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ESSAY REVIEW

Has Physics Theory Become Vacuous?

Lost in Math: How Beauty Leads Physics Astray by Sabine Hossenfelder. Basic Books, 2018. 302 pp. $30 (hardcover), $17.99 (paperback), $12.99 (Kindle or Nook). ISBN 978-0-465-09425-7.

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Modern science made its mark by gaining knowledge and understanding in a bottom-up manner: starting with observed phenomena and developing explanatory theories.

From about the middle of the 20th century, however, reliance on accepted theories became increasingly dogmatic. One indication of increasing dogmatism was a failure to acknowledge phenomena for which no obvious explanation already existed—unidentified flying objects, unidentified creatures (Loch Ness Monsters, yetis, Bigfoot), parapsychological phenomena. Dissatisfaction with ignoring such phenomena led to the founding of the Society for Scientific Exploration as well as other, typically more topic-specialized, groups. A further indication of increasing dogmatism was the continuing adherence in many mainstream matters to explanations no longer consonant with accumulating evidence (Bauer, 2012a).

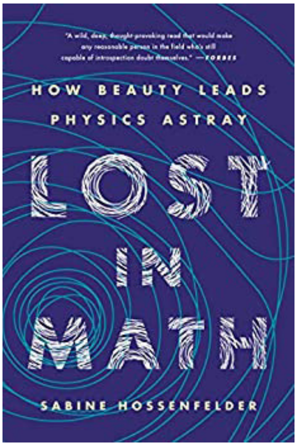
Nevertheless, it continues to be widely believed that science is carried on, and should be carried on, as described by the scientific method: The validity of theories is judged by their adequacy in explaining observable facts.

Lost in Math argues that theoretical physics is no longer a science in this sense, that it has become a playground of purely mathematical speculation, with judgments of potential validity made not by appeal to observables but to such aesthetic values or principles as elegance or beauty.

The book is enormously informative, extremely well-written, highly recommendable. Honestly and with full disclosure, Sabine Hossenfelder describes in the first person her grappling with the dilemma that her profession, theoretical physics, appears to be determinedly wrong-headed, at an impasse, a dead end, going nowhere, for instance producing 193 models for the early universe and 500 theories to explain a spurious signal (p. 235).

All the observed phenomena of fundamental particle physics and of cosmology appear to be explainable by quantum mechanics, special and general relativity, and the "standard model" that features just 25 particles.[1] However, there is no single mathematical formulation that encompasses all physical phenomena. In particular, gravitation and quantum mechanics are separate theories. Yet the community of theoretical physicists believes—takes it on faith—that there must be a single unified mathematical system from which all current theories can be derived; and for perhaps as much as half a century, theoreticians have attempted, without success, to find such a unified Theory of Everything (TOE)—as Albert Einstein had tried, also without success, for the last several decades of his life.

The Quest is based purely on faith because it lacks guidance from empirical fact. In the past, new theoretical developments came about in order to codify previously unexplainable phenomena. Lacking such clues, the quest for a TOE is being guided by beliefs about what properties the ultimate theory should have: simplicity, naturalness, symmetry, elegance, beauty. All those exist in the eyes of beholders rather than in any objective characteristic of mathematics or of observable reality, however, and defy objective definition. Hossenfelder gives splendidly understandable explanations for what those terms mean to the theorists, for example "symmetry" (pp. 23–26), "beauty" (p. 26 ff.), "naturalness" (pp. 91–94), "elegance" (pp. 94–95). She points out that inspiration or guidance by such intuitions did lead to some genuine advances in the past, but that they have also often led theorists astray (pp. 32–33).



String theory is also described lucidly (pp. 172–76), as are black holes (pp. 182–185). Readers further learn of particles that they have probably never heard of before: preons, sfermions, dyons, wimps, wimpzillas, cornucipons, cuscutons, and many more; even "unparticles" (p. 198).

Lost in Math narrates Hossenfelder's conversations with theoretical physicists seeking to clarify whether indeed the whole profession, including its leading lights, has abandoned the traditional scientific approach of aiming to understand and explain empirical, observable, phenomena. Reading the book is like getting a one-on-one, in-person tutorial, from a first-rate teacher who is not only master of the technical subject but also firmly grounded in common sense, as well as skilled at explaining technical issues to outsiders. Most readers will not need to take notes because each chapter concludes with a section "In Brief" that summarizes the chapter's main points.

The book also offers well-founded insights into the circumstances of contemporary science as a whole.

My enthusiastic praise for this book is echoed by many reviewers.[2] Perhaps the most meaningful compliments come from members of the physics community itself (e.g., Appell, 2018), especially those who disagree with Hossenfelder on various specific points: "Although I disagree . . . on many points, I recommend the book both as a well-written, moving intellectual autobiography and as an excellent exposition of some frontiers of foundational theoretical physics" (Wilczek, 2018); a philosopher of science remarks, "I first state my main disagreements. Then, I mostly praise the book" (Butterfield, 2019).

Hossenfelder exemplifies the ideal scientist: self-driven[3] to seek genuine understanding. That is not nowadays a promising career path, as Hossenfelder is fully aware: "Several well-meaning friends have tried to dissuade me from writing this book" (p. 197). Fortunately, she ignored this advice, but a price is being paid: "Hossenfelder has had a nomadic career of short-term research positions, but it would be good if she could find a permanent home and some security. Today's theoretical physics needs a few malcontents asking questions that other scientists only ask themselves" (Appell, 2018). Indeed, science as a whole sorely needs more dedicated truth-seekers willing to overcome conflicts of interest and pressures from peers and patrons and employers. As George Bernard Shaw noted, progress depends on unreasonable people[4]—individuals regarded as unreasonable by their peers because they refuse to capitulate to conformity and Groupthink; say, Hossenfelder re theoretical physics; Peter Duesberg, Kary Mullis, and others re HIV/AIDS, and other mavericks, cited for example in Bauer (2012a). Anyone interested in benefiting from Hossenfelder's work and ideas can do so at her well-regarded blog, http://backreaction.blogspot.com.

The first three chapters of *Lost in Math* are a historical survey of advances in fundamental physics up to the present. Most of the rest of the book relates interviews with leading theoreticians that accumulate to make a convincing case for Hossenfelder's views. There is simply no sound reason to expect that subjective feelings of beauty or elegance, or "Eureka" moments of exhilaration, would be a reliable indication of having found genuine understanding of the real world: "Why should the laws of nature care what I find beautiful?" (p. 3); "Science is an organized enterprise to overcome the shortcomings of human cognition and to avoid the fallacies of intuition" (p. 4).

Predictions that new effects would be seen in upcoming experiments have been wrong time and again without destroying faith in the basis for making the predictions (p. 94), reminiscent of End-of-the-World cults that continually revised their calculation of the apocalyptic date instead of abandoning the disproven basic assumption (Festinger et al., 1956).

A prize-winning physicist defended reliance on experienced intuition by analogy with poker: "A royal flush is just as likely or unlikely as any other hand. But there is still something about a royal flush that cries out for an explanation if you get three in a row" (p. 111). As Hossenfelder points out, that some striking coincidence attracts human attention does not mark it as an insight into Nature's realities; humans including physicists tend to assume that coincidences must be meaningful (p. 144), yet they may come about purely by chance, given the large number of opportunities (Bauer, 2019).

Hossenfelder writes with dry humor as well as passionately: "This is possibly the nicest way I've ever been told I'm stupid" (p. 177). When physicists base theories on something other than facts, "the thought makes me sweat" how climate scientists might choose their models (p. 34).[5] After interviewing a prominent fellow theoretician, "I understand why he has become so influential. In contrast to me, he believes in what he does" (p. 85). "Theoretical physicists used to explain what was observed. Now they try to explain why they can't explain what was not observed" (p. 108); as when they report their results as finding "interesting bounds": "In plain English, 'interesting bounds' means they didn't find anything" (p. 201).[6] "String theorists' continuous adaptation to conflicting evidence has become so entertaining . . ." (p. 174); "Why are so many jobs offered in string theory? Because string theory is cheap. . . . offer a couple of jobs in string theory and you have a modern physics department" (p. 174).[7] "In case I left you with the impression that we understand the theories we work with, I am sorry, we don't. We cannot actually solve the equations of the standard model, so what we do instead is solve them approximately by what is known as 'perturbation theory'" (p. 193). "This isn't the only math problem with the standard model or quantum field theories more generally. Another such problem is Haag's theorem, which states that all quantum field theories are trivial and physically irrelevant. That's somewhat disturbing, so physicists ignore the theorem" (p. 268, #22).

The book's concluding Chapter 10 encompasses a concise yet comprehensive description of the many forms of bias that are inherent features of human nature and that explain how human beings can go wrong individually, as well as in groups under the influences of peer pressure and Groupthink. Thus, experimenters may subconsciously try to replicate earlier work (p. 227 ff.). "The mother of all biases" is "the insistence that we certainly are not biased" (p. 231).[8]

This chapter should be read by everyone, quite independently of any interest in theoretical physics. Hossenfelder had noted earlier the human tendency to appreciate things that are new and surprising *but not too much so* (p. 89). I suspect she is not however familiar with the mass of literature on minority views and unorthodoxies that is the foundation and background of anomalistics and scientific exploration; for example, in the book's discussions of dark matter and dark energy

I looked in vain for reference to the work of Halton Arp (1987, 1998)—because if Arp is right, that some redshifts associated with quasars are not a purely Doppler Effect, then current calculations of cosmic distances and speeds are wrong and there may be no need to postulate those "dark" things.

Beyond the inevitable biases, contemporary science can go wrong because of its sheer growth. It is nowadays far from an elite vocation, and research is also hindered by the intractable volume of the specialized literature as well as career uncertainties and competition for resources (pp. 153–56, 170). "Almost all scientists today have an undisclosed conflict of interest between funding and honesty" (p. 197). "In the United States, the income inequality in academia is now larger than in industry or government" (p. 269, #2 citing Lok, 2016).

Appendix C (pp. 245–248) suggests how science might again be made to behave as an unbiased, disinterested, truth-seeking enterprise. Unfortunately, this is far from convincing. Hossenfelder's own experience, and this book, and other critiques of contemporary science (Bauer, 2017b; Ritchie, 2020) show clearly enough that the fundamental problem is that researchers are not independent self-supporting entrepreneurs and can pursue research only with resources made available by patrons, typically private or governmental institutions; and those resources are coupled to incentives that are not primarily to seek reliable truths about nature. Those incentives are what lead science astray, emphasizing productivity measured in publications or in commercial applications and making necessary a never-ending competition for resources; there is "a natural selection for bad science" (Smaldino & McElreath, 2016).

Lost in Math naturally stimulates a certain curiosity as to why society should support for decades a venture that will almost certainly result in no useful practical benefits. I suspect the answer is that physics has managed to keep the enormous prestige and status attained as a result of technical developments during World War II, most especially atom bombs and nuclear power reactors.[9] But it seems quite inconceivable that any future theoretical advances could have anything like the consequential practical impact as did $E = mc^2$. Why then should society provide a living for some 10,000 theorists (p. 1) and continue to build enormously expensive machines? The Large Hadron Collider at the international European Organization for Nuclear Research (CERN) in Switzerland costs about 1 billion dollars a year just to run; the last discovery made there, the Higgs boson, is estimated to have cost more than 13 billion dollars.[10] It seems much more likely that socially useful advances could come from areas that are currently dismissed as fringe science, say the harnessing of Zero Point Energy (Yam, 1997) or Low-Energy Nuclear Reactions ("cold fusion").[11]

Anyone interested in higher education might well be led also to consider whether the old model of research universities may have outlived its social value. Does it make sense that ground-breaking original research should be demanded of everyone whose purported primary role is actually the "higher" education of future generations?[13] That is a whole other story, of course, and volumes have been written about it elsewhere, for instance concerning postmodernist excesses like "critical theory" and infatuation with French philosophers that captured Departments of English Literature a couple of decades ago.

So Hossenfelder's book is not only a wonderful exposition of contemporary theoretical physics, it also stimulates thought on other and more general topics of present-day concern.

NOTES

[1] 12 fermions (6 leptons and 6 quarks), 12 gauge bosons (Z, W^-, W^+, 8 gluons), and the Higgs boson.

[2] More than a dozen favorable blurbs are gathered at https://www.revolutionbooks.org/book/9781541646766.

Ratings at Goodreads averaged 4/5, and 4.6/5 at amazon.com. As to those latter reviews: I've taken an interest in the significance, uses, and abuses of unsolicited as well as anonymous comments ever since my experience of anonymous student evaluation of teachers ("The new generations: Students who don't study"; http://faculty.tamucc.edu/dcrumbley/Crumbley%20Homepage/students-who-dont-study.html). I've always remembered, too, the tour guide who solicited written evaluations after our tour ended. I asked whether the company shared these with her, and she replied, "Yes. But now I no longer read them, because no matter how many nice ones there are, the one or two really nasty ones are what stay with you and sour you on your next clients."

The 380 reviews on Amazon of Hossenfelder's splendid book provide similar insight into the routine presence of a proportion of the ignorant or malicious commentary that fouls the Internet. Just under 10% of the Amazon reviews of *Lost in Math* were less than very favorable (less than 4/5). One very lengthy 2/5 review is by a prolific non-anonymous individual whose 46 reviews of books and other products averages 2.45 while all other reviewers gave those an overall average rating of 4.0.

[3] By contrast, the mass of research is nowadays done by people whose curiosity is not self-driven but rather *induced* by career opportunities and money—Gordon Tullock, *The Organization of Inquiry*, Duke University Press, 1966 (reprinted 2004, Liberty Fund). My eight years as a dean of arts and sciences (Bauer, 2012b) confirmed Tullock's observation: Most of the faculty viewed research as an obligation rather than a vocation; thus a sociologist once asked me, "Now that I've reached full professor, what remains for me to do?"

[4] George Bernard Shaw, "Reason," in "Maxims for Revolutionists," pp. 281–282 in the 1946 Penguin edition of *Man and Superman*.

[5] In fact, climate scientists are indeed much like theoretical physicists in putting theory ahead of facts: They attempt to create computer models of climate while ignoring long-standing facts in the geological literature that demonstrate a lack of correlation between levels of atmospheric carbon dioxide and global temperatures (Bauer, 2017a).

And economics, it turns out, is also in much the same boat as theoretical physics: "economists . . . mistook beauty, clad in impressive-looking mathematics, for truth," according to Paul Krugman (p. 224).

[6] Just as medical scientists pretend to knowledge and understanding when they speak of "essential" tremor and "idiopathic" conditions when the causes are unknown or nothing can be done about it.

[7] Citing Freeman Dyson, 2009, Birds and Frogs, *Notices of the American Mathematical Society*, 56(2), 221. An old joke has a dean boasting about saving money by growing the math department: "All they need are paper, pencils, and wastebaskets"; which is topped by a dean who favors sociology: "They don't even need wastebaskets."

[8] Illustrated for instance when researchers claim objectivity because of using "the scientific method."

[9] The credit has somehow accrued to physics, perhaps because of Einstein and $E = mc^2$, even though it was chemistry that first recognized nuclear fission, and the atom-bomb project was a multi-disciplinary effort involving, as well as physicists, mathematicians, engineers, chemists, and far from least maestro administrators—one of whom was indeed also a physicist.

[10] Alex Knapp, How much does it cost to find a Higgs boson?, July 5, 2012, *Forbes*. https://www.forbes.com/sites/alexknapp/2012/07/05/how-much-does-it-cost-to-find-a-higgs-boson/?sh=2c8372703948

[11] See "A library of papers about cold fusion." https://lenr-canr.org

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