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Serving a Silicon Master

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Serving a Silicon Master Mathematics by Experiment: Plausible Reasoning in the 21st Century. Jonathan Borwein and David Bailey, x + 288 pp. A K Peters, 2004. $45.

Experimentation in Mathematics: Computational Paths to Discovery. Jonathan Borwein, David Bailey and Roland Girgensohn. x + 357 pp. A K Peters, 2004. $49.

Once upon a time, in ancient Greece, science was platonic and a priori. The Sun revolved around the Earth in a perfect circle, because the circle is such a perfect figure; there were four elements, because four is such a nice number, and so forth. Then along came Bacon, Boyle, Galileo, Kepler, Lavoisier, Newton and their buddies, and revolutionized science, making it experimental and empirical.

But math remains a priori and platonic to this day. Kant even went to excruciating lengths to "show" that geometry, although synthetic, is nevertheless a priori. Sure, all mathematicians, great and small, conducted experiments (until recently, using paper and pencil), but they kept their diaries and notebooks well hidden in the closet.

But stand by for a paradigm shift: Thanks to Its Omnipotence the Computer, math-that last stronghold of dear Plato-is becoming (overtly!) experimental, a posteriori and even contingent.

But what are poor pure mathematicians to do? Their professional Weltanschauung-in other words, their philosophy-and more important, their working habits-in other words, their methodology-never prepared them for serving this new silicon master. Some of them, like the conceptual genius Alexander Grothendieck, even consider the computer (seriously!) the devil. But although many pure mathematicians strongly dislike and mistrust the computer, some others have already started to see the light. For example, the great noncommutative geometer Alain Connes stated in a recent talk that his computer had confirmed a certain conjecture of his for 30 special cases, and consequently he is absolutely certain that the general conjecture is correct.

Mathematicians who want to jump on this bandwagon (which, unlike most bandwagons, is here to stay) had better read both Mathematics by Experiment and Experimentation in Mathematics. Traditionalists may get annoyed, since the authors (Jonathan Borwein, David Bailey and Roland Girgensohn) don't make any bones about "math by experiment" being truly a paradigm shift. They even dedicate a whole section to the Kuhnian notion of paradigm shift, quoting Max Planck ("the transfer of allegiance from paradigm to paradigm is a conversion experience that cannot be forced") to make the point that we can't hasten acceptance of the new perspective, we can only be patient and wait for the old guard to die.

These are such fun books to read! Actually, calling them books does not do them justice. They have the liveliness and feel of great Web sites, with their bite-size fascinating factoids and their many human- and math-interest stories and other gems. But do not be fooled by the lighthearted, immensely entertaining style. You are going to learn more math (experimental or otherwise) than you ever did from any two single volumes. Not only that, you will learn by osmosis how to become an experimental mathematician.

One of the many highlights is a detailed behind-the-scenes account of the discovery of the amazing Borwein-Bailey-**Plouffe** (BBP) formula for À:

...

(By the way, the Bailey is David, but the Borwein is Jonathan's brother Peter. **Simon Plouffe**, a latter-day Ramanujan, is the webmaster of the celebrated Inverse Symbolic Calculator site.)

The BBP formula allows one to compute the billion-and-first digit of À (in base 2) without computing the first billion digits. It was discovered with the aid of the so-called PSLQ algorithm of Helaman Ferguson (who is also an "experimental mathematician" in another sense, being a noted mathematical sculptor). Once the formula is known, the proof is an elementary calculus exercise, but the haystack of such formulas is infinitely large, and to find the one that was "just right" required ingenious experimental mathematics, which the authors generously share with the readers.

There is also a very interesting chapter on normality, which attempts to tackle the famous, notoriously difficult problem of proving that the decimal (or any base) expansion of famous constants such as e and À behaves "randomly." Aside from some constructive-but-contrived numbers (for example, the Champernowne constant 0.12...891011...9899100101102...) and natural-but-nonconstructive numbers (such as Chaitin's ©), there are no known examples. Who knows? Perhaps the experimental approach outlined here will lead to the ultimate solution.

When you do experiments, serendipitous mistakes may lead to breakthroughs. In Experimentation in Mathematics, the authors describe an "electronic Petri dish" that was obtained by typing infty (the TeX symbol for infinity) rather than the correct infinity, during a Maple session. The software interpreted the word as a mere symbol and gave an actual (unexpectedly symbolic!) answer. This led to a beautiful conjecture that was later proved by Gert Almkvist and Andrew Granville. Although this particular discovery is not quite penicillin, we should expect in the future many more such serendipitous discoveries generated by "errors."

Like all successful accounts of new, rapidly growing areas, these books are going to be victims of their own success, because the further development that they are going to inspire will render them obsolete very fast. I am sure that in five years they will seem very naive; all their "controversial" pronouncements are destined to become true-but-trite. But then again, these two lovely books have the making of classics, and they will always be fun to read, even if they come to seem quaint rather than avant-garde.

But I've said enough! Buy these books, and read them, if possible, from beginning to end. Or simply open either of them at any random page and read just that page; you will most likely learn something new, fascinating and potentially useful. If you get hooked enough to read the books cover-to-cover, then you are ready to become a full-fledged experimental mathematician.-Doron Zeilberger, Mathematics, Rutgers University, New Brunswick/Piscataway Campus, New Jersey
SIDEBAR
This figure plots all roots of polynomials, ²^sub N^, with coefficients in {0,1, -1} up to degree N=18. The zeroes are colored by their local density normalized to the range of densities, from red (low) to yellow (high). The fractal structures and holes around the roots come in different shapes and have precise locations. From Experimentation in Mathematics.
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