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Taking distrust of science seriously

To overcome public distrust in science, scientists need to stop pretending that there is a scientific consensus on controversial issues when there is not

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We live at a time of unprecedented scientific and technological progress, and, yet, there is widespread confusion and concern about the impacts of scientific and technological advances on human health and the environment. Among the highly contested issues are genetically modified (GM) crops, vaccines, endocrine-disrupting chemicals, pesticides, cell phone electromagnetic emissions, salt intake, obesity, smokeless tobacco, electronic cigarettes, particulate air pollution, hydraulic fracturing ("fracking") to extract natural gas, and climate change. It is fair to say that, on many issues, this confusion is not limited to the lay public but also affects government agencies, professional organizations, and the scientific community. One of the dangers of such widespread and persisting confusion about these issues is that it contributes to an increasing public distrust of science, since scientists are seemingly incapable of resolving these controversies.

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During the past 5–10 years, much has been written about "distrust of science" and its root causes, with journalists, scientists, physicians, psychologists, and sociologists all contributing to this discussion. While this work contains valuable insights and perspectives on the problem, many authors make sweeping generalizations and lump together disparate questions that involve different methodologies and types of evidence. Reading this literature, it is striking how many commentators conflate controversies about vaccines and autism, GM crops, pesticides, and climate change, as if these were all instances of a single phenomenon. The failure to properly distinguish between these different controversies—and the science pertaining to them—has encouraged a tendency to emphasize the "scientific consensus", and to assert that "in the end, science, if not individual scientists, tend to get it right".

It is also clear from this literature that many diverse factors are correlated with, and may contribute to, distrust of science. These include religious belief, level of education, political affiliation, socioeconomic status, psychological orientation, and so on. However, the conspicuous presence of so many controversies, some of which have persisted for many years, undoubtedly adds to the widely decried distrust of science. If we want to communicate effectively with the public about high-profile, evolving scientific issues, we need to start by taking a closer look at the differences between them.

Not all controversies are equal

Not all controversies involving scientific questions fit the same pattern. On some issues, such as vaccines and GM crops, we have solid experimental and epidemiological data based on rigorous research, which enables us to make strong inferences about causality and the rate of adverse effects. On other issues, such as exposure to endocrine-disrupting chemicals or pesticides, we depend on observational studies in wildlife and humans, mechanistic studies in the laboratory, and animal experiments, where confounding factors and biases and the questionable relevance of animal models to human physiology make it difficult to draw strong causal inferences.

A second factor influencing the credibility and robustness of research results is the ability to accurately measure the exposure in question. When it comes to vaccines or to GM crops, scientists can precisely specify the dose and the characteristics of the exposure. When it comes to pesticides or other chemicals in the environment, exposures are at an extremely low level and detecting reliable effects in the presence of much more potent factors, such as smoking, obesity, sedentary lifestyle, diet, substance abuse, and so on, becomes a challenge.

> *"The controversy surrounding vaccines is purely one involving a widespread misunderstanding of the science by a vocal minority"*

Third, we have to recognize that not all areas of research are equal. For example, studies that link genetics and exposure to certain infectious agents to disease are much more robust than studies linking environmental exposures or dietary factors to disease [1]. Finally, there are well-recognized methodological and editorial biases influencing what gets published and what gets cited in the scientific literature.

In what follows, I briefly examine three of the most commonly cited controversies in

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order to identify factors that are invariant across different controversies—certain aspects get sensationalized, while others get less attention—and those that are specific to a particular issue and need to be acknowledged in all their specificity.

Vaccines

The introduction of vaccines to prevent common childhood diseases starting in the 1950s is a triumph of 20th century medicine and public health. Vaccines were well accepted by the public up until the publication of the infamous paper by Andrew Wakefield in the *Lancet* in 1998 that linked the combined measles, mumps, and rubella (MMR) vaccine to the occurrence of leaking intestines and autism in a dozen children. The results, which were later shown to be fraudulent, were latched on to by activists concerned about the apparently increasing prevalence of autism. Activist-stoked fears of the purported adverse effects of the MMR vaccine caused a drop in vaccination rates and outbreaks of measles in the UK, the USA, Germany, and other developed countries.

> *"... more than twenty years later, strong evidence is lacking, and the hypothesis remains, in the words of one observer, 'a cause without a disease'"*

There is no controversy within the scientific community about a link between vaccines and autism or the safety of vaccines generally [2]. The public debate is the product of the coincidence of two phenomena: the far-reaching effects of the Wakefield paper, especially on parents of children with autism, at a time when autism became a focus of societal attention in the late 1990s and early 2000s; and the fact that the younger generations had never known the reality of childhood diseases that were virtually eradicated by vaccines. The controversy surrounding vaccines is purely one involving a widespread misunderstanding of the science by a vocal minority. But this story also shows what a profound effect the publication of an alarming, if erroneous, scientific paper can have when it appears in a prestigious journal and galvanizes the public.

Endocrine-disrupting chemicals in the environment

During the 1980s and 1990s, biologists became aware that exposure to hormone-mimicking chemicals could affect reproduction in wildlife. Detection of—usually very low levels of—potentially endocrine-active chemicals in foods and consumer products led to the formulation of the "environmental estrogen hypothesis", which posits that exposure to hormonally active compounds might contribute to disorders ranging from birth defects of the reproductive system to cancer. In 1993, Richard Sharpe and Niels Skakkebaek, specialists in male reproductive development, published a hypothesis piece in the *Lancet* titled "Are oestrogens involved in falling sperm counts and disorders of the male reproductive tract?" They answered their own question as follows, "This possibility is not unlikely, given the view that humans now live in an environment that can be viewed as a virtual sea of oestrogens". Owing to the *Lancet* paper, along with growing interest in environmental estrogens among some groups in the USA and increasing attention from the media and regulators, the hypothesis prompted research that attempted to link exposure to chemicals in the environment to pathology in humans and test animals. However, more than twenty years later, strong evidence is lacking, and the hypothesis remains, in the words of one observer, "a cause without a disease" [3]. How is this to be explained?

Although potentially endocrine-active chemicals can be detected virtually everywhere in the environment and in human tissues, for most people, exposure to pesticides and industrial chemicals through food and water involves trace amounts. While these chemicals may be detectable in blood or urine using highly sensitive analytical techniques, there is little evidence that they have biological effects at these very low levels. Not surprisingly, many of the associations that have been reported with human disease have not been reproducible.

Second, those who believe that endocrine disruption is a serious public health problem tend to ignore the fact that pesticides currently in use have been tested for toxicity and have a generous safety margin. Third, much of the research that has attempted to link exposure to endocrine-disrupting chemicals to human health effects ignores the many real-world exposures that have documented health effects and that are likely to dwarf any effects of endocrine disruptors. These include the increasing consumption of calorie-dense foods and its attendant effects on the prevalence of obesity and diabetes; medications; endogenous hormone production; and physical activity/sedentary behavior.

> *"The opposed camps differ in their interpretation of the scientific studies, the biological mechanisms involved, and the philosophy regarding regulation"*

At present, a fierce battle is raging on both sides of the Atlantic between scientists who are convinced that exposure to endocrine-disrupting chemicals represents a serious threat to the population and that new regulations are needed to address the problem [4] and scientists and health and regulatory agencies that, after reviewing the same body of literature, find no evidence of a problem and stress the adverse consequences of poorly justified regulations [5]. The opposed camps differ in their interpretation of the scientific studies, the biological mechanisms involved, and the philosophy regarding regulation. Unlike the controversy surrounding the safety of vaccines, which is taking place outside the scientific community, here we have a dispute that pits two camps within the scientific community against each other. The two sides are not necessarily equally persuasive to an impartial observer, and it is significant that Richard Sharpe, one of the originators of the environmental estrogen hypothesis, has stepped back from it [6]. Nevertheless, it is much harder to explain to the public what is going on, especially when the side that claims that there is an imminent danger and which claims to be fighting against pro-industry scientists inherently has more credibility with the public.

Climate change

In terms of its sheer scope, complexity, and implications for future generations, the issue of climate change dwarfs any other scientific questions of the kind mentioned above.

Moreover, the formidable scope of the problem makes it harder to grasp—both for scientists and non-scientists alike—and invites over-simplifications, a preferential focus on certain trends/facts at the expense of others, and other cognitive pitfalls.

"In the public debate, a question of staggering complexity has been reduced to a binary choice between two extremes: either climate change is a "hoax" or is an unquestionable certainty"

We are told that there is an overwhelming "consensus" among scientists that climate change is man-made and is likely to have catastrophic effects over the coming century (https://climate.nasa.gov/scientific-consensus/). In the public debate, a question of staggering complexity has been reduced to a binary choice between two extremes: Either climate change is a "hoax" or is an unquestionable certainty. Effectively, the claim of a 97% consensus is political and is directed at the lay public, who may know little about the science but who, understandably, react to frightening scenarios involving impending catastrophe. In this situation, scientists who try to present a more nuanced view of the problem have paid a heavy price and are routinely pilloried as "climate change deniers".

The debate about climate change is not comparable to those about the safety of vaccines or GM crops. We do not have controlled studies that allow us to isolate the effects of an intervention. What we have are measurements of recent global temperature and atmospheric CO_2 levels, and the principle of the "greenhouse effect" that has been known for over a hundred years. According to Judith Curry, a climatologist and former chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology, there is broad agreement among scientists on three points: Global temperatures have increased since 1880; humans are contributing to a rise in atmospheric CO_2 concentrations; and CO_2 emits and absorbs infrared radiation [7]. However, she finds that there is considerable debate within the scientific community on the following crucial issues: whether the warming since 1950 has been dominated by human causes; how much the planet will warm in the 21st century and whether the warming is "dangerous"; and whether radically reducing CO_2 emissions will improve climate and well-being. As Curry writes, "Leveraged by the consensus on the three points above that are not disputed, the climate 'consensus' is being sold as applying to all of the above, even the issues for which there remains considerable debate" [7]. In other words, the "consensus" dangerously conflates what is known with what is crucial but not known, giving the public the message that the issue is closed. Curry cites a blog post by D. Ryan Brumberg and Matthew Brumberg "The Paradox of Consensus" that explains the alleged overwhelming consensus on climate change: "Consensus, in and of itself, is not necessarily a bad thing. The more easily testable and verifiable a theory, the less debate we would expect. But as a question becomes more complex and less testable, we would expect an increasing level of disagreement and a lessening of the consensus. On such topics, independent minds can—and should—differ" (Fig 1; https://iconoclastpapers.wordpress.com/2013/05/21/the-paradox-of-consensus/).

Curry is not the only climate scientist to criticize the drastic over-simplification of the climate change issue—other important voices are Richard Muller, Roger Pielke Sr., Steven Koonin, Richard Lindzen, and Bjørn Lomborg. However, she embodies the difficulty of pursuing science in a field that has been so highly politicized that funding for research, careers, and reputations are jeopardized when scientists attempt to stick to the science and identify gaps in our knowledge and key questions that still need answering. It has gotten to the point where she no longer knows how to advise young scientists who want to work in this field. The problem with the manufactured consensus is that, rather than making crucial distinctions and focusing on remaining questions in order to advance the science, it imposes a rigid dogma that, strangely for an issue as devilishly complex and untestable as climate change, ignores the need to fill in the missing pieces of the picture. It also alienates some people who might be more receptive to a more nuanced, realistic, and honest portrayal of what is known and not known.

None of this is to say that there is not a need for evidence-based policies to reduce the buildup of heat-trapping gases in the atmosphere and to move toward a more rational energy policy. It is to say that an overstated and politically enforced consensus does not provide a basis for assessing the problem or dealing with it effectively. In an interview this past year, the new editor of *Science* magazine, Jeremy Berg, stressed the need for a firm demarcation between what is scientific fact and policy and political preferences [8]. His statement is particularly

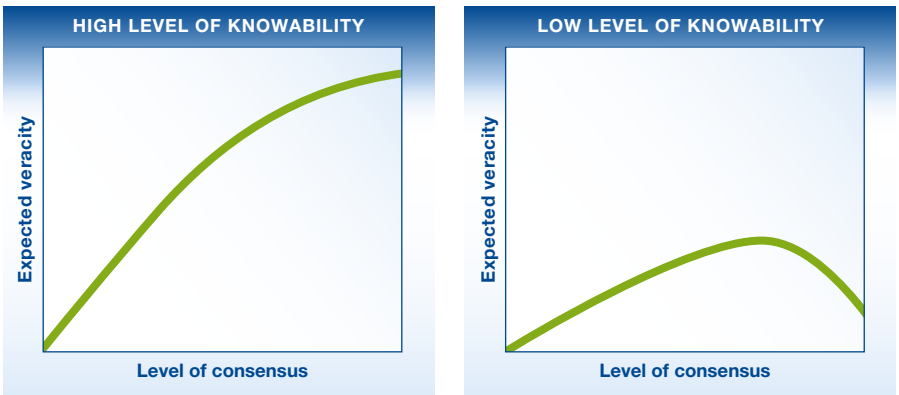

Figure 1. The relationship between veracity and consensus.
The graphs show how an increase in consensus affects the veracity of an idea or hypothesis depending on the level of knowledge. The fact that consensus views are challenged less frequently is a greater problem for low-knowability problems: Past a certain point, each increase in the level of consensus makes it more difficult for new information to emerge, which lowers the veracity. Adapted from Brumberg R & Brumberg M (2013) The Paradox of Consensus. https://iconoclastpapers.wordpress.com/2013/05/21/the-paradox-of-consensus.

Sidebar A: Further reading

Collins H (2014) *Are we all scientific experts now?* Polity Press
Feynman R (1974) Cargo cult science http://calteches.library.caltech.edu/51/2/CargoCult.htm
Gawande A (2016) The mistrust of science. *The New Yorker*, June 10
Ioannidis JP (2005) Why most published research findings are false. *PLoS Med* 2: e124
Kabat GC (2017) *Getting risk right: understanding the science of elusive health risks.* Columbia University Press
Manufo MR, Nosek BA, Bishop DVM, *et al* (2017) A manifesto for reproducible science. *Nature Human Behavior* 1: 0021
Daniel Sarewitz (2016) Saving Science. *The New Atlantis*, Spring/Summer
Trinquart L, Johns DM, Galea S (2016) Why do we think we know what we know? A metaknowledge analysis of the salt controversy. *Int J Epidemiol* 2: 251–260

significant in view of his predecessor's more activist position on climate change.

Understanding each controversy on its own terms

I have limited myself to describing three different scientific controversies that are having, and will continue to have, important consequences for society and our lives. While they all involve a hypothesized threat to our well-being, the actual evidence of a threat is very different, and what is going on in the science and the public discussion of the science is very different in all three cases. Other high-profile controversies are likely to share some features with one of the three examples but also display distinct features that need to be evaluated on their own terms.

Those of us who want to understand the phenomenon of distrust of science and counter it have to stop pretending that we can stay on the surface and behave as if the science relating to very different questions is always self-evident and can be neatly summarized in slogans. That may appeal to politicians but it does not do justice to the relevant science.

Conflict of interest

The author declares that he has no conflict of interest.

References

1. Tsilidis KK, Papatheodorou SI, Evangelou E, Ioannidis JP (2012) Evaluation of excess statistical significance in meta-analyses of 98 biomarker associations with cancer risk. *J Natl Cancer Inst* 104: 1867 – 1878
2. Hotez P (2017) The "Why vaccines don't cause autism" papers. *PLoS Blog*. http://blogs.plos.org/speakingofmedicine/2017/01/20/the-why-vaccines-dont-cause-autism-papers/
3. Breithaupt H (2004) A cause without a disease. *EMBO Rep* 5: 16 – 18
4. Trasande L, Zoeller RT, Hass U, Kortenkamp A, Grandjean P, Myers JP, DiGangi J, Bellanger M, Hauser R, Legler J *et al* (2015) Estimating burden and disease costs of exposure to endocrine-disrupting chemicals in the European Union. *J Clin Endocrinol Metab* 100: 1245 – 1255
5. Autrup HN, Berry SC, Cohen SM, Creppy EE, de Camargo JL, Dekant W, Dietrich D, Galli CL, Goodman JI, Gori GB *et al* (2016) Whither the impending European regulation of presumed endocrine disruptors? *Regul Toxicol Pharmacol* 82: A1 – A2
6. Sharpe RM (2014) Lessons learned in andrology: learning from experience – getting it wrong is alright. *Andrology* 2: 652 – 654
7. Curry J (2016) Advocacy research, incentives and the practice of science. Oct. 27 https://judithcurry.com/2016/10/27/advocacy-research-incentives-and-the-practice-of-science/
8. Matthews D (2016) Science editor-in-chief sounds alarm over falling public trust. *Times Higher Education*, August 18. https://www.timeshighereducation.com/news/science-editor-chief-sounds-alarm-over-falling-public-trust