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INTRODUCTION

Stephen Macedo

Science confronts a public crisis of trust. From the Oval Office in Washington and on news media around the world, the scientific consensus on climate change, the effectiveness of vaccines, and other important matters are routinely challenged and misrepresented. Doubts about science are sown by tobacco companies, the fossil fuels industry, free market think tanks, and other powerful organizations with economic interests and ideological commitments that run counter to scientific findings.[1]

Yet we know that scientists sometimes make mistakes, and that particular scientific findings now widely believed will turn out to be wrong. So why, when, and to what extent should we trust science?

These questions could hardly be more timely or important. As extreme weather events become more common, sea levels rise, and climate-induced migrations flow across borders, nations around the world confront mounting costs and humanitarian crises. Yet so-called experts do not always agree. A local television meteorologist may report that it is merely "some speculation from scientists" that global warming is contributing to extreme weather events, such as the "polar vortex" that hit the Upper Midwest and Northeast of the United States in late January 2019. On another channel, a scientist at a well-regarded research center insists that "we know why . . . . It's all because of human activities increasing the greenhouse gases in the atmosphere that trap a lot more heat down by the surface."[2]

As vitally important as climate science is to the future of humanity, that is only the tip of the iceberg. Are vaccines effective? Does the birth control pill cause depression? Is flossing good for your teeth? On these questions and so many others, scientists may agree yet doubts circulate. Who should we believe and why?

In *Why Trust Science?* Professor Naomi Oreskes provides clear and compelling answers to the questions of when and why scientific findings are reliable. She explains the basis for trust in science in highly readable prose, and illustrates her argument with vivid examples of science working as it should, and as it should not, on matters central to our lives. Readers will find here a vigorous defense of the trustworthiness of scientific consensus based not on any particular method or on the qualities of scientists, but on science's character as a collective enterprise.

A distinguished scientist and historian of science, Professor Naomi Oreskes has also emerged as one of the world's clearest and most influential voices on the role of science in society and the reality of man-made climate change.

This book grows out of the Princeton University Tanner Lectures on Human Values delivered by Professor Oreskes in late November 2016. On that occasion, four distinguished commentators, representing a variety of fields and perspectives, responded to Professor Oreskes's two lectures. This book contains the lectures, the four commentaries, and an extended reply by Professor Oreskes, all revised and expanded.[3]

Readers will find in the chapters that follow an overview of the leading philosophical debates concerning the nature of scientific understanding, scientific method, and the role of scientific communities. Oreskes defends the role of values in science, discusses the relationship between science and religion, and sets out her own credo as a scientist and defender of science. Our four commentators offer their perspectives on these issues, and

Oreskes closes with comments on the plight and promise of science in our time. A more detailed overview follows.

Why should we trust science? Professor Oreskes's initial answer is crisp and clear: scientific knowledge is "fundamentally consensual" and understanding science properly can help us "address the current crisis of trust."

Chapter 1 develops the problem of trust against the background of an account of philosophical debates about the nature of science and scientific method. In the eighteenth and nineteenth centuries, and before, trust often resided in "great men": science was regarded as trustworthy insofar as the scientists were. Gradually the alternative idea was advanced that careful observation and adherence to scientific methods were the bases of progress. Oreskes also surveys the varieties of empiricism that dominated philosophies of science in the first half of the twentieth century, and the challenge advanced by Karl Popper, who regarded the essence of science not as verification but openness to falsifiability, or "fallibilism."

Most important, on Oreskes's account, was the emergence of the idea of science as a collective enterprise. The "sociological view" of science was first advanced by Ludwik Fleck, in the 1930s, who held that the "truly isolated investigator is impossible . . . . Thinking is a collective activity." Oreskes endorses the idea that scientific progress depends on the collective institutions and practices of science, "such as peer-reviewed journals, and scientific societies through which scientists share data, grapple with criticisms, and adjust their views."

The central importance of scientific communities, their worldviews, and practices is the core of Professor Oreskes's view. When we focus on what scientists do, we find a variety of methods pursued with creativity and flexibility. She explores debates surrounding philosophies of science in the work of

Pierre Duhem, W.V.O. Quine, Thomas Kuhn, and others. She describes the social epistemology developed by feminist philosophers and historians of science, including the contributions of Helen Longino, who helped establish the idea that, as Oreskes puts it, "objectivity is maximized . . . when the community is sufficiently diverse that a broad range of views can be developed, heard and appropriately considered." Or, as she says later, "In Diversity There Is Epistemic Strength."

Professor Oreskes thus defends the "social turn" in our understanding of science while also describing the sense of threat that greeted the idea that scientific realities are socially constructed. Remember the obvious, she advises: scientists are engaged in sustained and careful study of the natural world. The empirical dimension is critical, but scientific expertise is also communally organized: objectivity arises from social practices of criticism and correction, most successfully in scientific communities that are diverse, "non-defensive," and self-critical.

We are warranted in placing "informed trust" in the "critically achieved consensus of the scientific community," argues Professor Oreskes. Individual scientists make mistakes, especially when "they stray outside their domains of expertise," and Oreskes provides some glaring examples. And science has no monopoly on insight into the natural world. Nevertheless, the practices and procedures of scientific communities increase the odds that scientific consensus is reliable.

We should trust the conclusions of the scientific community rather than the petroleum industry when it comes to climate change because the petroleum industry has a conflict of interest. It aims to profit by finding, developing, and selling petroleum resources, and it generally does that well. But those aims conflict with the pursuit of truth regarding climate change. As a general rule, we should be skeptical of the scientific claims of

organizations guided by the profit motive or ones precommitted to an ideological point of view. Good science presupposes "that participants are interested in learning and have a shared interest in truth. It assumes that the participants do not have a major, intellectually compromising conflict of interest."

And yet, scientists sometimes get things wrong, so, Professor Oreskes asks in chapter 2, how do we know that they are not wrong now? If our knowledge is perishable and incomplete, how "can we warrant relying on it to make decisions, particularly when the issues at stake are often socially or politically sensitive, economically consequential, and deeply personal?"

To investigate these important questions, Oreskes examines five examples of science gone awry: what do these examples have in common, and what can we learn from them?

The first is the "Limited Energy Theory," popular in the late nineteenth century, which held that women should not participate in higher education, on the grounds that energy expended on studying would adversely affect their fertility. The withering criticism to which this theory was subjected by Dr. Mary Putnam Jacobi had, as the reader will learn, little immediate effect on male scientists.

Another example is the rejection of continental drift. Many American scientists in particular were hostile to the theory, which they argued was based on flawed "European" methodology.

A third example is eugenics, which is most closely associated nowadays with the Nazis, but which had a wide variety of advocates and practitioners in the United States and other Western countries. Oreskes provides a fascinating account of the complex politics of eugenics in the United States and Europe.

Oreskes's fourth example is hormonal birth control and the evidence that it often causes depression. Many women experience the onset of depression after beginning certain birth

control formulas, and Professor Oreskes relates her own experience. Yet medical science long discounted as unreliable the self-reports of millions of women.

Oreskes's final case is dental floss and the flurry of news reports asserting that there is no hard evidence that flossing is effective. Probing deeper, Oreskes argues that the lack of randomized trials to test for the effects of flossing hardly amounts to a lack of evidence.

From these diverse cases, Professor Oreskes draws some general lessons, which she groups under the themes of consensus, method, evidence, values, and humility.

The importance of hard-won scientific consensus, as an indicator of trustworthiness, holds up very well across the five cases. Oreskes also provides a fascinating discussion of the difficult question—*vital to the role of science in a democracy*—of non-expert opinion and how scientists should respond to it. Non-scientists—from nurses and midwives to farmers and fishermen—often have information or evidence relevant to science-based decisions. Patients have vital information about their symptoms. Yet, "Just because someone is close to an issue does not mean he or she understands it; conventional notions of objectivity assume distance for just this reason." The cases help illustrate and sharpen the distinction between reliable scientific authority and the interest and ideology-based pseudoscientific dissent we witness surrounding climate change, evolution, and vaccines.

Drawing from her five examples, Oreskes warns of the "methodological fetishism" that leads some scientists to dismiss valuable forms of evidence because they do not fit their methodological precommitments. Evidence comes in a variety of forms.

Values inevitably play a role in shaping science, Oreskes insists. In looking back on eugenics, scientists may say that science was distorted by values, but values were also central to opposing eugenics and also the Limited Energy Theory. Because values play an inevitable role, diverse scientific communities are more likely to be able to detect unexamined assumptions, blind spots, and inherited biases: "A community with diverse values is more likely to identify and challenge prejudicial beliefs embedded in, or masquerading as, scientific theory." She also allows that there can be legitimate non-scientific objections—including ones based on religious or moral values—to policies that are justified partly by science but also by particular value claims.

And humility is important. Diverse scientific communities can correct for the blind spots of arrogant scientists, but the history of science counsels humility: the greatest scientists (and, one might add, philosophers) have sometimes become fetishists about method, drawn false conclusions from evidence, and fallen prey to the prejudices and biases of their times.[4] Even the best of scientists should remember that a complete grasp of the whole truth is yet far beyond us.

So, when should we trust science? In concluding chapter 2, Oreskes summarizes: when an expert consensus emerges in a scientific community that is diverse and characterized by ample opportunities for peer review and openness to criticism. Of course, any particular scientific claim may be false, so she reminds us of Pascal's Wager: consider the stakes of error. It may not be certain that flossing will be good for your teeth, but it is cheap and easy. It may not be certain that human actions and policy changes can reverse the dire effects of climate change, but consider the calamities that await our children and grandchildren if we now ignore scientific predictions that are correct.

In a coda to her two lectures, Professor Oreskes returns to the issue of scientists' values. In theory, scientific findings are one thing and the question of what if anything to do about them is another. So one might suppose that whereas the practical question of "what is to be done" inevitably implicates values, the question of what scientific evidence shows need not. Ideally, science should be able to leave political and moral controversies to others.

Things are not so neat and simple, however. Professor Oreskes observes that people equate science with what they think are its implications. Fundamentalist and evangelical Christians from Williams Jennings Bryan to Rick Santorum have worried that evolutionary accounts of human origins undermine human dignity and morality, by making humans, in Santorum's words, "mistakes of nature." Skepticism about climate science, on the other hand, is fed by the suspicion that environmentalists seek to undermine the "American way of life": big cars, motorboats, and high consumption.

In the face of such suspicions it is profoundly mistaken, argues Oreskes, for scientists to retreat to value neutrality. In the face of the question: why should ordinary people trust science and take it seriously? It cannot be effective to reply that scientists lack values! That is precisely what worries people. Moreover, it is perfectly obvious that scientists do have values—everyone does—and that those values influence their work. To hide your values, Oreskes observes, is to hide your humanity.

So, scientists should be honest about their values. Many people will share those values, and on that basis trust can be built. The Creation revered by Christians is the biodiversity cherished by Scientists, says Oreskes, and the evidence is overwhelming that these are now gravely threatened.

In concluding, Professor Oreskes offers an eloquent summary of her own credo: her guiding values as a scientist and environmentalist. "If we fail to act on our scientific knowledge and it turns out to be right, people will suffer and the world will be diminished."

In the next section of this volume, four distinguished commentators expand upon, elaborate, or criticize central features of Professor Oreskes's lectures.

Professor Susan Lindee is the Janice and Julian Bers Professor of History and Sociology of Science at the University of Pennsylvania, where she also holds a variety of administrative posts. Lindee argues that in responding to scientific skepticism we should draw attention to the science that we encounter and rely upon constantly in our everyday lives. We should "work our way up, from the toaster," to the frozen peas, the smart phones, and the other miracles of modern science and technology that enhance our lives.

Of course, science's contributions are not always so positive. Professor Lindee reminds us of the twentieth century's brutal history of technology-enhanced warfare. She suggests that historians of science have sought to distance pure science from technological applications because of technology's profoundly mixed legacy. Atomic scientists sought to maintain their moral purity by attributing the design of the bomb to mere engineers.

Marc Lange is the Theda Perdue Distinguished Professor and department chair in philosophy at the University of North Carolina, where he specializes in the philosophy of science. Lange notes that the question of why we should trust science seems to lead into a vicious circularity: isn't peer review just experts vouching for other experts?

Professor Lange suggests that asking for an external vindication of science as a whole may be unreasonable: science is

self-correcting in that it can subject any particular scientific claim to critical scrutiny, "But science *cannot* reasonably be expected to put *all* its theories in jeopardy *at once*."

Lange also raises the issue of what Thomas Kuhn described as revolutionary challenges to entire worldviews or paradigms, in which methods and theories "interpenetrate." Using the example of Galileo, he suggests that there is typically "sparse common ground" across paradigm shifts, and scientists can use it to build an argument for one of the rival theories against the others. Lange closes by urging philosophers and others to stop overemphasizing "incommensurability and under-determination" and to devote more attention to positive accounts "of the logic underlying scientific reasoning."

Ottmar Edenhofer is deputy director and chief economist at the Potsdam Institute for Climate Impact Research, as well as a professor at the Technical University Berlin. He offered a comment in Princeton, and is joined here by Martin Kowarsch, who is head of the working group on Scientific Assessments, Ethics, and Public Policy at the Mercator Research Institute. They begin by suggesting that the Trump administration accepts much climate science but opposes ambitious climate change mitigation efforts, partly because it heavily discounts the costs of climate change outside the United States. Thus, scientific consensus does not equal policy consensus, and so they ask how Oreskes's account of trust in science may need to be extended or amended for science-based policy assessments. They advise experimentation aimed at incremental learning about alternative policy pathways, and argue that costly mistakes have been made due to insufficient awareness of the complexity of the policy alternatives.

Edenhoffer and Kowarsch agree with Oreskes that value neutrality is impossible. They build on Deweyan pragmatism to

propose that all socially important values—"equality, liberty, purity, nationalism, etc."—should be included in policy assessments: this may open the door to new and creative proposals.

Finally, Jon Krosnick offers some thoughts, inspired by Professor Oreskes's lectures, on the current state and future of science. Krosnick is Frederick O. Glover Professor in Humanities and Social Sciences and professor of communication, political science, and psychology at Stanford University, where he also directs the Political Psychology Research Group.

Professor Krosnick describes a number of famous (now infamous) and influential scientific findings—in biomedicine, psychology, and elsewhere—whose results scientists have been unable to replicate. In some cases the data were fabricated, in other cases investigators admitted to repeating an experiment until the desired result was produced.

Flawed research results partly from faulty methods, argues Krosnick, and also the desire for career advancement. Academic departments and professions place a premium on publishing surprising and counterintuitive findings. Is it any wonder that many of these prove unfounded on closer inspection? Journals rarely publish negative results so refutation of bad research is slowed. He insists that scientists must face up to the problems and address the counterproductive motivations that are now rampant.

In her wide-ranging *Reply to Critics*, Professor Oreskes deepens and enriches her argument.

She praises Susan Lindee for her brilliant historical account of scientists' attempts to distance themselves from the technological applications of their work, yet expresses doubt that becoming clearer-eyed about the science embodied in frozen peas and smart phones will have much effect on people's attitudes to climate science. Americans do not reject science in general but

rather particular "scientific claims and conclusions that clash with their economic interests or cherished beliefs."

In response to Marc Lange, Professor Oreskes expresses doubt that trust in scientific experts is viciously circular. The "social markers of expertise are evident to non-experts," she argues, and it is relatively easy to figure out that climate science deniers are non-experts and that the American Enterprise Institute is pre-committed to certain policy outcomes. Expert scientific consensus does tend to be reliable.

In response to Edenhofer and Kowarsch, Professor Oreskes agrees that more work is needed on how to move from science to policy. Yet she insists that when powerful actors to seek to undermine public trust in the science associated with progressive climate policy, the *roots* of their skepticism are typically not in distrust of science but rather in economic self-interest and ideological commitments. Oreskes reiterates that if scientists are honest about their values, as she recommends, then they will often find that there is considerable overlap on the values behind climate policy disagreements, and this may help us build greater trust.

Professor Oreskes turns, finally, to Jon Krosnick's assertion that science faces a "replication crisis." While allowing that there have been notable examples, often involving the misuse of statistics, she points out that the rate of retractions—that is, retractions as a percentage of published articles—is tiny: perhaps less than .01%. If the rate has risen, that may reflect a salutary increase in critical scrutiny of findings, rather than a higher incidence of faulty research. Or it may reflect unwarranted media coverage of flashy single-paper results in psychology and biomedicine.

Oreskes pushes back against Krosnick's wider suggestions about a crisis in science. His examples furnish no evidence that

fraud is commoner in science than elsewhere. Moreover, in some of Krosnick's examples fraud was discovered and punished expeditiously. Refutation and retraction are paths to progress. She reminds us that her argument has been that we should trust scientific *consensus*, not the single studies to which Krosnick draws attention, and reiterates that motivated industry funding of research is a serious problem.

In an afterword penned just before this book went to press, Professor Oreskes notes that the problem of trust in science—and in news and information more generally—has exploded since she delivered the Princeton Tanner Lectures in the fall of 2016. Many more Americans believe in the reality of climate change than once did, but America is led by a science and fact-denying chief executive who is reversing hard-won progress on climate policy. It remains the case that much doubt about consensus findings in science is manufactured by those with financial or ideological interests in derailing science-based policies, just as she and Erik Conway argued in *Merchants of Doubt*.

Professor Oreskes closes by reiterating that science merits our trust when scientific results achieve consensus among the expert members of diverse and self-critical scientific communities. And she offers a final example—controversies over the use of sunscreen—to illustrate this book's core theme.

Like all excellent books, this one addresses many questions and also raises some. While Professor Oreskes argues that progress and reliability in science depends more on the qualities of scientific communities than on the character of individual scientists, she also argues that scientists' inevitably have values and that they should be honest about them. Do not well-working scientific communities depend on the predominance of good values—of intellectual honesty and truth seeking—among scientists? And if diversity is important in scientific communities,

of what kinds? The inclusion of women and members of racial, ethnic, religious, and other minority populations has obviously been very good for all of the sciences, and scholarship generally. Are there social sciences (and perhaps other fields of inquiry) in which greater ideological diversity would be helpful?

Readers will come away from this volume armed with a far better understanding of the vitally important enterprise of modern science and the reasons why we should trust scientific consensus. All who care about the future of humanity on this fragile earth should hope that this timely and important book gains a wide audience, before it is too late.

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