted to truth or certainty or precision is as much a part of the history of science as one that aims first and foremost at objectivity. The Newtons and the Leeuwenhoeks served other epistemic virtues, and they did so in specific and distinctive ways. It is precisely close examination of key scientific practices like atlas-making that throws the contrasts between epistemic virtues into relief. This is the strongest evidence for the novelty of scientific objectivity.

Objectivity the thing was as new as objectivity the word in the mid-nineteenth century. Starting in the mid-nineteenth century, men of science began to fret openly about a new kind of obstacle to knowledge: themselves. Their fear was that the subjective self was prone to prettify, idealize, and, in the worst case, regularize observations to fit theoretical expectations: to see what it hoped to see. Their predecessors a generation or two before had also been beset by epistemological worries, but theirs were about the variability of nature, rather than the projections of the naturalist. As atlas makers, the earlier naturalists had sworn by selection and perfection: select the most typical or even archetypical skeleton, plant, or other object under study, then perfect that exemplar so that the image can truly stand for the class, can truly represent it. By *circa* 1860, however, many atlas makers were branding these practices as scandalous, as "subjective." They insisted, instead, on the importance of effacing their own personalities and developed techniques that left as little as possible to the discretion of either artist or scientist, in order to obtain an "objective view." Whereas their predecessors had written about the duty to discipline artists, they asserted the duty to discipline themselves. Adherents to old and new schools of image making confronted one another in mutual indignation, both sides sure that the other had violated fundamental tenets of scientific competence and integrity. Objectivity was on the march, not just in the pages of dictionaries and philosophical treatises, but also in the images of scientific atlases and in the cultivation of a new scientific self.

Histories of the Scientific Self

If objectivity was so new, and its rise so sudden, how did it then become so familiar, so profoundly assumed that it by now threatens to swallow up the whole history of epistemology and of science to boot? If indeed it emerged as a scientific ideal borne out in practices only in the mid-nineteenth century, why then? What deeper historical forces — intellectual, social, political, economic, technological — created this *novum*?

These are just the sort of questions we asked ourselves when we first began to explore the history of objectivity. Certainly, great changes were under way *circa* 1800, changes so momentous that they are commonly designated as "revolutions": the French Revolution, the Industrial Revolution, the Kantian revolution, the second Scientific Revolution. We further wondered about the influence of expanding bureaucracies, with their rhetoric of mechanical rule-following, or of certain inventions, such as photography, with its aura of unselective impartiality. But after exploring these sorts of explanations, we in the end abandoned them as inadequate — not because we thought these factors were irrelevant to the advent of objectivity, but because they were only remotely relevant. What we sought was an explanation in which cause and effect meshed seamlessly, not one in which a powerful but remote force (one of those "revolutions") drove any number of the most diverse and scattered effects at a distance. We did not doubt either the existence or the efficacy of the remote forces, or even their ultimate links to our explanandum, the advent of objectivity. What we were after, however, were proximate links: an explanation on the same scale and of the same nature as the explanandum itself.

If training a telescope onto large, remote causes fails to satisfy, what about the opposite approach, scrutinizing small, local causes under an explanatory microscope? The problem here is the mismatch between the heft of explanandum and explanans, rather than the distance between them: in their rich specificity, local causes can obscure rather than clarify the kind of wide-ranging effect that is our subject here. Local circumstances that may seem to lie behind, for example, a change in surgical procedures in a late Victorian London hospital are missing in an industrial-scale, post-Second World War physics lab in Berkeley, and yet in both cases a similar phenomenon is at issue: the pitched battle over how to handle automatically produced scientific images. Looking at microcontexts tells us a great deal—but it can also occlude, like viewing an image pixel by pixel.

The very language of cause and effect dictates separate and heterogeneous terms: cause and effect must be clearly distinguished from each other, both as entities and in time. Perhaps this is why the metaphors of the telescope and microscope lie close to hand. Both are instruments for bringing the remote and inaccessible closer. But relationships of cause and effect do not exhaust explanation. Understanding can be broadened and deepened by exposing other kinds of previously unsuspected links among the phenomena in question, such as patterns that connect scattered elements into a coherent whole. What at first glance appeared to be apples and oranges turn out to grow from the same tree, different facets of the same phenomenon. This is the sort of intrinsic explanation that seems to us most illuminating in the case of objectivity.

What is the nature of objectivity? First and foremost, objectivity is the suppression of some aspect of the self, the countering of subjectivity. Objectivity and subjectivity define each other, like left and right or up and down. One cannot be understood, even conceived, without the other. If objectivity was summoned into existence to negate subjectivity, then the emergence of objectivity must tally with the emergence of a certain kind of willful self, one perceived as endangering scientific knowledge. The history of objectivity becomes, *ipso facto*, part of the history of the self.

Or, more precisely, of the scientific self: The subjectivity that nineteenth-century scientists attempted to deny was, in other contexts, cultivated and celebrated. In notable contrast to earlier views held from the Renaissance through the Enlightenment about the close analogies between artistic and scientific work, the public personas of artist and scientist polarized during this period. Artists were exhorted to express, even flaunt, their subjectivity, at the same time that scientists were admonished to restrain theirs. In order to qualify as art, paintings were required to show the visible trace of the artist's "personality"— a certain breach of faithfulness to what is simply seen. Henry James went so far as to strike the word "sincerity" from the art critic's vocabulary: praising the paintings of Alexandre-Gabriel Decamps in 1873, he observed that "he painted, not the thing regarded, but the thing remembered, imagined, desired — in some degree or other intellectualized."[20] Conversely, when James himself self-consciously tried to write with "objectivity," he described it as a "special sacrifice" of the novelist's art.[21] The scientists, for their part, returned the favor. For example, in 1866, the Paris Académie des Sciences praised the geologist Aimé Civiale's panoramic photographs of the Alps for "faithful representations of the accidents" of the earth's surface, which would be "deplorable" in art, but which "on the contrary must be [the goal] towards which the reproduction of scientific objects tends."[22] The scientific self of the mid-nineteenth century was perceived by contemporaries as diametrically opposed to the artistic self, just as scientific images were routinely contrasted to artistic ones.

Yet even though our quarry is the species, we cannot ignore the genus: however distinctive, the scientific self was nonetheless part of a larger history of the self.[23] Here we are indebted to recent work on the history of the self more generally conceived, particularly the explorations by the historian Pierre Hadot and the philosophers Michel Foucault and Arnold Davidson of the exercises that build and sustain a certain kind of self. In Greek and Roman Antiquity, for example, philosophical schools instructed their followers in the spiritual exercises of meditation, imagination of one's own death, rehearsal of the day's events before going to sleep, and descriptions of life's circumstances stripped of all judgments of good and evil.[24] Some of these techniques of the self involved only the mind; others, such as fasting or a certain habitually attentive attitude while listening, also made demands upon the body. Sometimes they were supplemented by external instruments, such as journals and other *hupomnemata* that helped disciples of this or that sage to lead the closely examined life.[25] Like gymnastics, spiritual exercises were supposed to be performed regularly and repeatedly, to prepare the self of the Epicurean or the Stoic acolyte to receive the higher wisdom of the master.

Although the scientific self of objectivity of course arose in an entirely different historical context and aimed at knowledge rather than enlightenment, it, too, was realized and reinforced by specialized techniques of the self: the keeping of a lab notebook with real-time entries, the discipline of grid-guided drawing, the artificial division of the self into active experimenter and passive observer, the introspective sorting of one's own sensations into objective and subjective by sensory physiologists, the training of voluntary attention. These techniques of the self were also practices of scientific objectivity. To constrain the drawing hand to millimeter grids or to strain the eye to observe the blood vessels of one's own retina was at once to practice objectivity and to exercise the scientific self.

Scientific practices of objectivity were not, therefore, merely illustrations or embodiments of a metaphysical idea of self. That is, our view is not that there was, before the relevant scientific work, an already-established, free-floating scientific self that simply found application in the practices of image-making. Instead, the broader notion of (for example) a will-based scientific self was articulated — built up, reinforced — through concrete acts, repeated thousands of times in a myriad of fields in which observers struggled to act, record, draw, trace, and photograph their way to minimize the impact of their will. Put another way, the broad notion of a will-centered self was, during the nineteenth century, given a specific axis: a scientific self grounded in a will to willessness at one pole, and an artistic self that circulated around a will to willfulness at the other. Forms of scientific self and epistemic strategies enter together.

Epistemic Virtues

Understanding the history of scientific objectivity as part and parcel of the history of the scientific self has an unexpected payoff: what had originally struck us as an oddly moralizing tone in the scientific atlas makers' accounts of how they had met the challenge of producing the most faithful images now made sense. If knowledge were independent of the knower, then it would indeed be puzzling to encounter admonitions, reproaches, and confessions pertaining to the character of the investigator strewn among descriptions of the character of the investigation. Why does an epistemology need an ethics? But if objectivity and other epistemic virtues were intertwined with the historically conditioned person of the inquirer, shaped by scientific practices that blurred into techniques of the self, moralized epistemology was just what one would expect. Epistemic virtues would turn out to be literal, not just metaphorical, virtues.

This would take techniques of the self far beyond the ancient directive to "know thyself," which Hadot and Foucault associated with programs of spiritual exercises. Epistemic virtues in science are preached and practiced in order to know the world, not the self. One of the most deeply entrenched narratives about the Scientific Revolution and its impact describes how knower and knowledge came to be pried apart, so that, for example, the alchemist's failure to transmute base metals into gold could no longer be blamed on an impure soul.[26] Key epistemological claims concerning the character of science, which was, in principle, public and accessible to knowers everywhere and always, depend on the schism between knower and knowledge. Of course, certain personal qualifications were still deemed important to the success of the investigation: patience and attentiveness for the observer, manual dexterity for the experimenter, imagination for the theorist, tenacity for all. But these qualities have been seen in most accounts of modern science as matters of competence, not ethics.

Yet the tone of exhortation and admonition that permeates the literature of scientific instruction, biography, and autobiography from the seventeenth century to the present is hardly that of the pragmatic how-to manual. The language of these exhortations is often frankly religious, albeit in different registers—the humility of the seeker, the wonder of the psalmist who praises creation, the asceticism of the saint. Much of epistemology seems to be parasitic upon religious impulses to discipline and sacrifice, just as much of metaphysics seems to be parasitic upon theology. But even if religious overtones are absent or dismissed as so much window dressing, there remains a core of ethical imperative in the literature on how to do science and become a scientist. The mastery of scientific practices is inevitably linked to self-mastery, the assiduous cultivation of a certain kind of self. And where the self is enlisted as both sculptor and sculpture, ethos enters willy-nilly. It is useful for our purposes to distinguish between the ethical and the moral: *ethical* refers to normative codes of conduct that are bound up with a way of being in the world, an ethos in the sense of the habitual disposition of an individual or group, while *moral* refers to specific normative rules that may be upheld or transgressed and to which one may be held to account.

It is not always the same kind of ethos, or the same kind of self, that is involved: both have histories. In the period covered by this book, ethics shift from the regimens of upbringing and habit associated with the Aristotelian tradition to the stern Kantian appeal to autonomy; selves mutate from loose congeries of faculties ruled by reason to dynamic subjectivities driven by will. These changes leave their mark on the epistemologies of science and on scientific selves. It is perhaps conceivable that an epistemology without an ethos may exist, but we have yet to encounter one. As long as knowledge posits a knower, and the knower is seen as a potential help or hindrance to the acquisition of knowledge, the self of the knower will be at epistemological issue. The self, in turn, can be modified only with ethical warrant. (For this reason, even merely prudent bodily regimens of diet and exercise have, from Antiquity to the present, had a strong tendency to take on a moral tinge.) Extreme modifications of the self, through the mortification of flesh and spirit, are *prima facie* evidence of ethical virtuosity in numerous periods and cultures. Science is no exception, as the heroic literature on voyages of exploration, self-experimentation, and maniacal dedication testify.[27]

Epistemic virtues are virtues properly so-called: they are norms that are internalized and enforced by appeal to ethical values, as well as to pragmatic efficacy in securing knowledge. Within science, the specific values and related techniques of the self in question may contrast sharply with those of ancient religious and philosophical sects intent upon rites of purification and initiation preparatory to the reception of wisdom. This is why the rhetoric of the alchemists, Paracelsians, and other early modern reformers of knowledge and society rings so strangely in modern (or even eighteenth-century) ears. These visionaries sought wisdom, not just truth, and enlightenment, not just knowledge. Post-seventeenth-century epistemic virtues differ accordingly in their aims, content, and means. But they are alike in their appeals to certain tailor-made techniques of the self that were tightly interwoven with scientific practices. It is precisely this close fit between techniques and practices that supplies the rationale for the at-first-glance-roundabout strategy of studying notions as abstract as truth and objectivity through concrete ways of making images for scientific atlases. Epistemic virtues earn their right to be called virtues by molding the self, and the ways they do so parallel and overlap with the ways epistemology is translated into science.

New epistemic virtues come into being; old ones do not necessarily pass away. Science is fertile in new ways of knowing and also productive of new norms of knowledge. Just as the methods of experiment or of statistical inference, once invented and established, survive the demise of various scientific theories, so epistemic virtues, once entrenched, seem to endure — albeit to differing degrees in different disciplines. But the older ones are inevitably modified by the very existence of the newer ones, even if they are not replaced outright. Truth-to-nature after the advent of objectivity is a different entity, in both precept and practice, than before. The very multiplicity of epistemic virtues can cause confusion and even accusation, if adherents of one are judged by the standards of another. Scientific practices judged laudable by the measure of truth-to-nature — such as pruning experimental data to eliminate outliers and other dubious values — may strike proponents of objectivity as dishonest. Even without head-on collisions, the presence of alternatives, however mistily articulated, places an onus of justification on practitioners, as we shall see in the case of the atlas makers who wrestled with the merits of drawings versus photographs, idealization versus naturalism, or symbols versus images. One reason to write the history of epistemic virtues, and to write it through a medium as specific as scientific atlas images, is that the existence and distinctness of these virtues is clarified — as well as the possibility, even, in some cases, the necessity of choice among them. History alone cannot make the choice, any more than it can make the choice among competing moral virtues. But it can show that the choice exists and what hinges on it.

The Argument

Each chapter of this book, with a single deliberate exception, begins with one or more images from a scientific atlas. These images lie at the heart of our argument. We want to show, first of all, how epistemic virtues can be inscribed in images, in the ways they are made, used, and defended against rivals. Chapters Two and Three set out a contrast between atlas images designed to realize epistemic virtues of truth-to-nature, on the one hand, and mechanical objectivity, on the other. Eighteenth-century and early nineteenth-century anatomists and naturalists and their artists worked in a variety of media (engraving, mezzotint, etching, and, later, lithography) and with a variety of methods (from freehand sketching to superimposed grids to the camera obscura). But almost all the atlas makers were united in the view that what the image represented, or ought to represent, was not the actual individual specimen before them but an idealized, perfected, or at least characteristic exemplar of a species or other natural kind. To this end, they carefully selected their models, watched their artists like hawks, and smoothed out anomalies and variations in order to produce what we shall call "reasoned images." They defended the realism — the "truth-to-nature" — of underlying types and regularities against the naturalism of the individual object, with all its misleading idiosyncrasies. They were painstaking to the point of fanaticism in the precautions they took to ensure the fidelity of their images, but this by no means precluded intervening in every stage of the image-making process to "correct" nature's imperfect specimens.

In the middle decades of the nineteenth century, at different rates and to different degrees in various disciplines, new, self-consciously "objective" ways of making images were adopted by scientific atlas makers. These new methods aimed at automatism: to produce images "untouched by human hands," neither the artist's nor the scientist's. Sometimes but not always, photography was the preferred medium for these "objective images." Tracing and strict measuring controls could also be enlisted to the cause of mechanical objectivity, just as photographs could conversely be used to portray types. What was key was neither the medium nor mimesis but the possibility of minimizing intervention, in hopes of achieving an image untainted by subjectivity. The truth-to-nature practices of selecting, perfecting, and idealizing were rejected as the unbridled indulgence of the subjective fancies of the atlas maker—the arc retraced by Worthington's conversion from truth-to-nature symmetry to the "objective view" described in the Prologue. These older practices did not disappear, any more than drawing did, but those who stuck to them found themselves increasingly on the defensive. Yet even the most convinced proponents of mechanical objectivity among the scientific atlas makers acknowledged the high price it commanded. Artifacts and incidental oddities cluttered the images; the objects depicted might not be typical of the class they were supposed to represent; atlas makers had to exercise great self-restraint so as not to smuggle in their own aesthetic and theoretical preferences. These features of objective atlases were experienced by authors as necessary but painful sacrifices. Mechanical objectivity was needed to protect images against subjective projections, but it threatened to undermine the primary aim of all scientific atlases, to provide the working objects of a discipline.

At this juncture, we step back from the atlas images themselves: in Chapter Four we embed the changes described in Chapters Two and Three within the history of the scientific self. We first follow the scientific reception of the post-Kantian vocabulary of objectivity and subjectivity in three different national contexts, using the German physicist and physiologist Hermann von Helmholtz, the French physiologist Claude Bernard, and the British comparative anatomist Thomas Henry Huxley as our guides. Despite wide divergences on the usage of the new terminology, these influential scientists agreed on the epistemological import of the objective-subjective distinction for their own experience of ever-accelerating scientific change. We then turn to the new kind of scientific self captured by the new terminology. The self imagined as a subjectivity is not the same as the self imagined as a polity of mental faculties, as in Enlightenment associationist psychology, or as an archaeological site of conscious, subconscious, and unconscious levels, as in early twentieth-century models of the mind. The history of the scientific self was part of these broader developments, but it had its own specific character. We examine it both macroscopically, from the standpoint of the literature of scientific personas — exempla of scientific lives — and microscopically, from the standpoint of detailed activities like keeping a notebook of observations or training voluntary attention, the nodes at which scientific practices and techniques of the self intersect.

Alongside the epistemic virtues of truth-to-nature, mechanical objectivity, and trained judgment emerges a portrait gallery of scientific exempla: the sage, whose well-stocked memory synthesizes a lifetime of experience with skeletons or crystals or seashells into the type of that class of objects; the indefatigable worker, whose strong will turns inward on itself to subdue the self into a passively registering machine; the intuitive expert, who depends on unconscious judgment to organize experience into patterns in the very act of perception. These are exemplary personas, not flesh-and-blood people, and the actual biographies of the scientists who aspired to truth-to-nature, mechanical objectivity, and trained judgment diverge significantly from them. What interests us is precisely the normative force of these historically specific personas, and indeed the very distortions required to squeeze biographies into their mold, to transmute quirky individuals into exempla. These efforts are evidence of the minatory force of epistemic virtues. We are still more interested in the minutiae of the ways of seeing, writing, attending, remembering, and forgetting that concretize personas in persons and do so collectively, at least in situations in which scientific pedagogy has been institutionalized. For an account of the forging of the scientific self, pedagogy is central — as central as Plato's Academy or Aristotle's Lyceum were for the forging of the philosophical self in Antiquity.

The calibration of the eye — being taught what to see and how to see it — was a central mission of the scientific atlas. Atlases refined raw experience by weeding out atypical variations and extraneous details. Starting in the mid-nineteenth century, however, the strictures of mechanical objectivity cast doubt upon judgments of the typical and the essential as intrusions of dangerous subjectivity. Better to present the object just as it was seen, to the point of leaving in scratches left by lenses or accepting distortions in perspectives introduced by the two-dimensional plane of the photograph. Some atlas makers drew the logical conclusion from these *laissez-voir* policies: readers were obliged somehow to figure out for themselves what the working objects of the discipline were; the objective atlas maker forbore to advise them. The very rationale for scientific atlases crumbled. In late nineteenth- and early twentieth-century science, this crisis provoked two diametrically opposed responses which are treated in the next two chapters. One sought to abolish images (though not diagrams) altogether, in the name of an intensified, "structural" objectivity (Chapter Five); the other abandoned objectivity in favor of trained judgment (Chapter Six).

Chapter Five alone begins without an image. Structural objectivity waged war on images in science. Its proponents, who were mostly mathematicians, physicists, and logicians, carried the self-denial of mechanical objectivity to new extremes. Not content to censor the impulse to select and perfect images, they called for a ban on images, even on mathematical intuitions, as inherently subjective. They understood the threat of subjectivity in different terms than the advocates of mechanical objectivity had: the enemy was no longer the willful self that projected perfections and expectations onto the data; rather, it was the private self, locked in its own world of experience, which differed qualitatively from that of all other selves.

This conviction that much of mental life, especially sensations and representations, was incorrigibly private and individualized was itself the product of a highly successful late nineteenth-century scientific research program in sensory physiology and experimental psychology. Confronted with results showing considerable variability in all manner of sensory phenomena, some scientists took refuge in structures. These were, they claimed, the permanent core of science, invariant across history and cultures. Just what these structures were—differential equations, the laws of arithmetic, logical relationships—was a matter of some debate. But there was unanimity among thinkers as diverse as the logician Gottlob Frege, the mathematician Henri Poincaré, and the philosopher Rudolf Carnap that objectivity must be about what was communicable everywhere and always among all human beings — indeed, all rational beings, Martians and monsters included. The price of structural objectivity was the suppression of individuality, including images of all kinds, from sensations of red to geometrical intuitions. This austere brand of objectivity is still alive and well among philosophers.[28]

But structural objectivity found little favor among the scientific atlas makers. How could they dispense with images? These scientists of the eye sought less draconian solutions to the crisis of mechanical objectivity. Chapter Six surveys these responses. Around the turn of the twentieth century, many scientists began to criticize the mechanically objective image: it was too cluttered with incidental detail, compromised by artifacts, useless for pedagogy. Instead, they proposed recourse to trained judgment, not hesitating to enhance images or instrument readings to highlight a pattern or delete an artifact. These self-confident experts were not the seasoned naturalists of the eighteenth century, those devotees of the cult of the genius of observation. It did not take extraordinary talents of attention and memory plus a lifetime's experience to discern patterns; ordinary endowments and a few years of training could make anyone an expert. Nor did the expert seek to perfect or idealize the depicted object; it was enough to separate signal from noise in order to produce the "interpreted image." Far from flexing the conscious will, the experts relied explicitly on unconscious intuition to guide them. In place of the paeans to hard work and self-sacrifice so characteristic of mechanical objectivity, practitioners of trained judgment professed themselves unable to distinguish between work and play — or, for that matter, between art and science. They pointed out the inadequacy of algorithms to distinguish pion from muon tracks in bubble-chamber photographs or the electroencephalograms of seizures caused by grand mal and petit mal epilepsy, instead surrendering themselves to the quasi-ludic promptings of well-honed intuitions.

There are novelties yet in store. We close, in Chapter Seven, with a glimpse of a new kind of atlas image — for example, one of the flow of turbulent fluids — constructed by computer simulations. These images no longer *represent* a particular fluid at a certain place and time; they are products of calculations hovering in the hybrid space between theory and experiment, science and engineering. In some of them, making and seeing are indistinguishable: the same manipu-

(continued...)

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