technical organization that could enhance its competitive position in the emerging area of long-distance telephone communications. But the role of scientific and engineering disciplines, such as physics and electrical engineering, in the pursuit of industrial innovation was only beginning to be appreciated. Around 1915, AT&T gave University of Chicago physicist Frank Jewett the task of bringing in technical experts to develop amplifiers for the vacuum-tube repeaters that maintain signal strength along transmission lines. Jewett recruited Kelly, Harold Arnold, Harvey Fletcher, and other students of his friend physics Nobelist Robert Millikan. Those students understood the value of "a knowledge of the things and methods of science" and the need to "bring to bear an aggregate of creative force on any particular problem."

The success of the vacuum-tube repeater eventually led to the formation of Bell Telephone Laboratories in 1925 as a separate R&D arm. Kelly's early vision of an "institute of creative technology" hinged on hiring such brilliant minds as William Baker, John Bardeen, Walter Brattain, Pierce, Shannon, Shockley, and Charles Townes. Those scientists, and a few others, formed the nucleus of a research organization that also featured systems engineers and technology developers.

Through multiple interviews, particularly with some former Bell Labs executives, Gertner reveals many characteristics of a culture and institutional environment that spawned a large number of innovations. Bell Labs focused on the broad mission; motivated its researchers to continually strive for technology innovation; maintained an "end-to-end" business service as a matter of public trust; applied systems engineering thinking, which eased the integration of research and manufacturing; trusted its visionary and technically savvy leaders; recruited the "best and the brightest" researchers, who would not have to worry about applying for federal funding; and created an environment that encouraged long-term thinking and afforded its workers a "circumscribed freedom" that was at the same time "liberating and practical."

Unusual for a corporate lab, Bell Labs was a place where office doors were open and the boundaries between disciplines were porous: Theorist Bardeen had an office in the lab of experimentalist Brattain, and the two recorded data side by side when transistor action was discovered. It was also a place where Shannon wandered the halls on a pogo stick, vice president of research Baker sat and interacted with staff members in the large cafeteria, and Kelly asked the research staff to investigate "not what is known" but rather "what is not known."

In the last chapter of *The Idea Factory*, entitled "Echoes," Gertner asks the following: In a time of venture capitalists, open innovation, and highly successful information technology companies such as Apple, Google, and Facebook, is there a need for an organization like Bell Labs? Can we expect venture-driven companies, including ones reaping healthy profits, to invest in truly long-term research projects? Those are important questions for science policymakers as they debate the merits of different innovation models.

For answers, Gertner suggests looking beyond the information technology industry to such areas as the life sciences, which has the Howard Hughes Medical Institute's Janelia Farm Research Campus in Virginia, and clean energy, which includes energy innovation hubs championed by Steven Chu, a former Bell Labs researcher and the current secretary of the US Department of Energy.

In my view, we need new modalities of public–private partnerships to enable radical innovation for the public good. *The Idea Factory* is well worth delving into as a source of lessons learned in how to build forward-looking, innovative technology institutions.

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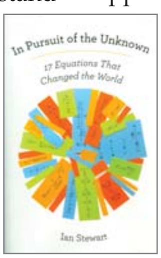
In Pursuit of the Unknown

17 Equations That Changed the World

Ian Stewart
Basic Books, New York, 2012. $26.99 (342 pp.). ISBN 978-0-465-02973-0

Emeritus professor of mathematics Ian Stewart is a well-known and well-regarded writer on popular mathematics. As a testament to his outstanding expository skills, he succeeded Martin Gardner—a tough act to follow—in writing the Mathematical Games column at *Scientific American*. Stewart's new book, *In Pursuit of the Unknown: 17 Equations That Changed the World*, tackles an equally tough challenge.



"Equations that changed the world" is a phrase guaranteed to intrigue the sort of person who, if given a choice between the latest issues of PHYSICS TODAY and the *Economist* while trembling in the waiting room of a dentist, would pick the latter. That person may be intelligent and literate, but not a physicist, mathematician, or engineer.

I write that not because *In Pursuit of the Unknown* is a bad book—far from it, as I'll soon explain—but because the subtitle is likely to prompt a regular reader of PHYSICS TODAY to retort, "What do you mean, 17 equations? I can think of at least 50. Maybe even 75 if you give me until lunch!" Stewart, I'm sure, is well aware of that and writes (unfortunately, not until the end of the book), "It took a lot more than seventeen equations to get us where we are today." In comparison, Dana Mackenzie's *The Universe in Zero Words: The Story of Mathematics as Told Through Equations* (Princeton University Press, 2012) covers 24 equations, not all of which overlap with Stewart's. But given the reality of publishing, one can hardly fault Stewart, or Mackenzie, for not writing the 177 314–page book required to discuss every important equation.

In general, an assessment of equations to include would probably be 50% "No argument with that choice" and 50% "I wonder how that one made the final cut." In Stewart's collection, the first category includes the Pythagorean theorem (about which Stewart unfortunately repeats a tasteless joke that no teacher with any sensitivity would ever tell in lecture), Newton's inverse-square law, and Maxwell's equations. The second category contains the Navier–Stokes equations, Euler's formula for polyhedra, and the Black–Scholes equation (with which financial traders nearly destroyed modern banking). The wave equation, Fourier transforms, the second law of thermodynamics, $i = \sqrt{-1}$, and $E = mc^2$ are in the mix, too. Of course, my selection of which category each of those falls into is as eccentric as Stewart's. And that's my point. I can't help but wonder, however, how Boolean algebra's wonderful $1 + 1 = 1$, which is at the foundation of our modern digital world, failed to make an appearance. Perhaps it was too obvious.

Each equation gets its own chapter, which opens with the equation itself, accompanied by a helpful explanation of what each symbol means. Each chapter is written in Stewart's easy prose, which never fails to both educate and entertain. The chapters are populated by lots of historical details—a feature of the book I particularly enjoyed. The occasional slips do occur. There's the temporarily confusing typo (page 26) in a discussion on the invention of logarithms, where we suddenly go from multiplying 2.67 by 3.51 to multiplying 2.87 by 3.41 and then back again. Then there's the more seriously erroneous statement (page 107) that a probability density function $\phi_X(x)$ gives the probability that the value of the random variable X is x. In fact, $\phi_X(x)\Delta x$ is the probability that X has some value in the *interval* x to $x+\Delta x$.

My biggest concern about the book is the huge variation in mathematical expectation that Stewart has made. The logarithm chapter, for example, has a long exposition on how exponents work, whereas the chapters on Maxwell's equations and the Navier–Stokes equations feature casual uses of vector differential operators to calculate curls, gradients, and divergences. However, for readers who can handle that variance, *In Pursuit of the Unknown* is an interesting and highly entertaining book. It would make a great gift for a bright high school grandchild who has expressed interest in a technical life, or for a physicist's own secret reading.

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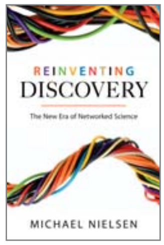
Reinventing Discovery

The New Era of Networked Science

Michael Nielsen
Princeton U. Press, Princeton, NJ, 2012.
$24.95 (280 pp.).
ISBN 978-0-691-14890-8

One primary reason I play golf is that occasionally I pull off a stroke no professional golfer could hit better. Of course, a professional golfer consistently hits such strokes. But occasional brilliance from nonprofessionals raises the question of whether a team of amateurs can beat a professional golfer if at every hole the best shot from the amateur pool is selected.

A related experiment has been tried in chess: In 1999 chess champion Garry Kasparov played against an "online world team"—some 50 000 people from 75 countries—and he ultimately won after 62 moves. Kasparov hailed it as the "greatest game in the history of chess"; a pivotal 10th move by the world team has since been added to the legendary moves of chess. Even the way Kasparov won is instructive: The world team selected its 51st move after Microsoft's online voting system was compromised; the move, which circumvented "the wisdom of the crowd," gave the chess champion an advantage that he converted into victory 11 moves later.



In *Reinventing Discovery: The New Era of Networked Science*, Michael Nielsen posits that in disciplines with a "shared praxis," online communities above a critical size can scale collective intelligence and significantly enhance cooperative problem-solving capabilities. Some mathematics and science problems are well suited for this "amplification of collective intelligence." In the Polymath Project, a particular mathematical problem was solved by an online collective of 27 mathematicians in 37 days; in marked contrast, the proof of Fermat's last theorem and of the Poincaré conjecture were the results of lengthy individual heroic struggles by Andrew Wiles and Grigori Perelman, respectively.