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Scientific Controversies: Authentic and Contrived

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Review of David Harker (2015) *Creating Scientific Controversies: Uncertainty and Bias in Science and Society*, Cambridge University Press, Cambridge UK. ISBN: 9781107706903, 266 pages, price (PB): $28.99 (paperback)

1 Characteristics of Real Science and Real Scientific Controversy

Science is more of a journey than a destination. And, as to be expected of any journey taken by diverse travellers to an unexplored place, there may arise disagreements over how to get there, what is seen, and what it all means. If the place is relatively unimportant and the number of travellers few, the discord rarely spreads far. But if the destination is important, the travellers are many, and the outcome of getting there (or not) is consequential, disagreements can escalate into a broadly sweeping controversy with a lot at stake.

Some 25 years ago, I had the pleasure of contributing an invited paper (M P Silverman, 1992, "Raising Questions: Philosophical Significance of Controversy in Science", *Science & Education* **1**: 163-179) to the inaugural volume of this journal on the provocative topic of the significance of controversy in science. The article was based in part on a course I was teaching—*Role and Resolution of Controversy in Science*—since about 1987. One objective of this course was to counter what I perceived at the time to be an unhealthy tendency of the public to accept uncritically the daily reports in the news media of scientific advances. What made that tendency societally unhealthy in my view was (a) news reports of such advances were often premature, inaccurate, or totally false—a state of affairs effectively (and hilariously) highlighted in recent times by "philosopher-comedian" John Oliver (*Scientific Studies*: Last Week Tonight, HBO, 8 May 2016); and (b) the misunderstanding by the public that scientific knowledge was certain and unassailable. In the opening words of my 1992 article:

> Turn on the radio; hear the announcer report: "Scientists have found that…"; and you can be sure that one more seemingly unimpeachable fact has entered the mainstream of public belief.

Much has changed in the past quarter century. Today, with the veritable torrent of (mis)information coursing through networks of social media, as well as traditional journalism, the position of much of the public (at least in the US, if not also elsewhere) in regard to science has reversed itself. My concern today is that much of the public, deluged by contradictory assertions by presumed authorities and handicapped by a deteriorating public educational system that teaches science too late and badly, cannot distinguish real science from nonsense, and so distrusts any science as transient and unreliable. This reversal in public acceptance of valid scientific findings has accompanied, and indeed helped foster, the evolution of a very different kind of scientific controversy. These are pseudo-controversies manufactured by entities with vested interests having little to do with the discovery or elucidation of scientific principles or the objective examination of scientific phenomena. It is this dark side of scientific controversy that has been explored in trenchant practical detail by historians Naomi Oreskes and Erik Conway (*Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury, NY, 2010) and from an academic perspective by philosopher David Harker, whose book is the subject of this review.

To put into perspective what characterises a legitimate (in contrast to a contrived) scientific controversy, here is an illustration drawn from a very recent controversy in nuclear physics. The point at issue is the rate at which radioactive nuclei decay. To the layman it may seem that this topic is one of those relatively unimportant "destinations". However, that would be a seriously errant judgment. Radioactive elements are found all throughout the Earth, other planets, the asteroids, and the stars—and are freshly generated and dispersed into the cosmos when stars explode. They are the energy source for a molten Earth core and mantle, leading to volcanism, mobility of the continents, and other geologic processes. Their rates of decay provide the clocks for dating the age of the Solar System, the age of the Earth, the evolution of life on Earth, and for demonstrating (one of many lines of evidence) that the rising carbon concentration in the Earth's atmosphere is due primarily to human activity. In short, the rates at which radioactive nuclei decay affect *virtually all* natural sciences from astrophysics to zoology—and has societal implications insofar as it impacts cultural and religious beliefs.

In the approximately one hundred years following the discovery of radioactivity, physicists and chemists established through numerous experiments that the rate of decay of a radioactive sample is (a) a constant intrinsic to each nuclear species and (b) unaffected by the environment (e.g. temperature, pressure, light, etc.). Ernest Rutherford, whose investigations of radioactivity were seminal to the development of nuclear physics, referred to these properties as the "law of radioactive change". During the past 10 years, however, there have been challenges by diverse researchers who claimed that strange emissions from the Sun affect the decay rates of radioactive nuclei here on Earth, 150 million km from the Sun. As a participant drawn to the controversy by a broad involvement in the study of radioactive nuclei spanning nearly 20 years, I can say that, if valid, these observations were inexplicable within the framework of the laws of physics as they are currently understood (M P Silverman, 2014, *A Certain Uncertainty: Nature's Random Ways*, Cambridge University Press, Cambridge, 1984). The resolution of the controversy (at least for the present) occurred last year (M P Silverman, 2016, "Search for Anomalies in the Decay of Radioactivity Mn-54", *Europhysics Letters* **114**: 62001 1-6). A detailed examination of what would have been a particularly vulnerable nucleus (Manganese-54) if the Sun's influence on nuclear decay was real, showed no violation of the law of radioactive change, but rather exquisite agreement with predictions of standard nuclear physics. A highlighting of this work by the Institute of Physics was one communal recognition that the controversy was probably laid to rest (Hamish Johnston, *PhysicsWorld.com* 27 July 2016).

For purposes of comparison with what is to follow shortly concerning the problem of contrived controversies, it is of interest to ask these questions: (a) What created *this* controversy? (b) Why was it resolvable? (c) What could reopen it? The answers are reasonably straightforward. The controversy originated and evolved when various groups obtained results in disaccord with expectations based on previously well-established principles. The controversy was resolvable because a comprehensive, quantitative, theoretical analysis of carefully acquired data, that could have revealed such anomalies at a level *10 times lower* than what was claimed to have been observed, found no such effects at all. And last, to continue the controversy in view of the preceding outcome, those who would still claim that the established physical law is wrong, must first explain why their observations cannot be attributable to instrumental artifacts, and why these perceived anomalies were *not* seen by the more sensitive tests conducted recently.

Underlying the foregoing considerations is an essential component whose general importance and relevance to the subject of controversy in science I cannot emphasise too strongly: Physics is a *real* science. A *real* science is a tightly constrained intellectual structure. It requires a broadly applicable self-consistent base of laws/concepts/principles amenable to comprehensive, reproducible experimental verification by well-understood and reliable procedures and instrumentation. I will go further. Not only is physics a *real* science, but nothing that conflicts with the laws of physics or is conceptually disconnected from the laws of physics can be a real science. A discipline, for example, whose content is determined by a referendum of participants, and which can change according to the political tenor of the times, is not a science. A discipline whose fundamental principles are primarily qualitative, open to a wide spectrum of interpretation, and whose supporting phenomena are not amenable to decisive, reproducible, empirical recognition or confirmation, is not a science. In this regard, it is worth noting that the American Anthropological Association decided that anthropology is *not* a science (Nicholas Wade, "Anthropology a Science?", www.nytimes.com /2010/12/10/science/10anthropology.html). This is a point to keep in mind if one were to delve into the current controversy over the human status of Neanderthals.

The insistence that a discipline be like physics to be a science is not a rhetorical statement nor expression of occupational chauvinism. Rather, without a solid base of self-consistent empirically verified quantitatively testable principles, a purportedly scientific controversy can be little more than an argument over semantics and personal opinions and biases.

In *Creating Scientific Controversies* [*CSC*], the author devotes a lot of space—indeed more than one half the book—to discussing what he and other philosophers think science is. There is the usual nod to Karl Popper and falsifiability and to Thomas Kuhn and paradigm shifts; a lot of theorising about what theories are; and deliberations over reasoning and cognitive biases. Given that the author (a philosopher) has allocated about 150 pages to what science is, and that I (a physicist) have defined a *real* science in about two sentences, I suspect we would differ significantly as to which fields of study to admit into the "temple of science"[1].

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[1] The phrase is taken from Einstein's speech ("In the temple of science are many mansions…") before the German Physical Society in 1918, celebrating the 60th birthday of Max Planck. From my own reading of Einstein's papers, I infer that he would be very particular about what sciences occupied those "mansions".

2 Characteristics of a Contrived Controversy

The principal theme of *CSC*—how to detect created controversies—begins with an outline of utilitarian guidelines in Chapter 7. Although brief, and in some cases obvious, the discussion is not uninformative to readers who have had little experience in scientific matters. Foremost among the signposts is the question of motive—or, to put the matter more succinctly than the author: "Follow the money"[2]. As documented scrupulously by Oreskes and Conway in *Merchants of Doubt* [*MOD*], the controversies over the scientific evidence that tobacco smoke causes cancer, or that human activities involving the combustion of fossil fuels abet climate change, have far less to do with uncertainties in the underlying science than with financial losses and gains among instigators of the controversies. Money enters in two ways: (a) losses anticipated by companies who fear that scientific evidence against their product would lead to tighter regulations, and (b) gains to certain prominent individuals, in particular scientists, hired as advocates by the companies. It is category (b) that I regard as especially worrisome. An ordinary intelligent citizen does not need a PhD in physics to figure out that Philip Morris or Exxon Mobil would do everything possible to promote their products. However, when one of the foremost architects of a disingenuous programme to create uncertainty in the scientific process in order to paralyse remedial actions by government turns out to be a former president of the US National Academy of Sciences [NAS], how is a layman supposed to process *that*?

The strongest ethical bond that makes science as a collective activity even possible is trust. As a physicist, my initial reaction, when reading another scientist's published paper, is to believe that errors, if I find any, were unintentional. Regrettably, there are instances in science where an entire paper is created for purposes of deception. *MOD* recounts the egregious case involving former NAS president Fred Seitz who, together with another scientist, composed and circulated "a lengthy piece challenging mainstream climate science, formatted to look like a reprint from the *Proceedings of the National Academy of Sciences."* [*MOD*, p 244] I was one of the scientists to whom Seitz's "PNAS paper" was sent. When I realised that no such paper was actually published in PNAS, I knew from that moment on not to trust climate research by Seitz and his collaborators.

A second strategy advanced in *CSC* is to rely on scientific consensus. In other words, the layman must try to ascertain what a majority of scientists with the expertise to understand the issues in question believe is correct. This can be an informative way to proceed, but consensus is not simply a matter of numbers—even if the numbers quantify supposed experts. The problem arises acutely in the controversy over climate change. As a scientist who investigates climate change from the novel perspective of making *underground* temperature measurements (M P Silverman, 2014, "Statistical Analysis of Subsurface Diffusion of Solar Energy with Implications for Urban Heat Stress", *Journal of Modern Physics* **5**: 751-762) that complement the more familiar land–, sea–, and satellite–based methods, I have frequently made reference in invited lectures to the widely publicised 2013 study (J Cook et al., 2013, "Quantifying the consensus on anthropogenic global warming in the scientific literature", *Environ. Res. Lett.* **8**: 024024 1-7) claiming that about 97% of some 12,000 peer-reviewed scientific studies of climate

[2] The phrase was popularised by the docu-drama *All The President's Men*, and is thought to derive from the informant who revealed the Watergate Scandal.

change comprise a consensus that human activity drives global warming. A not atypical response by one or two people in the audience is to invoke statistics claiming large numbers (usually in the tens of thousands) of climate experts *deny* anthropogenic climate change. This does not necessarily mean they deny that climate is changing; rather, they believe such variability is "natural" and not induced or significantly affected by human activity.

How, then, is a layman to distinguish credible from unreliable experts? An obvious method—although by no means necessarily easy for a layman to implement—is to accept as credible experts those who publish original research in peer-reviewed journals devoted to their claimed field of expertise. According to *CSC* [p 193]: "In fact, the peer-reviewed literature quickly dispels with [*sic*] all the objections, and many more." Well…not quite. While potentially helpful, this strategy may fail for a very simple reason. The contrarians in a controversy, whose papers are almost always rejected by the establishment reviewers, can very well start their own journals or publish their own books, a reaction greatly facilitated by the rise of online open-access publishing. The controversy over "cold fusion", not discussed in *CSC*, provides one such example. First reported by two electrochemists in the late 1980s, the discussion and investigation of the phenomenon went "viral" (to use the jargon of the internet age). After close examination by nuclear physicists with appropriate instrumentation and expertise, the claim of chemical-assisted nuclear fusion in a room-temperature electrolytic cell was ultimately rejected by the physics community. Nevertheless, there is a diehard group of researchers who continue to publish their "discoveries" in a field that a consensus of physicists has dismissed as "pathological science". (See: https://en.wikipedia.org/wiki/Cold_fusion)

If the quantity of supporting experts and their weight of literary output are insufficient to establish whom to believe in a purportedly scientific controversy, what else remains? I offer this suggestion (with a cautionary reminder to follow): When faced with a scientific controversy involving a *real* science, it is a good bet to go with the conclusions of the principal professional organisation(s) that represent that science. If, for example, I did not have the expertise to read and understand the papers in *Nature*, *Science*, and numerous other internationally regarded periodicals in which climate research is published, I would seek the policy position of the American Physical Society [APS] (https://www.aps.org/policy/statements/07_1.cfm):

> The evidence is incontrovertible: Global warming is occurring….While there are factors driving the natural variability of climate…no known natural mechanisms have been proposed that explain all of the observed warming in the past century.

My reasoning would be: (a) Physics is a mature real science whose theoretical and experimental content can usually be trusted. (b) A major international organisation of physicists like the APS is unlikely to be beholden to special interests. (c) Therefore, the stated policy position of the APS is likely to be based on an unbiased evaluation of all pertinent available evidence. The validity of assumption (b), however, is critical to arriving at conclusion (c), a point the layman should always bear in mind when trying to determine which side of a scientific controversy is the more credible.

3 Certainty of Experts vs Wisdom of Crowds

Experts in a scientific controversy—no matter how many, how accomplished, or how much they may represent the consensus view of their professional organisations—can nevertheless be driven by considerations having less to do with contested principles of science than with a reward structure that is threatened by caution and regulation. In that case assumption (b) above may not be valid, and "Follow the money" is still the most effective way to probe whether arguments presented by participants in a scientific controversy are scientific or self-serving. This reminder is especially fitting in the controversy over genetically modified (GM) food.

As recounted in *MOD*, the tactic used by tobacco and oil companies was to deceive the public into believing that the underlying science was *too uncertain* to warrant regulation. In the case of GMO (O for organism) companies, however, the misrepresentation of the science is the reverse. They claim the science *is certain enough* to assure the public that consequences of widespread commercial exploitations of gene-manipulation technology are of negligibly low risk. Regrettably, the author of *CSC* has swallowed whole the industry's line when he concluded [*CSC* p 239]

> Not all GMOs are sufficiently risk free to put on the market, but this provides very poor justification for prohibiting their development and distribution more generally.

On the contrary, prevailing circumstances provide very adequate justification for constraining the development and general distribution of GMOs.

The promotional blurb on the back cover of *CSC* claims that, by "drawing on work in cognitive psychology, social epistemology, critical thinking, and philosophy of science," the author shows readers how better to understand scientific controversy. Nevertheless, it is clear to at least the scientist writing this review that notwithstanding input from various "…ologies" and philosophy of science, the author's critical thinking has disregarded the most important ethical principle underlying scientific research: the *precautionary principle*. That scientific research may entail risk is undeniable. If it does, scientists are free to expose *themselves* to risk if they so choose, but they have no recognised right that I know of to expose others unknowingly or against their will to the same risk. I am not a specialist in molecular genetics. I am, however, a trained chemist as well as atomic and nuclear physicist. I understand enough of the molecular biological literature to know that the artificial placement of genes in a genome and the prediction of the consequences of such placement, both for individuals and for ecosystems upon release of such organisms, are *not* well-enough understood to make reliable assurances of safety, especially in the long term.

Scientists who do research *responsibly* adhere to the precautionary principle. I draw again on physics to provide an instructive, if not dramatic, example. When, during the dire times of the Second World War, physicists of the Manhattan Project developed the "atom bomb"—i.e. bomb employing nuclear fission—*no open-air* test of the bomb was conducted until after careful theoretical analysis confirmed that detonation of such a bomb could not cause an atmospheric conflagration[3]. (See, for example, the interview of

[3] The fear by some of the physicists was that nuclear fission in the atmosphere might generate a sufficiently high local temperature to induce large-scale nuclear fusion of hydrogen.

former Manhattan Project director and Nobel Laureate in Physics Arthur Holly Compton by author Pearl S Buck in her essay: "The Bomb—The End of the World?", *American Weekly* (8 March 1959) pp 8-9, 14.) The probability of such an occurrence was believed to be very low—orders of magnitude lower, I would guess, than the occurrence of an ecological disaster from the release of GM products. Nevertheless, even amidst the extreme wartime pressures to save lives and secure national survival, the first open-air test of the atomic bomb was not carried out until the possibility of catastrophic widespread destruction was excluded with a very high degree of certainty. Compare *that* to the casual development and spread of GMOs and the insistence by GMO companies that GM foods not even be identifiable to the US public by labels.

Even in 1945 physicists could predict the interactions of quantum particles with greater certainty than biologists today can predict the activity of genes. And yet, rather than confining experiments on genome modifications to indoor laboratories, GMO researchers and producers have grown products in *open* fields, facilitating the wide release of non-natural genetic material into the environment. There is no dire situation that justifies such haste and irresponsibility. The reason often given, to prevent global starvation, is a red herring. Unrestricted dissemination of GM foods can never provide a stable food supply to an exponentially increasing human population. Indeed, any company truly concerned with global starvation would utilise its resources better to devise humane ways to reduce human fertility and provide inexpensive methods of contraception. Like controversies created by oil and tobacco companies, the motivation of GMO companies is really about money, a race for patents and profits. Only after *controlled* experimentation and a much more advanced predictive capacity of molecular genetics have established beyond reasonable doubt the long-term safety (both environmental and for human consumption) of GM products, should the dissemination (*with* labelling) of GMOs be permitted by regulatory agencies.

The controversies over climate change and GMOs, taken together, exhibit an interesting statistical asymmetry between the US public and the American Association for the Advancement of Science (AAAS) with an important philosophical lesson that the author of *CSC* has again missed. First the asymmetry: A recent publication by the PEW Research Center (Pew Research Center, January 29, 2015, "Public and Scientists' Views on Science and Society", p 37 http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/) reported that

(a) the statement that climate change is mostly due to human activity is supported by 87% of AAAS scientists and 50% of US adults;
(b) the statement that GM foods are safe to eat is supported by 88% of AAAS scientists and 37% of US adults.

Undoubtedly various opinions exist as to the cause of the large statistical discrepancy between the views held by the public and those held by AAAS scientists with respect to climate change and GM food safety. Here is mine.

There is strong, palpable, diverse, positive evidence *for* climate change. One sees it in physics (e.g. temperature measurements), in chemistry (e.g. atmospheric greenhouse gases), in geology (e.g. melting of glaciers and ice shelves), in biology (e.g. lengthening of growing seasons, temperature-driven relocations of animal and plant species, earlier emergence of insects) in numerous ways. That is why statement (a) enjoys the greater public support. In contrast, the best that GMO advocates might say is the double negative that there is *no* evidence to show that GM food is *not* safe. Such an optimal statement would in fact be untrue because evidence of problems with GM foods and the environmental dispersal of GMOs have been reported in scientific journals. (See, for example, (a) A Dona and I S Arvanitoyannis, 2009, "Health Risks of Genetically Modified Foods", *Critical Reviews in Food Science and Nutrition* **49** 164-175; (b) F Zawide, "Emerging Risks of Genetically Modified Foods", *Environmental Health Perspectives,* https://ehp.niehs.nih.gov/isee/2016-p3-252-3494/.) Moreover, as any "critical thinker" knows, such a double-negative statement provides no evidence that the statement "GM food *is* safe" is true. That may be why statement (b) is rejected by 63% of the US adult population (assuming the PEW report is accurate). The US public—and add to that the publics of other countries in Europe, Africa, and elsewhere where imports of US GM products are banned—do not need a course in formal logic to sense the distinction between a position supported by strong evidence and a position argued on the basis of lack of evidence. Given the perceived financial conflicts of interest, the public does not expect researchers and producers of GM products to look for, find, or divulge evidence of individual harm or ecological damage that would result in loss of profits. I am reminded of the well-known quote from Sinclair Lewis (https://en.wikiquote.org/wiki/Upton_Sinclair): "It is difficult to get a man to understand something, when his salary depends upon his not understanding it." Just replace "understand" by "find" and "salary" by "company".

Regarding the GMO controversy, the strong rejection by the public (of many nations) of the consensus of AAAS scientists (most of whom, I would surmise, are not experts in gene-manipulation technology) is *not*, in my opinion, another example of the societal trend, which I lamented at the start of this review, to reject science in general. Rather, it seems to me illustrative of a philosophically important state of affairs whereby the knowledge collectively demonstrated by a large number of *nonspecialist* individuals acting independently may at times be *more reliable* than the opinions expressed by experts. Such a situation has been described anecdotally in *The Wisdom of Crowds* by business columnist James Surowiecki (Anchor, New York, 2004) and examined experimentally and quantitatively by me in "The Guesses of Groups" in my book *A Certain Uncertainty*. There is, in fact, a rigorous mathematical relation concerning the guesses of groups that anyone concerned with the role of experts in scientific controversies might find philosophically thought-provoking.

The content of the relation, known as the "jury theorem", can be expressed in a narrative form pertinent to the GMO controversy as follows. Suppose a group of N non-scientifically trained individuals are asked the question: "Are GM foods safe to eat?" This is a question with a binary outcome, either "yes" (to be accorded +1) or "no" (to be accorded –1). The members of the group are not specialists in molecular genetics, but neither are they necessarily totally ignorant; they can be assumed to read newspapers, listen to radio and television, talk with neighbours or colleagues at work. In short, they are receptive to the flow of general information, however uncertain. If, in response to the question, each member really had no idea of the correct answer and guessed randomly—i.e. with a probability of ½ or 50% for each outcome—the expected mean response of the group would be 0. In such a case, the group response would provide no information; there would be no "wisdom" in this crowd.

Now suppose, however, that each group member understood just enough about the question that the probability of his/her giving the correct answer was a very tiny amount ϵ (read: epsilon) better than ½ . It might surprise the reader to learn that, despite the great (but not total) uncertainty of each individual response, the *mean* response of the group will provide the *correct* answer to the question with a probability approaching *virtual certainty*, i.e. 100%, as the number N of respondents gets larger and larger. For example, if the probability that a member makes a correct reply is just 51% (i.e. ϵ = 0.01), it takes fewer than N = 14000 people for the group mean to provide the correct answer with a probability of 99%. In the GMO controversy, the group size (various national publics) is in the many millions, compared with the much smaller number of GMO "experts". The resounding "No" to the question might well represent the wisdom of the crowd. It is to be understood, of course, that the jury theorem is just a mathematical theorem; it follows rigorously from given assumptions. Whether the assumptions pertain in some specific societal context, is a question readers must decide for themselves.

4 Concluding Remarks

In my 1992 article in this journal, I wrote of controversies over scientific principles with ramifications primarily confined to the scientific communities involved. Whether continents moved or not, whether an asteroid caused mass extinctions 65 million years ago or not, whether matter was made of discrete atoms or not—the outcomes to these and other controversies hotly debated by participating scientists had little, if any, adverse effect on the general public. However, the controversies such as discussed in *MOD* and *CSC*, where financial self-interest and political ideology play a large role, *do* impact public health, education, and safety in ways both immediate and long-term. In these controversies, the methodology of real science—work carefully, work responsibly, acquire evidence thoroughly, and interpret it consistently—is disregarded so as to prevent or avoid regulatory action on behalf of the public. It is very important in such cases of artificially contrived controversies (like climate change) or of rashly denied controversies (like GM food) for the public to understand as much as possible both the relevant scientific issues and the strategies employed for deception.

From its style and content, *Creating Scientific Controversies* is primarily a book for academics, more appropriate perhaps as a one-semester lower-division philosophy textbook than for reading by the general public (in contrast to *Merchants of Doubt*) or by specialists with a professional philosophical or historical interest in controversial scientific issues. Structurally, *CSC* is divided into three parts concerned respectively with the nature of science, the nature of argument, and the recognition of artificial controversies. Considerably more than one half of this short book provided, in my opinion, little information or insight beyond what readers interested in the philosophy of science could obtain from other more discerning works. In part three, which was the focal point of the book to judge from the preface and cover description, the author examined controversies relating to anthropogenic climate change, intelligent design, GMOs, AIDS, and autism. From the fact that five controversies together comprising the most important content of the book occupied fewer than 70 out of 260 pages, the reader might well surmise that the examinations were somewhat superficial.

Nevertheless, although there are opinions expressed by the author in *CSC* that I do not agree with, and issues that I believe the author should have thought through more carefully, the use of the book by a scientifically well-informed course instructor could potentially help students recognise deceptive pseudo-scientific arguments when they encounter them. I hope this will be the case, for I can think of few things more destructive to the long-term stability of a nation than the disregard of sound science in the implementation of public policy.

Mark P Silverman is George A Jarvis Professor of Physics at Trinity College. He conducts research in nuclear physics, statistical physics, and climate change. His most recent books are *A Certain Uncertainty: Nature's Random Ways* (2014) and *And Yet It Moves: Strange Systems and Subtle Questions in Physics* 2nd Ed (2015), both published by Cambridge University Press. Further information is available at www.mpsilverman.com and www.amazon.com/e/B001HMOC5O.