The New Science Wars

Hal Berghel, University of Nevada, Las Vegas

Science and scholarship are under attack from all sides. To a large degree the lack of appreciation is due to a fundamental misunderstanding about the nature of scientific inquiry.

We've entered a new era in scientific commentary. During the Renaissance and Enlightenment, natural philosophers like Francis Bacon drew upon natural laws and deductive logic. During the 19th and 20th centuries, philosophers and logicians waxed eloquent using inductive logic, probability, and statistics. However, the current millennium finds politicians and ideological partisans who equate good science with their own personal ideologies, beliefs, and suppositions. In last month's column, I illustrated this point with FCC Chairman Ajit Pai's critique of NSF funding of a project that models information-sharing activities on social networks.[1] Another high-profile political encroachment into science came at a 2015 congressional hearing on Planned Parenthood, when Jason Chaffetz (R–Utah) mischaracterized its services over the past decade. "In 2006," he claimed, "Planned Parenthood performed more prevention services and cancer screenings than abortions, but in 2013, there were more abortions." He defended his position with the chart shown in Figure 1a.

The dueling axes were of course intended to demonstrate an inverse correlation that in fact didn't exist. But, as *Mother Jones*'s Kevin Drum pointed out,[2] when the scales are shown correctly, as in Figure 1b, Chaffitz's bogus correlation disappears altogether. Mark Twain's maxim that "figures don't lie, but liars figure" comes to mind. The scales differ by an order of magnitude, so it's difficult to imagine that this oversight was accidental. Information design pioneer Edward Tufte refers to such useless, information-obscuring, quantitative displays as chartjunk.[3] In an interesting series of TED talks, Hans and Ola Rosling argue that as scientists we must be more vigilant in our fight against global ignorance.[4] A good start is for domain knowledge experts to take more control over their domain's narratives.

SCIENCE UNDER SIEGE

How did we get to the point where high-profile figures could foment fashionable nonsense without repercussions? There was a time when people who misrepresented facts would attract public ridicule, but those days seem to be gone forever. Society has apparently developed an extreme tolerance for deceit, lies, misrepresentations, and sundry forms of flimflam and humbug from politicians, celebrities, commercial media personalities, talk radio hosts, online provocateurs, groupthink-tank
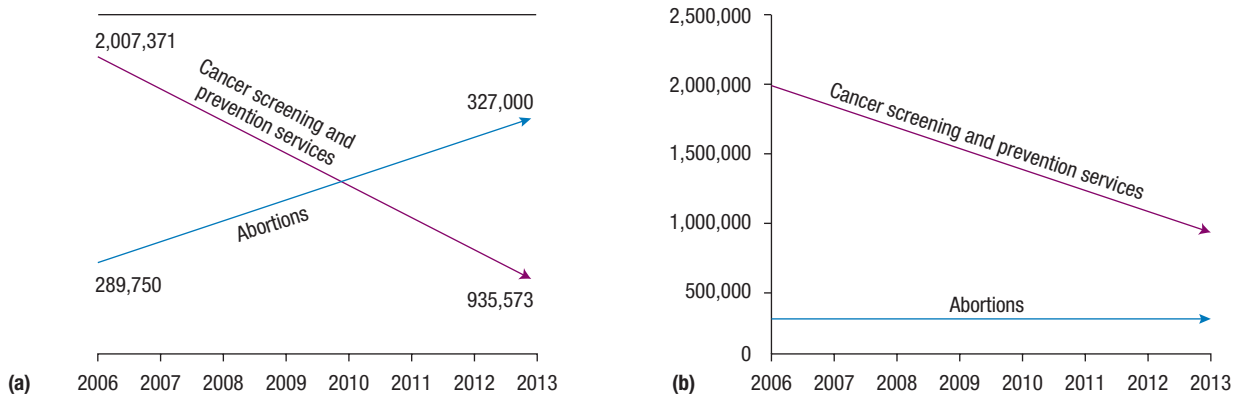
Figure 1. Number of cancer screenings and prevention services versus number of abortions performed by Planned Parenthood from 2006 through 2013: (a) version presented by Congressman Jason Chaffetz at a hearing on 29 September 2015 (Source: Americans United for Life) showing an inverse correlation and (b) version with correct scale showing no such correlation (Source: K. Drum, "Lying with Charts, Anti-Abortion Edition," *Mother Jones*, 29 Sept. 2015; www.motherjones.com/kevin-drum/2015/09/lying-charts-anti-abortion-edition).

spokespersons, and other hucksters and misinformation mongers. Where's the public blowback for fake news these days? It's mind-boggling how much absurdity passes for information without critical comment. But if we allow this flimflam and humbug to infect the scientific enterprise we're doomed, for it has been science and the academy that have propelled the US—and the industrialized West for that matter—to the level of success and economic prosperity that it enjoys today. This isn't to diminish the importance of business and industry, but curiosity-driven research is what fuels the launch-stage engine of innovation. Without Einstein's special theory of relativity, there would be no accurate GPS; were it not for the work of Thomson, Bohr, Fermi, Dirac, and Pauli, there would be no semiconductor industry; but for Fleming's discovery of penicillin, there would be no antibiotics; and so on. None of these achievements were encouraged, nurtured, or even understood by politicians and ideologues at the time—or now, for that matter.

Of course, criticism and misuse of science and its methods aren't new. Over the past century, science has been under continuous attack from pacifists, religious fundamentalists, postmodernist social scientists, and cultural critics for a variety of independent reasons. But the phenomenon of politicians posing as scholars is relatively new, and is as frightening as having to sit through a Schoenberg piano concerto with a hangover. Academics and scientists would do well to learn from the past century's science wars and insert themselves into the current one with the greatest force they can muster to ensure that the narrative doesn't get corrupted any more than it has. Science and scholarship are inextricably intertwined with politics: the federal funding agencies are ultimately overseen by politicians, the ownership of federally funded research was determined by politicians (for example, the Bayh–Dole Act), patrons of higher education are increasingly attaching partisan strings to gifts,[5,6] and right-wing politicians have attempted to influence

the direction of research.[7,8] To try to separate science and research from politics is an uphill fight against political reality. And things are about to get much worse.

THE WEAPONIZATION OF NONSCIENCE

We frame our observations with a question: If politicians objected to federally funded research on Goldbach's conjecture, the continuum hypothesis, the Pauli exclusion principle, or the real cause of the Alpha effect in chemical kinesis, would it be reasonable to take them seriously? Or, for that matter, would it make sense to allow politicians to determine whether a bridge design was adequate or a chemical compound was stable at room temperature? Certainly not! But when a research objective has potential cultural significance or symbolism, or possible significance for social and economic policy, partisan politicians and ideologues come out of the woodwork to opine—usually ineloquently.

Science isn't perfect. But although the development of scientific theories

might sometimes be messy, it's never messianic. Say what you will about the occasional but inevitable mistakes of serious science, they're rarely motivated by politics, ideology, or religion. Of course there are exceptions, but they tend to be ephemeral and usually have a short shelf life. The geocentric model of the universe lasted far longer than it should have because it favored prevailing religious orthodoxy. There was a reason why Copernicus insisted on posthumous publication of his great work—a lesson lost on Galileo to his great cost. The miasmatic theory of disease and the four humors theory

faced with the cold realities of fact and experiment, good scientists almost always go where the preponderance of evidence and logic takes them. There's no room for sentimentality and irrationality, and as such the scientific method is inherently progressive and self-healing.

For the most part even scientific misjudgments were reasonable in their time—they offered good explanations of observed events given the current limits of technology, theory, or data. Under normal circumstances, even plausible ideas last only as long as they accord with the bulk of prevail-

"absence of evidence" argument (that the absence of evidence is no evidence of absence) that Donald Rumsfeld used so successfully to support his conclusion that Saddam Hussein had weapons of mass destruction despite strong evidence to the contrary. Nonscience has always been with us, but it has only become a serious political weapon in the last half-century, and through this period of weaponization the majority of academics, scientists, and scholars have remained silent. This silence has to a measurable degree contributed to the various denier movements regarding climate change, the ill effects of smoking and environmental pollution, the link between poverty and underperformance in schools and the workplace, and so on.[9]

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of physiology also served humanity poorly but persisted because they were acceptable to the controlling interests. One could say the same of phlogiston and caloric theories of heat, the flat earth model, and, if we wanted to get really fancy, the notion of absolute space and time and the spontaneous generation of species. Wrong-headed science is most persistent when embraced by the power in place.

We can use theories of the atom to illustrate scientific evolution. From the atomic indivisibility theory of Democritus (400 BC), to John Dalton's indivisible but individual atoms (~1810), to J.J. Thomson's "plum pudding model" (~1904), to Ernst Rutherford's planetary model (~1911), to Niels Bohr's energy shell model (~1913), to the current standard model built on fermions and leptons—the reasonableness of science consistently shone through: the old dogma was abandoned with little fanfare in the face of contravening evidence, and the best explanation at that point won the day. I'm not claiming that scientists who invested their career in developing a theory were willing to cast it off whimsically, but

ing scientific doctrine. This is in direct contrast with nonscientific errors that were never fostered by trained scientists and scholars, lacked explanatory power and predictive capacity from the start, weren't confirmable, failed to harmonize with antecedent theories, and, most importantly, appealed to metaphysical, mystical, or religious dogma for validity. Well-known examples include Bishop James Ussher's dating of creation at 6 pm on 22 October 4004 BC, apocalyptic cultist Dorothy Martin's premonition on the end of the world on 21 December 1954, the Zodiacal calendar, natal horoscopes, Leonard Lauder's lipstick index, creationism, aromatherapy, the inheritance of acquired characteristics—the list goes on and on. Note that each of these ideas was considered unreasonable in its time by legitimate domain knowledge experts and only enjoyed widespread support by, and influence on, sympathetic tribalists.

The momentum behind nonscience is usually some combination of three non sequiturs: appeal to ignorance, the fallacy of denying the antecedent (aka: modus moron), and the famous

A NEW STRATEGY

Science is in the business of asking and answering questions that are intellectually respectable. The criterion for respectability is always the favored fruit of enlightened and prepared minds. The domain is wide open: nothing reasonable is excluded a priori. However, once we agree on these terms, there's no predicting where science may go. It can lead us to the conclusion that all living species arise and evolve by means of small variations that result from natural selection (Charles Darwin, 1859) just as easily as the conclusion that measurement of space and time must always be made relative to a frame of reference and can't be absolute (Albert Einstein, 1905). Science is an open-ended journey—that's half the fun. But open-ended journeys can lead to places that some would declare off-limits when in conflict with beliefs, ideals, and values, irrespective of any disconfirmation.

So why do these science wars last so long? There are two reasons.

First, the principle of cognitive dissonance[10] suggests that humans strive for cognitive consonance, and will go to any length to dismiss conflict. Conflicts produced by reason (read: science) will tend to be more easily dismissed

<ALT>-FAQs>

One successful offering at the recent DEF CON conference in Las Vegas (www.defcon.org) was the Voter Hacking Village. Participants had an opportunity to exploit several dozen voting machines obtained through eBay and government auctions—at least one with the original voter registration records still loaded. Successful hacking demonstrations included exploits of WinVote and Diebold.[1] Not surprisingly, the grandfather of voting machine hacking, Harri Hurst, helped organize the event.[2] A good time was had by all.

The organizers of and participants in this event should all receive public service certificates for their yeoman work on behalf of democracies across the globe and should be encouraged to expand their village to include university labs. One of the greatest benefits Hursti and his colleagues could provide is information on how their efforts might be duplicated by undergraduates worldwide. I have in mind a website with contact information for government auctions, eBay resources, and technical reports broken out by exploits, voter machine models/vendors, and so on. An even greater service would be to include electronic management systems for voting machines, as these are the most likely to be hacked by those who would seek to corrupt US elections.[2,3]

To borrow a phrase from the late Edsger Dijkstra, voting machines are mistakes carried through to perfection, and the greatest service the computing community can perform is to expose the existing system's inherent vulnerability to the population at large. For those nervous Nellies concerned with attendant risk, I would point out that the dark forces among us who would subvert the voting franchise already understand the nature of these vulnerabilities; only the public and politicians seem to be in the dark. The best strategy to mitigate our risk would be to expand the knowledge base under the control and watchful eye of the university classroom and laboratory, and through the computing students and faculty to the broader academy, media, and public. But unless US policy on voting machines changes soon, it's just a matter of time until an election is hacked by antidemocratic domestic or foreign agents.

There are no technological barriers to fair voting—our obstacles are political. Unfortunately, the decision makers at all levels who approve, certify, endorse, purchase, and implement corruptible voting machines are either incapable or unwilling to understand the vulnerabilities of voting machines and the potential impact on undermining democracy. It should be remembered that election commissioners and elected officials sign off on the purchase of voting equipment. We need to draw enough attention to the vulnerabilities to force them into making responsible decisions—they won't do it on their own when their only exposure to the technical foundations comes from vendors and their sales representatives.

I should add that the DEF CON event was only possible because of a 2015 ruling change by the Librarian of Congress to Section 1201(A)(1) of the Digital Millennium Copyright Act (DMCA) that exempts "circumvention of technological measures that effectively control access to copyrighted works shall not apply to persons who engage in noninfringing uses of certain classes of such works" (www.copyright.gov/1201/2015/fedreg-publicinspectionFR.pdf). This makes it possible for researchers to reverse-engineer code, such as that in voting machines, for study. As Cory Doctorow points out, noninfringing exemptions should be the default as a public good,[5] for how else could the end user verify the integrity of voting machines, life support technology like implants, financial software, and so on? In fact, the Electronic Frontier Foundation (EFF; eff.org) is suing the government over the alleged unconstitutional use of the DMCA at this writing.[6]

The possibility of election corruption is arguably the most important issue before us, for if we can't guarantee fair voting we're a democracy in name only. Several organizations are engaged in this issue, including Verified Voting (www.verifiedvoting.org), the EFF, and the Electronic Privacy Information Center (epic.org). I will note in passing that Internet voting is currently DOA—not because it's a bad idea (which it is for security reasons) but because it makes voting so easy that it necessarily enlarges the franchise.

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than those produced by tenaciously held belief systems and tribal values. If some facts have to be discarded, the dispassionate product of science will be the first to go if the incognoscenti have their way.

Second, scientists and scholars haven't seriously entered the science war because many feel it undignified to engage over scientific issues with non-scientists. This is a fundamental mistake for any number of reasons, not least of which is that the science neophytes have votes and might vote along tribal lines unless they're brought into meaningful dialogue with those informed about science and can appreciate the long-term benefits that spring therefrom. Although scientists might not like to admit it, science is always political. A case in point is the Bayh–Dole Act, which commercializes federally supported research with indifference to the taxpayers that funded it. In a very real sense, the taxpayer ends up paying for the research twice: at both inception and consumption. From the taxpayer's point of view, it would be far more economical to put the research into the public domain and let anyone commercialize it without license—at least that would bring competition into the marketplace. As it stands, exclusive licenses from the research organization to private companies is common.

We need to completely rethink science and innovation policy, this time with primary focus on the interests of taxpayers, citizens, and the scientific and academic community rather than commercial, ideological, and political interests. And while we're at it, we must reach out to the public (and nontribalist politicians) in an attempt to get the scientific narrative back on the rails. All too often we act as if our colleagues in industry, government, and academia are representative of the general population when it comes to domain knowledge, and we wrongly assume that what's obvious to us is obvious to everyone. To remain relevant,

we must make our case to the voters. If we fail to do that, ideologues and politicians will continue to fill the vacuum and distort the narrative to include their biases. Even the science-literate part of the public can't be counted on to share our passions.

We can begin by disabusing the public of the false, worn-out notion that science is about facts and truth. It's not, and never has been. By failing to establish this reality, we provide deniers, naysayers, tribalists, and antiscience scoundrels the opportunity to create and exploit a false "credibility gap." Most antiscience begins with the argument that the absence of absolute proof is equivalent to indeterminacy. This has been used to undermine research on evolution, the hazards of smoking, acid rain, climate change, stem cells, and virtually every other scientific enterprise that offends partisan camps.[9,11] By failing to establish a broader rapport with the public, we have legitimized the claim that any position short of absolute truth is unworthy of consideration.

We need to get the word out that science is about probabilities, some higher than others, and the best hope is a policy based on the best evidence. The March for Science on Earth Day and STEM the Divide aren't going to cut it with deniers. ⊏

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HAL BERGHEL is an IEEE and ACM Fellow and a professor of computer science at the University of Nevada, Las Vegas. Contact him at hlb@computer.org.