# Scientists' Bookshelf

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# The Error of All Things

### D. Graham Burnett

The Measure of All Things: The Seven-Year Odyssey and Hidden Error That Transformed the World. Ken Alder. x + 422 pp. The Free Press, 2002. \$27.

cheap yardstick, split from white pine-typically stamped with 36 inches on one copper-ribbed edge and 100 centimeters on the other, a meter beside a yard. The two measures, nearly the same length, comfortably share the same narrow stage but are separated by a conceptual gulf. One side comes down to us out of stubborn English tradition, the other from the world of the French Revolution. One, the span of a man's arm, comes out of market day and the haggles of earthy tradesmen; the other was plucked, we might say, from the cold, high starsfrom an Enlightenment dream of perfected man and perfected reason. Think about that the next time you flip your vardstick.

You will, after reading Ken Alder's thoughtful and elegant new book, which tells the story of how the meter came to be: how its length was set and how it found its way into your hands. Alder uses this rich tale of intrigue, enterprise and irony to press a set of broader assertions about what science is and how it has changed in the past three centuries. *The Measure of All Things* makes a welcome introduction for the nonspecialist to recent thinking in the history of science, but even scholars in the field will find things to think about in these pages.

D. Graham Burnett is an assistant professor in the Program in History of Science at Princeton University. He is the author of Masters of All They Surveyed: Exploration, Geography and a British El Dorado and an editor of The History of Cartography, a multivolume work in progress (both from University of Chicago Press).

In 1792 two French astronomers set out from Paris-one headed north, one south-to measure the distance between Dunkirk and Barcelona with unprecedented care. Their purpose? To lay the groundwork for a new and universal system of measurement. How? By creating a new standard unit of length, to be derived from nature herself. Forget the distance from the king's nose to the tip of his thumb, the aune and the ell, the befuddling patchwork of local measures in ancien régime France. The new standard of measurement, as befitted the spirit of a new age of universal rights and ideals, would be based on something universal: the size of the Earth, the shared home of humanity. The result would be a system of measures for all people.

Enlightenment savants had calculated that one ten-millionth of the distance from the North Pole to the equator would make a handy unit (one projected to be about the same length as an *aune* or an ell, as it happened, which was convenient). The two astronomers, Jean-Baptiste-Joseph Delambre and Pierre-François-André Méchain, had been commissioned to survey enough of that distance to make it possible to calculate this new fundamental unit, the meter.

Making long-distance measurements of great precision and accuracy is never easy. Engineers and geodesists today would use the Global Positioning System or laser range-finding theodolites to do this sort of work. Best practice in the late 18th century involved fitting together a number of different kinds of observations, each demanding work in the field with finicky instruments of brass and glass. Astronomical observations fixed the terrestrial coordinates of the endpoints of the line to be measured, but these points then had to be squared with a set of observations made



The French astronomers Jean-Baptiste-Joseph Delambre (*left*, as painted by Per Eberhard Gogell in 1803) and Pierre-François-André Méchain (*right*, as painted posthumously by Narcisse Garnier in 1824) surveyed the distance from Dunkirk to Barcelona at the end of the 18th century to get data for calculating the quarter meridian, from which a new unit of measurement was derived—the meter. Both are wearing the uniform of the Academy of Sciences. From *The Measure of All Things*.

along the line itself: first, the angles of triangles sighted from hilltop to hilltop along the whole way; second, the actual paced-off length of one side of one of those triangles, a length which could then be projected through the whole chain of triangles using trigonometry. It was an immensely complex business, demanding patience, fortitude, fine eyes and a ready hand for reams of numbercrunching arithmetic.

The bloody spasms of a revolution do not facilitate such an enterprise. But as Méchain and Delambre set about their task, the whole French political and social order came onto the chopping block. This lends both urgency and picaresque color to Alder's narrative, which follows the men through the provinces, where they hole up in belfries to make their observations. even as the churches are being confiscated out from under them. They present their ormolu commission papers to surly peasant mobs only to discover that the governments who issued them have since dissolved, so fast are things changing in Paris.

Delambre and Méchain both survived the "seven-year odyssey" of the book's subtitle, and in two ways it did, as advertised, "transform the world." First, they succeeded, after a fashion: They brought back data that enabled an international cast of mathematicians and geographers to arrive at a value for the quarter meridian, and from it to derive the length of what would be called the *mètre*. Reified in a bar of platinum alloy, it was the basis of the whole metric system of weights and measures. Although that system had its vicissitudes through the 19th and 20th centuries, it has indeed become the measure of most things in most places.

Is this a transformation of the world? Alder nicely buttresses this hyperbolic claim, arguing that the whole political economy of the ancien régime was bound up with old styles of measurement: Land could be parceled out in terms of yield, weights were assessed in terms of man-labor-days, a loaf of bread was supposed to sell for a "just price." Replacing all this fuzzy, mancentered "anthropometry," the metric system aimed to give newly free citizens a new ratio for a newly "rational" world, a tool with which to assess their economic interests and make reliable calculations. A universal metrology would make the "market" more than a place to go on Saturday-it would make the market, that abstract ideal of liberal political economy. By these lights the meter meant more than a new name for an old length; it meant a new sort of society.

Yet, in Alder's telling, the "sevenyear odyssey" transformed the world in an even more literal way. Méchain and Delambre returned to Paris with measurements so fine and extensive that the meter-makers were thrown into confusion by them. Plotting the data suggested that the Earth's shape

# UNSHELVED

# Sixteen Tons, and What Do You Get?

Coal is a commodity utterly lacking in glamour. It is dirty, old-fashioned, domestic, and cheap. Coal suffers particularly when compared to its more dazzling and worldly cousin, oil, which conjures up dramatic images of risk takers, jet-setters, and international conspiracies. Oil has always given us fabulously wealthy celebrities to love or hate, from the Rockefellers to the sheiks of the Middle East. "Striking oil" has become a metaphor for sudden, fantastic wealth-riches derived not from hard work but from incredible luck.

Coal does not make us think of the rich, but of the poor. It evokes bleak images of soot-covered coal miners trudging from the mines, supporting their desperately poor families in grim little company towns. Long past the time when it was actually part of our daily lives, coal is still considered mundane. Earlier generations' familiarity with coal bred contempt for it; and though the familiarity has faded, the contempt lingers. Even today, children may have heard the warning that if they are bad, they will find nothing but a lump of coal in their Christmas stockings. They may never have seen coal, may not even know what it is, but they know that a lump of it (indeed, a lump of anything) is not something they want. Where oil is seen as a symbol of luck, coal is seen as a symbol of disappointment.

> Coal: A Human History Barbara Freese Perseus Publishing, \$25

Unshelved offers a glimpse of books recently received at the Bookshelf. A complete list of such books can be found at http://www.americanscientist.org/bookshelf/newbooks.html.

# NANOVIEWS

We need look no further than our own homes and offices to find a veritable museum of technologyor so posits Joel Levy in the introduction to Really Useful: The Origins of Everyday Things (Firefly Books, \$24.95). Reading his lavishly illustrated museum guide, one is easily convinced. Here Levy provides capsule histories of everything from bar codes to brassieres, from laser printers to lawn mowers. Along the way he provides abundant insights into the machines and appliances that surround us. Who knew, for example, that Velcro (below) was invented by a Swiss mountaineer, Georges de Mestral, who noticed the tenacity of the cockleburs that collected on his clothing during a fateful Alpine hike in 1948? And who would have guessed that early on the Chinese used tinted glasses not to screen out glare but to hide the eves of judges? Those with even a passing interest in the historical roots of such familiar devices will find Levy's book delightfully informative.-D.A.S.



was a mess. No elegant geometrical curve could accommodate the survey materials. Several centuries of scientific debate about the true form of the globe (sphere? pumpkinlike "oblate ellipsoid"? something more egg-shaped?) was ending in a tautology: The shape of the Earth was ... the shape of the Earth—a particular, unique, dented, lopsided thing. The seven-year odyssey transformed the world in earnest by giving to science a new form for the globe—that irregular spheroid today called the geoid.

But Alder's chunky subtitle promises the story of not just a voyage that transformed the world but also a "hidden error" (the phrase suggests scandal, deception, malfeasance) that *also* transformed the world. The book delivers here too, although not in precisely the way one might think.

Was there a hidden error that corrupted the meter? Is that ruler of yours wrong on account of some Gallic double-dealing? Not exactly. Admittedly, your meter is wrong, in that ten million meters wouldn't quite get you from the North Pole to the equator via Paris. And yes, there was some double-dealing in the observations used to calculate the meter's length: Méchain, seeking to fix the southern endpoint of his line, ran into some ugly discrepancies in his results, and rather than report them directly, he fussed and fudged for years while trying to clean up the data. Anxiety over the whole affair, Alder concludes, pushed Méchain to the edge of madness and hounded him to his death.

Dramatic stuff. But Méchain's fudge had a minuscule effect on the length of the meter itself, a distortion completely lost in the mathematical patch-up job that proved necessary once it became clear that the Earth had an entirely irregular form. What is one ten-millionth of a quarter meridian? Depends on where you are. Depends on when you want to know.

How, then, could Méchain's "error," which came to light after his death, plausibly be said to have transformed the world? Here Alder reaches for his most subtle and ambitious claim: What transformed the world was *error itself*. Méchain may have believed he had made an error, but in fact, unbeknownst to him, in the kaleidoscope of his data he had caught a flashing glimpse of the *phenomenon* of error. There was no "mistake" that he could

find and simply correct. He was chasing a specter. And the ghost he kept almost seeing was nothing less than the limits of his ability to get the answer right. His plight will make sense to a statistician, or to any scientist familiar with the workhorse tools of error analysis, those mathematical techniques that enable researchers to separate precision from accuracy and to assess what is attainable in a specific situation. Méchain, though, had no such tools to hand. Some of the most important of these-for instance, the method of least squares-were refined (or even developed) exactly to deal with the enormous and complex set of data that he and Delambre brought back to Paris in 1798.

In those tomes of calculations and observations, mathematicians "found" the concept of error, and, in the early years of the 19th century, they created a theory to deal with it: a metric of metrics. Science itself was transformed, Alder claims. Left behind was the savant world of Méchain and company-for whom the pursuit of enlightenment was a titanic confrontation with the dark demon of error. For them, error loomed like secular sin, and they bound their spirits to the rectitude of their measurements. A new science arose, and a new scientist-more functionary than sage, a professional who calibrated himself along with his instruments. Gone were the high priests of Reason, who had been the souls of their machines. Science would never be the same.

These are large claims. Are they right? Suffice it to say that there is a rightness in them, and they are valuable for what they suggest about the deep ways in which scientific ideas, practices and sensibilities can change through time. At the same time, Alder cannot really make this big argument in any detail here, in a book intended for a general readership. In pressing the point he is drawing on (and in certain ways extending) complex and technical work done on the history of statistics and probability in the past two decades. Not everyone will agree with him; a lively discussion could be fired by rehearsing chapter 11 of The Measure of All Things among historians of science; I plan to try it shortly.

What about the meter, anyway? It had been dreamed up as a sliver of a universal form, to be forged by the absolutes of the cosmos. But as the platinum bar went into its triple-locked box, onlookers whispered about highly human contingencies—Why had Méchain hung around in Italy for so long? Was something amiss?—and about the disconcerting discovery that wrinkled old Mother Earth seemed to have no absolutes to offer. Dragging eternal and inhuman universals into the world of people, time and place has always been a messy business, as the French Revolution would prove in more ways than one.

But the meter survived, in the end, not because it came from nature or the stars, not because it existed beyond the grubby taint of human fingerprints, but for exactly the opposite reasons. The seven-year slog, the vicissitudes of the Revolution, the travails of Delambre and Méchain had become a grand tale of scientific heroism. Human beings had mingled their labor with this specific length and made a powerful saga out of that labor. The meter had been cast, tempered in sweat and blood.

Mark Twain once opined that nothing took more work than to make a speech look spontaneous. There is in this witticism a profound proposition, relevant to a great deal of work being done in history of science these days: Nothing takes more work than to make something look natural. Natural law, natural order, natural man-none of these ever washes up on the shore, perched on the half shell, a present from nature. Only hard work drags them into the light: Sleeves must be rolled up, expeditions undertaken, laboratories built, instruments tweaked. So too with natural measures, as Ken Alder shows so well in this fine book.

Hard work? One suspects Delambre and Méchain would nod.

# Science Across Cultures

# Anthony Grafton

**Lost Discoveries: The Ancient Roots of Modern Science—From the Babylonians to the Maya.** x + 453 pp. Dick Teresi. Simon and Schuster, 2002. \$27.

arly in the 1990s, Dick Teresi set out to write an exposé. Multiculturalism was on the rise in the schools and generating controversy in legislatures, school boards and the media. No specimen of it created more heat or less light than the Portland African-American Baseline Essays. According to this curriculum, the ancient Egyptians had built flying machines, mastered psychokinesis and even devised electric batteries. Some of these claims rested on fragments of archaeological evidence, interpreted with little or no reference to their original contexts. Others had no basis whatsoever, except their creators' desire to instill pride in African-American schoolchildren, Teresi-a skilled and prolific science writer-accepted a magazine assignment and began to debunk what looked like bad science and bad history.

The journalist who came to scoff remained to pray. Teresi found the Baseline Essays as implausible as he had expected. But as he studied other claims for the scientific achievements of non-Europeans, he realized that a great many of them were valid. Westerners rejected them not because they were unfounded but because they undermined what he calls "the traditional account" of the rise of Western science. Historians and scientists believed that the Greeks created science in the first millennium B.C., while non-Westerners remained mired in "prescientific" ignorance until Europeans enlightened them. But the more research Teresi did, the clearer it seemed to him that central achievements of Western science and technology had in fact been anticipated-sometimes by centuries-by Mesopotamian diviners and Chinese philosophers, Islamic astronomers and Mayan priests.

Teresi argues this case in detail in *Lost Discoveries*. His fluently written book rests on a great deal of research and offers the reader a vast amount of information about the sciences, from physics to geology and beyond. Teresi not only



According to Sex in Advertising: Perspectives on the Erotic Appeal (Lawrence Erlbaum Associates, \$65 cloth, \$29.95 paper), roughly onefifth of all advertising uses overt sexual content to sell a product. Editors Tom Reichert and Jacqueline Lambiase have brought together a collection of 15 essays by scholars in the humanities and the sciences to cover such topics as the history of sexuality in advertising, our physiological and psychological responses to the sexy ads, and current trends in the "art." One of the more interesting essays, written by Wilson Bryan Key, explores the subliminal sexual content in advertising. Some of it is outrageous: Consider the magazine ad for Betty Crocker's cake mix that has an anatomically correct vulva sculpted into the chocolate icing (below). Key, who takes for granted that subliminal advertising actually works, focuses on the fact that advertisers (and many consumers) continue to deny its existence. He argues that mediadriven fantasies have become dominant forces in our lives. These ideas. and others in the book, offer a disturbing view of our cultural landscape. Whether or not one agrees with the authors' conclusions, they do provide interesting food for thought. Incidentally, the piece of cake on the fork (above) is a painting, not a photograph.-M.S.



Anthony Grafton is Henry Putnam University Professor of History and director of the Davis Center for Historical Studies at Princeton University. His most recent book is Bring Out Your Dead: The Past as Revelation (Harvard University Press, 2002).

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