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HISTORICAL PERSPECTIVE

Three Stages of Modern Science

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Abstract—The common view of science is a *mis*understanding of today's science that does not recognize how "modern" science has changed since its inception in the 16th to 17th centuries. Science is generally taken to be objectively reliable because it uses "the scientific method" and because scientists work disinterestedly, publish openly, and keep one another honest through peer review. That common view was not too unrealistic in the early days and the glory days of modern science, but it is quite wrong about contemporary science, which has ceased to be trustworthy because it is subject to commercial and bureaucratic influences that have spawned highly damaging conflicts of interest, institutional as well as personal. The birth of "modern" science is credited uncontroversially to "The" Scientific Revolution of the 17th century, but it has not been widely understood that there have been three distinctly different stages of scientific activity since then. In the first stage, amateurs were seeking to satisfy their curiosity about how the world works. There were essentially no controlling interests other than truth-seeking. Missteps taken resulted chiefly from the inherent difficulty of making discoveries and from such inherent human flaws as pride and avarice. The second stage, roughly the 19th century, saw science becoming a career, a plausible way to make a living, not unlike other careers in academe or professions like engineering: respectable and potentially satisfying but not any obvious path to great influence or wealth. Inevitably there were conflicts of interest between furthering a career and following objectively where evidence pointed, but competition and collegiality served well enough to keep the progress of science little affected by that conflicting career interest. The way to get ahead was by doing good science. In the third and present stage, which began at about the middle of the 20th century, science faces a necessary change in ethos as its centuries-long expansion at an exponential rate has changed to a zero-sum, steady-state situation that has fostered intensely cutthroat competition. At the same time, the record of science's remarkable previous successes has led industry and government to co-opt and exploit science and scientists. Those interactions offer the possibility for individuals to gain considerable public influence and wealth. That possibility tempts to corruption. Outright fraud in research has become noticeably more frequent, and public pronouncements about matters of science are made for self-interested bureaucratic and commercial motives. The public cannot now rely safely on the soundness of advice from the scientific community.

Keywords: historical changes in science—science become untrustworthy

Introduction

A Society for Scientific Exploration is inevitably concerned with what it means to be scientific, to do science. But almost everyone has wrong ideas about that, including most scientists and those who write or comment about science.

There are two chief reasons for that. One is confusing how science might ideally proceed with what the reality is. The other is failing to understand that today's science is very different from what it was only about half a century ago.

Science is unlike idealized views of it primarily because of conflicts of interest; and the degree to which scientists experience conflicts of interest has increased enormously over the centuries, most especially since World War II. Many people nowadays are willing to acknowledge that Wall Street and Big Pharma enjoy the best Congress their money can buy, but few people seem to understand that nowadays we are also stuck with the best science that money can buy (Mirowski 2011).

Put it another way: Science has become too big to fail. The National Academies of Engineering, Medicine, and Science are too big to fail; the National Institutes of Health are too big to fail; the Centers for Disease Control & Prevention are too big to fail; the World Health Organization is too big to fail—in the sense that their pronouncements about matters of science cannot be effectively countered even by groups of dissenting experts. The institutions of science and medicine determine what is to be believed. If the evidence actually points elsewhere, so much the worse for the evidence and for those who try to speak for it.

The uncomfortable realization that science has become seriously untrustworthy follows from the observation that, in a wide and varied range of fields, unwarranted dogmatism and suppression of competent minority views—which are not supposed to happen in science—have become rampant (Bauer 2012a): concerning aboriginal cultures (Dreger 2011), Alzheimer's disease, cosmology, dangers of mercury and of second-hand smoke, dinosaur extinction, efficacy of anti-depressants and of many other drugs, evolution of birds from dinosaurs (Feduccia 2012), first humans in the Americas, global warming, HIV/AIDS theory, human sexual diversity (Dreger 2008), low-energy nuclear transformations ("cold fusion"), plate-tectonics theory (continental drift), safety of genetically modified organisms and their products, special relativity theory, string theory, theory of smell.

Evidence and Interpretation

The claim that science could be mistaken over so many matters, through excessively dogmatic adherence to an insufficiently proven mainstream view, goes against what is widely taught and believed about science and the reliability of the scientific method: How could science possibly be so dogmatic and perhaps even mistaken on so many topics?

I had found myself posing a similar rhetorical question when I first read Tim Dinsdale's book about the Loch Ness Monster (Dinsdale 1961). I had found quite credible his tale of having the enormous good luck to capture on film a large animal moving through the water (and the film itself has since borne up well against challenges, for example detailed analysis by up-to-date technology [Bauer no date]). But when I came to Dinsdale's Chapter 9, titled "Monsters Galore," about similar creatures in lakes and seas all over the world, I said to myself, "This is just too much. One such critter not known to science is hard enough to swallow, let alone dozens of them!"

I don't recall how long it took me to recognize how illogical that reaction was. *If* Nessies exist, then it's much more likely that they have siblings or cousins elsewhere, than that one lake in the whole world would be the only place where there are such creatures.

So too with science being excessively dogmatic and suppressing competent alternative views and thereby becoming unreliable. If this had been noted on just one topic, it would seem an aberration that "science" could be so "unscientific" and one would doubt the claim. However, when dissenting experts in widely disparate fields have attested to dogmatic suppression of reasonable evidence-supported viewpoints on the dozen-and-a-half topics listed above, indications are that something about contemporary scientific activity is drastically different from what we had come to expect.

Admittedly, at first sight it seems extraordinarily unlikely that all official institutions could be seriously mistaken over the influence of greenhouse emissions on global warming, say, or over the belief that HIV caused AIDS. But recognizing that a number of less prominent fields have experienced unwarranted hegemony of a less-than-proven hypothesis does suggest that scientific activity is more subject to dogmatism and less open to self-correction than the popular view would have it. And if so, then perhaps "science" could be wrong also and even over something like climate change, where significant dissent from the official view is given no shrift at all in professional or popular media.

The popular view of science sees it as a search for truth, disinterested and objective, as though secluded in an academic ivory tower and unhindered by anything but seeking the truth. That view came about in part because of the phenomenal progress of scientific understanding since the 17^{th} century and because of an oversimplified, bowdlerized description of those early times and the doings of such intellectual giants as Galileo and Newton. But today's science is nothing like the science of those early days, and not many of today's scientists are anything like those intellectual giants.

Modern science has seen three distinctly distinguishable eras.

The First Era of Modern Science

In the first era of modern science, amateurs were seeking authentic knowledge as a matter of sheer and often worshipful curiosity.

Historians are in reasonable agreement that modern science had its beginnings at about the turn into the 17^{th} century. The crucial circumstance, marked by such events as the founding of the Royal Society of London, was that a scientific community began to come into being.

Earlier times had seen individuals gaining bits of scientific knowledge and acquiring and sharing remarkable technological skills, but these remained discrete, not at all like the modern integration of all scientific disciplines and their applications under the stewardship of professional guilds. "The" Scientific Revolution of about the 17^{th} century saw the beginnings of that integrated venture by something like a coherent association of knowledge seekers. They were doing "natural philosophy," seeking to understand Nature. Some of the participants were clergy to whom the study of Nature was a way to serve God, a way to understand His ways better, while others were doing it just because they wanted to, whether out of sheer curiosity or in the hope of finding materially useful things. The essential point is that they were working primarily as amateurs, following their passions, not distracted by external conflicts of interest.

In this first era of modern science, flaws and errors stemmed partly from the inherent difficulty of understanding how the world works and partly from human characteristics. People naturally took pride in their discoveries and wanted to be recognized for making them, and to be acknowledged as having made them first, and perhaps even to profit materially from them, and they could be heavily invested in their own theories, sure they were right and others wrong. So there were arguments, sometimes quite bitter, typically over who had priority for a discovery. But those arguments were not exacerbated by interests external to scientists and knowledge-seeking.

That first era of modern science has left its mark on the contemporary view, according to which scientists are self-driven by curiosity with their only interest being to discover what the truth is. That certainly remains accurate for some individual scientists, but it isn't accurate overall: Most researchers nowadays are employees doing what they're paid to do, and influenced by a variety of conflicts of interest whose consequences can be decisive.

The Second Era of Modern Science

In the second era of modern science, science became a career.

By the early 19th century, natural philosophy had accumulated a respectable amount of trustworthy knowledge and understanding of Nature, enough to inspire confidence that even more could be learned in the future. The term "science" was becoming used in something like its modern form; William Whewell is generally credited with first use of the term "scientist" in the 1830s. So the professional identity of "scientist" came into being, and with it the possibility of doing science as a career, a livelihood: at first primarily through teaching, with research as an optional sideline, but soon also through carrying out applied research, beginning perhaps with the synthetic-dye-stuff industry. In the later 19th century, Germany pioneered what have become "research universities," where the teaching of undergraduates tends to play a subsidiary role (Knight 1986).

Now it became not just a matter of personal satisfaction to get there first and to be acknowledged for it and to be right while others were wrong, it was henceforth a way to succeed in practical terms, making a career and attaining better positions. Making great discoveries could even lead to high social status, for example being inducted into the British peerage like William Thomson who became the first Baron Kelvin, or Ernest Rutherford who became the first Baron Rutherford of Nelson in New Zealand.

During the First World War, Germany lost access to the previously imported nitrates needed for explosives as well as fertilizers, and Ernst Haber found out how to synthesize the needed chemicals from the atmosphere's nitrogen. Many other fundamental discoveries turned out to have practical applications. Industrial scientists could sometimes share the benefit from making patentable discoveries. But, by and large, the rewards from being a scientist were more intangible than material, from the satisfaction of doing the work and being able to earn a decent living from doing something interesting. In this second era of modern science, from about mid-19th century to about mid-20th century, science was in many ways an attractive career, but it was not a path one would choose if seeking wealth or an entrée into the halls of power. The conflicts of interest to which researchers were subject were largely personal ones: They had to mesh doing science honestly with doing what would advance their career. That rarely hindered the drive to do good science, because by and large the way to succeed personally was by doing the best, most original, and most trustworthy science.

The Third Era of Modern Science

The third era of modern science, the contemporary scene, sees science enmeshed inextricably with technology, big money, and big politics, bringing highly influential external and institutional conflicts of interest. Up to this time, scientific activity had been almost entirely the product of individual choices and endeavors. Nowadays it is increasingly a corporate endeavor, and corporations are not people. For example: Historians have described the influence of the Rockefeller Foundation on biological research, as recently as the 1930s, in terms of the character of its president, Warren Weaver; today, by contrast, the influence exerted by the National Institutes of Health results largely from bureaucratic inertia and relatively little from the characters of the individual administrators, who are bureaucratically homogenized and corporately restrained. Thus at the Food and Drug Administration, there have been a number of examples where “larger considerations”—expounded in self-interested fashion by drug companies—have overruled the technical judgments of the scientific staff.

The Second World War introduced this present era of science, in which research can lead to great wealth and to considerable influence on national and international policies. Science has thereby become inseparable from powerful external vested interests. Sheer size of the enterprise has brought bureaucracy to the control and funding and publishing of research. Research may then be for political purposes or for commercial profit rather than for simply truth-seeking. Applications of research may be determined by personal or private or corporate interests even to the exclusion of the public good (Krimsky 2003). The distinction between “pure” science seeking basic understanding and “applied” science based on trustworthy fundamental knowledge has become largely meaningless as more research is funded by patrons interested only in profitable outcomes, not abstract new understanding (Ziman 1994).

Something like a perfect storm ensued because these changes happened to coincide with an inevitable change from seemingly unlimited expansion of scientific activity to an essentially zero-sum game in which the total resources available for research can no longer grow in the way they had for at least a couple of centuries.

Derek Price (1975, 1986), groundbreaking historian of science, had recognized that during the first two eras of modern science, every available quantitative measure of science had increased at an exponential rate, doubling about every 15 years since the 17th century: numbers of articles published, numbers of scientific journals, numbers of people who could be described as scientists. The ethos of scientific activity was consonant with that, an expectation that every promising avenue could be explored, every new result could find publication, every graduating potential researcher could find employment doing science. By the 20th century, insiders as well as outsiders were looking to numbers as gauges of success in science: numbers of articles published, numbers of students mentored, and especially in the third era of modern science numbers of grants collected and total amount of money raised.

Price also saw that science, broadly defined as "Research & Development" (R&D), had been gaining an increasing proportion of Gross Domestic Product (GDP). By roughly mid-20th century, that had grown in developed societies to about 2% to 3% of GDP, provided by private and corporate patrons as well as by government agencies. That 2% to 3% proportion of GDP could hardly continue to grow appreciably. Science had reached its limit of growth relative to the rest of society and would have to adjust to a relative steady-state—at the same time as research in most fields was becoming more and more sophisticated and expensive. Doing one thing would increasingly mean not doing other things; an early harbinger came in physics with the abandoning as too expensive of a Superconducting SuperCollider.

Under the new circumstances, the numbers of prospective researchers graduated should approximate the numbers needed to replace retiring researchers. New journals would rarely need to be established. Measures of success would need to be more qualitative than quantitative. The ethos of scientific activity that had worked well for two or three centuries would need to be replaced by a significantly different one.

It's a very tall order, to change the culture that had successfully sustained a working community for a long time (Bauer 2012b). The scientific community has to accommodate a change in ethos of similar magnitude and revolutionary sort as when Western culture changed from largely religion-based to largely secular, a transformation that isn't fully completed after more than a century. The cultural changes that have been needed in science for some decades now have barely been broached, and in some ways are being furiously resisted; researchers still try to publish as much as they can, for instance, and to train as many students as they can, and there is a continuing proliferation of new journals and new publishers made possible by the low cost of digital publication (Beall no date).

John Ziman (1994), distinguished physicist turned STS (science, technology, and society) scholar, had detailed the needed changes in ethos nearly two decades ago. The traditional norms, whose definitions are generally credited to Robert Merton, were that science was a universal public good characterized by disinterestedness and organized skepticism, to which Ziman added "originality." These norms, articulated toward the end of the second era of modern science, are appropriate to something like the first era of science: curious people seeking understanding for its own sake, skeptical of new claims since experience had shown them to be fallible; Ziman's addition of originality recognized the value of creativity and progress.

In the second era, personal careerism and institutional interests sometimes interfered with disinterestedness or with organized skepticism; but in the third era, the present-day era, the norms of scientists' behavior are unrecognizably different. Ziman pointed out that research is now largely a matter of authoritative professional experts hired to produce desired results, and the traditional universality of science is typically subordinate to local demands, often commercial ones.

What Ziman did not emphasize is that, under the new regime, the media and the public may be fed "scientific results" that are nowhere near as trustworthy as they used to be since they may be promulgated for bureaucratic, institutional, or profit-making purposes, and not because of any wish to disseminate genuine knowledge. Reports from the World Bank or agencies of the United Nations may be shockingly wrong from a purely scientific point of view (Bauer 2012a:Chapter 8).

Furthermore, the enormous expansion in numbers of researchers has inevitably diluted their average quality, and the possibility of wealth and political influence has also brought a difference in the personalities of those who self-recruit into research. Increasingly, science is being done not out of the inherent curiosity of disinterested knowledge-seekers but rather, as Gordon Tullock put it, out of *curiosity induced, pretended to, by offers of rewards* (Tullock 1966). The necessity for researchers to obtain grants means that what they do is controlled by patrons: Government agencies issue "Requests for proposals" to study a given topic, private foundations also manage to make clear what they are interested in supporting, and industrial offers of research funds rarely make any bones about what is to be studied.

The funding of research has been at something like a zero-sum steady-state for about half a century now, but numbers of would-be researchers and ambitions of researchers have not adjusted to that reality. The funding of research has become absurdly dysfunctional, with scientists spending more time in preparing grant proposals and related activities than in actual research: The success rate of grant applications to the National Institutes of Health is now 18%—more than 4 of every 5 grant applications fail—and the average biomedical researcher becomes a Principal Investigator for the first time at age 42 (Bauer 2012c).

These circumstances have brought cutthroat competition, dishonesty, and the result that public pronouncements from researchers and their patrons or employers cannot be taken as truthful (Bauer 2012d). What the media and the public and the policymakers hear about matters of science has become untrustworthy to a dangerous degree, on such hugely portentous matters as HIV/AIDS and global warming (Bauer 2012a) and the efficacy and safety of prescription drugs (Bauer 2012e), and much more.

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