but is rather the consequence of the medium through which the gestures are expressed. The authors aptly quote the linguist Charles Hockett: "When a representation of some four-dimensional hunk of life has to be compressed into the single dimension of speech, most iconicity is necessarily squeezed out." The concentration on speech may have created a myopic view of what language is really all about.

Once it is understood that speech is gestural, the notion of a switch from manual to vocal language becomes easier to comprehend. Indeed, language may have always involved vocalizations and movements of the face as well as of the hands, and signed languages are as much facial as manual. Conversely, spoken language is characteristically accompanied by manual gestures. Evidence from primate vocalization and hominin fossils indicates, though, that the anatomical and neural changes necessary for the intentional production of articulate sounds took place late in hominin evolution; the ability to sustain autonomous speech may not have developed until *Homo sapiens* emerged about 200,000 years ago, or it may be an even more recent phenomenon than that.

Armstrong and Wilcox refer to evidence that the FOXP2 gene, known to be involved in vocal articulation, underwent a mutation within the past 100,000 to 200,000 years, and they suggest that this genetic alteration may have been a final, crucial step on the path to spoken language. The advantages that may have led to the selection of vocalization as the dominant mode include a couple that have already been mentioned—the ability to communicate at night or when obstacles intervene, and the freeing of the hands for manufacture and other purposes—as well as the development of pedagogy, lower energy requirements and the fact that acoustic signals command attention more readily than do visual signals.

The view that language is an embodied system is finding increasing support from neurophysiology, and especially from the so-called "mirror system" in the primate brain, which is activated both when such an animal performs an action and when it observes the same action being performed by another individual. This system also links the sounds of actions to their production. In humans, it includes brain areas involved in language. These facts imply that the evolution of language, far from being a "big bang" at the dawn of our own species, developed out of the mirror system and so has deep roots in primate behavior. Nevertheless it remains true that human language has a complexity and expressive power not observed in other species. Armstrong and Wilcox suggest that the critical steps from raw gesture to a gestural language, perhaps somewhat comparable to modern signed languages, probably began more than two million years ago, with the emergence of the genus *Homo* and the ensuing large increase in brain size. This development may have been a response to the dramatic ecological changes during the Pleistocene, driving an enhanced dependence on cooperation and social communication.

The idea of embodiment effectively removes language from its pedestal as an encapsulated, symbol-manipulating system and returns it to the general provenance of human cognition and of biology. Language, then, is not special. Of course there is still the problem of explaining how gestures came to communicate abstract ideas or how syntax evolved.

Armstrong and Wilcox suggest that we can understand abstract ideas through metaphor, which is grounded in bodily dimensions and movement. For example, the notion of understanding can be represented metaphorically by the action of grasping, and in spoken English the word *grasp* is often taken to mean "understand." Syntax is increasingly viewed as a natural process of grammaticalization, whereby some signs or words lose their meaning and serve purely functional roles.

This book appears at a time when theories about language and its evolution are in flux, and only time will tell whether the notion of language being embodied will gain general acceptance. There will of course be resistance, given the strong tradition of basing the properties of language on those of speech.

Although *The Gestural Origin of Language* is not always an easy read—its ideas sometimes become swamped in jargon—it is an important book. The authors, who have added solidity to the gestural theory of how language first evolved, are part of a sea change in the way we view language and indeed ourselves.

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MATHEMATICS

Theorems to Savor

James Propp

THE ART OF MATHEMATICS: Coffee Time in Memphis. Béla Bollobás. xvi + 359 pp. Cambridge University Press, 2006. $85 cloth, $34.99 paper.

The mathematician and puzzle connoisseur Peter Winkler once joked, with a nod to Isaac Newton, "If I have seen farther than others, it is because I have stood on the shoulders of Hungarians." One of these Hungarians is the late Paul Erdős, famous within mathematics for his contributions to number theory and combinatorics and famed more broadly for his unique lifestyle and lingo (children are "epsilons," God is the "Supreme Fascist," God's collection of the best mathematical proofs is "The Book," and so forth). Many of Erdős's collaborators and successors are also Hungarian, and others have adopted what might be called "the Hungarian style," with an emphasis on snappy problems and clever solutions. I can think of no better way to get acquainted with these people and their work than to spend a few months periodically dipping into Béla Bollobás's new collection of mathematical puzzles, titled *The Art of Mathematics: Coffee Time in Memphis*.

Bollobás (the name is pronounced "bowl o' bosh") is one of the most ardent keepers of the Erdős flame. Since Erdős died—or, as Erdős would say, "left"—in 1996, Bollobás has organized a conference in his honor every year at the University of Memphis. (Full disclosure: I spoke at the 2006 conference.) Bollobás, a professor who divides his time between Trinity College (Cambridge) and the University of Memphis, has worked for decades in functional analysis, combinatorics and graph theory. In the course of years of teaching and research, he has devised (or learned of) many easily stated problems whose solutions possess one or more of the hallmarks that mathematicians prize, such as economy, surprise and fecundity.

Here is one of my favorites: Suppose 10 chairs are arranged in a circle, half of them occupied by students. Show that there exists some whole number n between 1 and 9 such that if each of the 5 students moves n chairs clockwise in the circle, 3 or more of them will end up sitting in a previously occupied chair.

This is not how Bollobás actually poses the problem in his book; in problem 3 (in a series of 157 problems), he asks the reader to consider a more general situation. But the key idea that solves Bollobás's problem can be discovered by thinking about the special case I've described—and by following the clue that Bollobás helpfully provides in a separate section devoted to hints. (If you want to think about this on your own, now would be a good time to put aside this book review!) Bollobás's clue is a short question that at first seems like a non sequitur: "What about a random rotation?"

If we choose n randomly, then each student has a 4-out-of-9 chance of ending up in a previously occupied chair. So on average, the number of students sitting in previously occupied chairs will be $\frac{4}{9} + \frac{4}{9} + \frac{4}{9} + \frac{4}{9} + \frac{4}{9}$, or $\frac{20}{9}$, which is slightly greater than 2. Now comes the punch line: The only way the *average* value of an integer-valued quantity can exceed 2 is if it sometimes is 3 or greater.

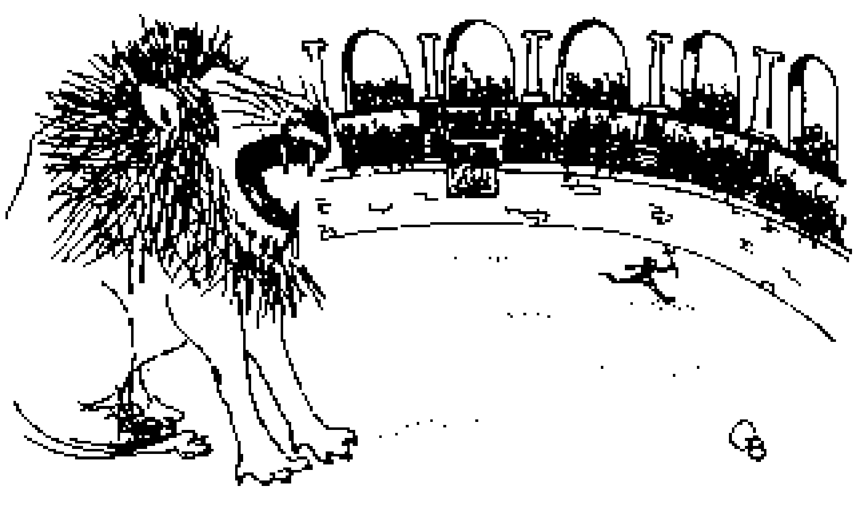
This proof exhibits economy (the chief idea is contained in the five-word hint), surprise (who would think to bring randomness and probability into solving a problem like this?) and fecundity (the probabilistic method has been an enormously powerful tool in the hands of Erdős and others). Bollobás's book is full of tasty little morsels like this one, puzzles whose solution requires attacking them from some unexpected angle. The ability to come up with creative approaches to problems can be cultivated, but it cannot be taught; it is more of an art than a craft. Hence the first half of the book's title.

I prefer Bollobás's original title, *Coffee Time in Memphis* (which his editor convinced him to lengthen); it bears more of the stamp of Bollobás's personal style. This is a book that developed in the author's mind through the course of conversations with students and colleagues, sometimes in offices or classrooms but just as often in departmental lounges or cafés.

Mathematicians love to find elegant solutions to their research problems, but they can't always be sure that the challenges they set for themselves *have* sweet answers. It can be a great relief from these uncertainties to work on a problem secure in the knowledge that it has a pleasing solution, which the problem-poser will, if pressed, reveal. Bollobás has included in the book the sorts of problems with which he loves to tease his colleagues and students, with pleasure on both sides.

Fans of books on recreational mathematics should be warned that this one is not for the fainthearted or the mathematically unprepared. For instance, the first sentence of the solution of problem 84 reads, "This assertion is considerably trickier than the usual run-of-the-mill limit questions based on subadditivity or submultiplicativity; here we have to be a little more careful." Bollobás assumes his reader is already acquainted with (and perhaps a bit jaded by) large chunks of the advanced mathematics curriculum. If you do not come equipped with a knowledge of principles like continuity, compactness, contractibility and countability of the rational numbers (to mention just the ones that start with "c"), you will not find all of these problems to be fair challenges; you might want to read this book with a partner and take turns being the one to peek at the sections containing the hints and solutions. On the other hand, some of the puzzles require nothing more than elementary arithmetic and the right perspective on the problem. Some of my own favorites in this latter vein are problems 7, 13, 20, 21, 24, 31, 34, 40, 48, 55, 87, 102 and 119. If you find these more accessible problems fun, you would probably also enjoy Peter Winkler's two collections of brainteasers—*Mathematical Puzzles: A Connoisseur's Collection* (A K Peters, 2004) and *Mathematical Mind-Benders* (A K Peters, 2007)—as well as *Proofs from THE BOOK,* by Martin Aigner and Günter M. Ziegler (3rd ed., Springer, 2004).

Who are the right readers of Bollobás's book? Mathematicians, certainly—especially younger ones who are still building up their mental toolkits. Corporate recruiters in Silicon Valley will probably find some of these problems to be good ways of assessing the mental athleticism of potential hires; in fact, I wouldn't be surprised to learn that some of these puzzles are already being used in this way. On the other side of the interview desk, job seekers might want to practice delivering



"A lion and a Christian in a closed circular Roman arena have equal maximum speeds. What tactics should the lion employ to be sure of his meal? In other words, can the lion catch the Christian in finite time?" ***Hint:*** **"Let *O* be the centre of the circle, *L* the lion and *M* the Christian. What happens if *L* keeps on the radius *OM* and approaches *M* at top speed?" Problem 1, from *The Art of Mathematics*. (Drawing by Gabriella Bollobás.)**

the solutions to some of the more accessible puzzles, adding some pauses and brief false turns to make the whole thing sound unrehearsed. Likewise, mathematics professors administering oral examinations to Ph.D. students, and Ph.D. students seeking to pass those examinations, might want to go through this book. In addition, students at all levels (high school on up) may find in the notes a source of attractive unsolved research problems.

Erdős's collaborator Paul Turán once remarked that a mathematician is a machine for turning coffee into theorems. If so, then many of the theorems in Bollobás's book represent some extremely potent espresso. It would be a mistake to gulp them down too quickly. If enjoyed at a deliberate rate, alone or in conversation, these problems should have a stimulating effect on the prepared reader who takes the time to savor them.

James Propp is a professor of mathematics at the University of Massachusetts, Lowell. His research interests include combinatorics, probability and dynamical systems. He is currently at work on a general-interest book, Who Proved Fermat's Theorem?, *forthcoming from Princeton University Press.*

ASTRONOMY

Sunspotting

Alex Soojung-Kim Pang

THE SUN KINGS: The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began. Stuart Clark. xii + 211 pp. Princeton University Press, 2007. $24.95.

On September 1, 1859, English amateur astronomer Richard Carrington, who had been studying the face of the Sun for six years, observed a vast sunspot complex. Startling in scale, it stretched nearly a 10th of the way across the disk, which meant it was almost 10 times the diameter of the Earth. Carrington sketched the spots, and then as noon approached, he saw something he thought to be unprecedented: Two beads of white light (solar flares) appeared over the group of sunspots, intensified for a few minutes, then faded and vanished. [His drawing of what he saw is reproduced on page 540.] As far as he knew, no one had ever described such a phenomenon before.

Within a few days, Carrington began to learn of other remarkable events. At the observatory at Kew, recordings made on photographic paper by a ray of light bounced off a compass needle showed that the Earth's magnetic field had been disturbed at the exact same time that Carrington had seen the solar flares. Other strange things happened about 18 hours after the solar flares: Telegraph operators in Europe and the Americas had to struggle to keep their lines open and functioning. Around the globe, sailors and others saw remarkable auroras. And scientists measuring the Earth's magnetic field saw their instruments fluctuate wildly.

Were the sunspots and flares related to, or perhaps even the cause of, these events? Had the Sun released a vast burst of energy that later reached the Earth and was powerful enough to disrupt global communications and light up the night sky? The idea seemed farfetched. The Sun was normally steady and predictable in its provision of light and heat. Carrington thought the possibility that the sunspots and auroras were linked should be considered; if the Sun were capable of huge swings in its behavior and unseen solar energy could somehow reach and affect the Earth, that would be important to know.

Such arguments were not entirely new, but they were hard to accept. And Carrington's own work did not prove definitively that the phenomena were connected. Nevertheless, science journalist Stuart Clark, in his new book *The Sun Kings,* places Carrington at the fulcrum of a century-long debate over the effects of sunspots, because he drew on two very different sorts of scientific observations—studies of sunspots and of the Earth's magnetic field—that together would eventually allow astronomers to see the relation between solar and terrestrial activity.

In England, the first notable speculations about the influence of the Sun on the Earth's magnetic field and climate had been made more than half a century earlier by William Herschel, best known as the discoverer of the planet Uranus. In the decades between Herschel and Carrington, a number of scientists developed new tools to study the Sun or oversaw careful, decades-long studies of solar behavior. Herschel's son, John, was a pioneer in solar photography, which helped automate the work of sunspot observation. Astronomers and geologists established magnetic stations, and from 1802 to 1839, what Clark refers to as "the magnetic crusade" (Alexander von Humboldt was a leading participant) focused on mapping and detecting changes in Earth's magnetic field, a task made more urgent by the dramatic growth in world trade and the expansion of European navies. Physicists determined that chemical elements, when burned, emit light at particular wavelengths; chemists' success mapping spectral lines raised the tantalizing possibility that the Sun's chemical composition could be deduced from its light. In 1850, Humboldt, in one of the volumes of his massive masterwork, *Kosmos,* published a chart based on observations made over a 42-year period by German pharmacist Heinrich Schwabe, who found that sunspots followed a roughly 11-year-long cycle, having been very numerous in 1828, 1837 and 1849.

Richard Carrington is almost unknown today; even most historians of Victorian astronomy probably have no more than a passing familiarity with the name. But it would have come as little surprise to his contemporaries that Carrington had the good fortune to observe his remarkable sunspot or that he speculated that it was connected to the unusual auroras. He was part of a generation of Victorian amateurs who, supported by industrial wealth (his father was a brewer), were pushing back the frontiers of knowledge. Educated at Trinity College, Cambridge, Carrington built his own state-of-the-art observatory in 1852 and proceeded to refine Schwabe's theory. In 1857, he published a notable star catalog. The following year he was forced to take over the family business after the death of his father. In 1859, he won the Royal Astronomical Society's Gold Medal for the catalog, and after