Science to Action: Thoughts on Convincing a Skeptical Public

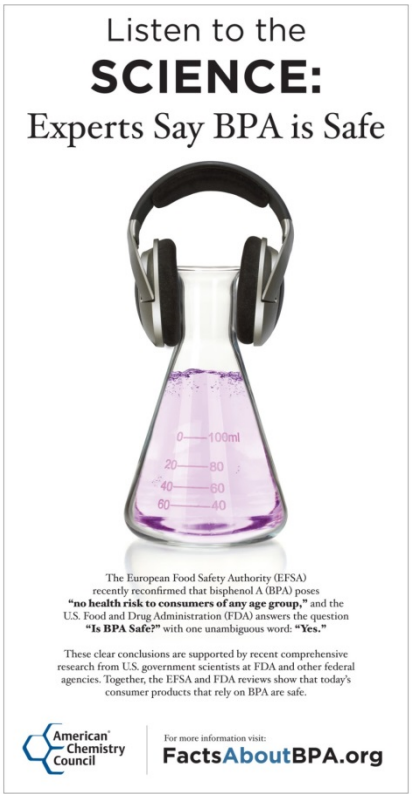
William H. Press
The University of Texas at Austin

April, 2016

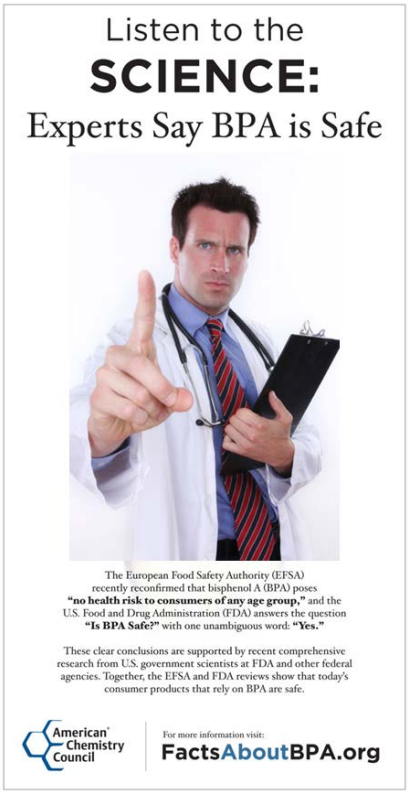
This article is a condensed version of the talk originally given by me as the 2015 William D. Carey Lecture of the American Association for the Advancement of Science (AAAS), and several times subsequently in other forums. I am grateful to AAAS for providing the initial platform for me to express these views, for which I bear sole responsibility.

Scientists have the obligation to make the case to the public that funding science is a good use of their tax dollars. That is one "bookend" of our communication to the public. This talk is about the other bookend: How do we convince the public to listen to us as scientists, at the other end of the scientific process, when we have something important to say on public issues?

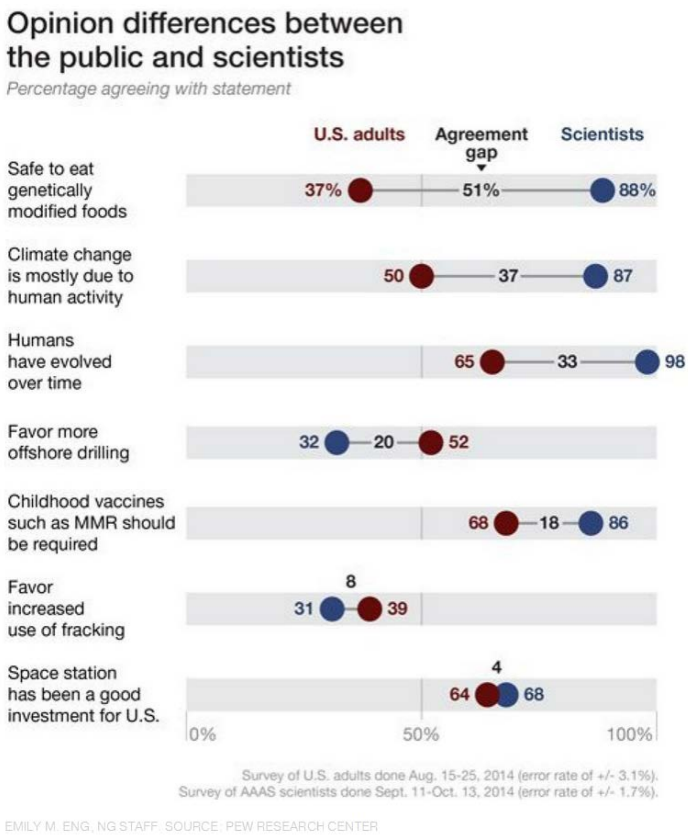
I was moved to think about this question by a full page advertisement that ran in the Wall Street Journal, USA Today, and other papers in February, 2015. My immediate reaction upon opening the physical newspaper page to this ad, was that it epitomizes everything *bad* about how to address the public. The subject of the ad is bisphenol A, better known as BPA, a principal ingredient in polycarbonate plastics. I have no particular axe to grind here about this controversy itself. My objection is to the mode of communication.



Is that an Erlenmeyer flask with earphones on it? What is this trying to communicate? The headlines says, “Listen to the science!” and “Experts say...!” The tone of this ad strikes me as remarkably patronizing, even disdainful, of the public that it purports to address. And it only gets worse. The fine print in the ad says that the U.S. FDA answers the question “Is BPA safe?” with the unambiguous word “Yes.” In fact, if you look into the issue, you find that the FDA's position, that BPA presents no public health hazard, derives in part from its voluntary withdrawal, by manufacturers, from many food chain applications. So the story is rather more complicated than this ad implies. In my opinion, the only way that this ad could be worse is if they had changed the picture to look like this:



How might we convince the public of science-based positions, and how well are we doing? It is an important question, and it is pretty clear that we are not doing well. The chart below shows the results of a Pew poll as republished in *National Geographic*. The poll finds many issues where the opinion of the public diverges significantly (often greatly) from the expressed opinions of scientists: Are genetically modified foods safe? Is climate change mostly due to human activity? Is the human species the result of evolution? Large or overwhelming majorities of scientists say yes to these questions. The public is not as convinced. (As a side comment, my guess is that the 2% of scientists who appear not to believe in evolution instead interpreted the question as meaning, “Has evolution of humans occurred after the species Homo sapiens became established as a single gene pool”, an interesting question in population genetics.) These three questions are about well-established scientific facts. This failure is one of STEM education.



The next four questions shown in the chart are a bit different. The public is significantly more in favor of offshore drilling than are scientists; slightly more in favor of increased use of fracking than scientists; less supportive of required childhood vaccinations. Scientists' and the public's views on the International Space Station are fairly congruent, so we don't *always* disagree! These four questions have a different character from the first three. They are not questions about scientific fact. They are judgment questions about societal values where scientists and the public reach different conclusions. That, in a nutshell, is the subject of this talk.

We can view these two kinds of questions as reflecting two different "storylines" about science. Let me elaborate on that, turning each of the storylines into a familiar (even trite) little tale:

> Storyline No. 1. Scientists who are motivated by a sense of pure discovery observe, measure, and characterize a new phenomenon. Other scientists and engineers, motivated by a desire to create applications, may develop technologies and inventions that utilize the new phenomenon. The results are often new products, jobs, and industries.

This story is the template for our communication to public about why science, both basic and applied, makes sense as a good investment for society.

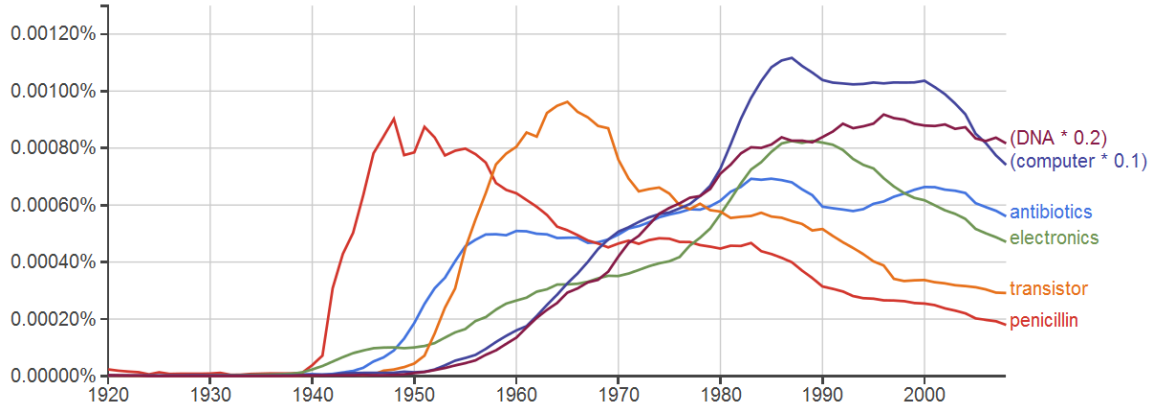
But what about this different story?

Storyline No. 2. Scientists familiar with the relevant data recognize a danger or hazard to the public. In an advocacy role, they convince the public that action is needed, often despite opposition from economic interests or people who disagree with the evidence. The result (in the best cases) is appropriate, wise action by government and favorable outcomes for the public—in agreement with the scientists' recommendations.

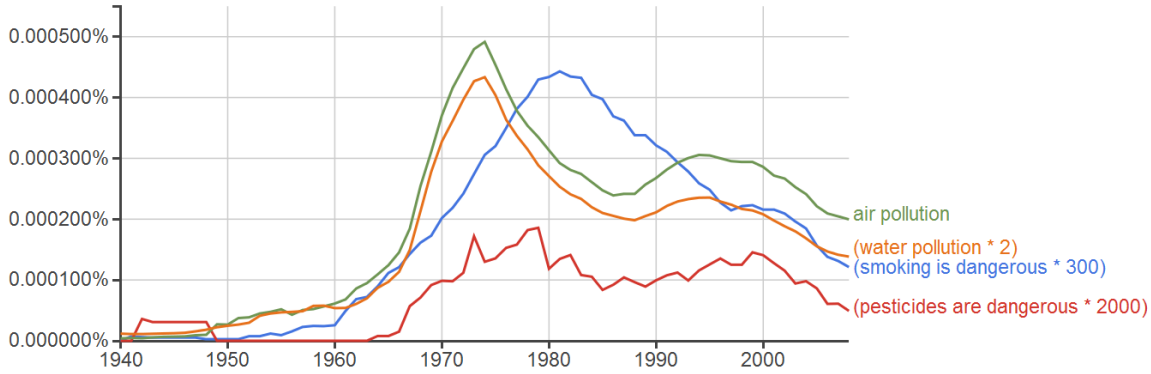
The two stories are quite different. They are both good stories. As scientists we should be proud of both and find occasions for telling both. Problems arise, however, when we conflate the two. My thesis is that the storylines require different approaches to public communication.

As illustrations, I show some Google N-grams, graphs of how often, as a function of year, a given word or phrase occurs in all books and periodicals that have been scanned by Google. While N-grams are in no sense precise or controlled indicators of social trends, they often give some idea of the relative ups and downs of public attention to a subject.

The figure below shows the trajectories of words I have chosen to exemplify successes of Storyline No. 1, namely discoveries and inventions that rapidly "changed the world", and which (to a greater or lesser degree) remain in the public discourse.

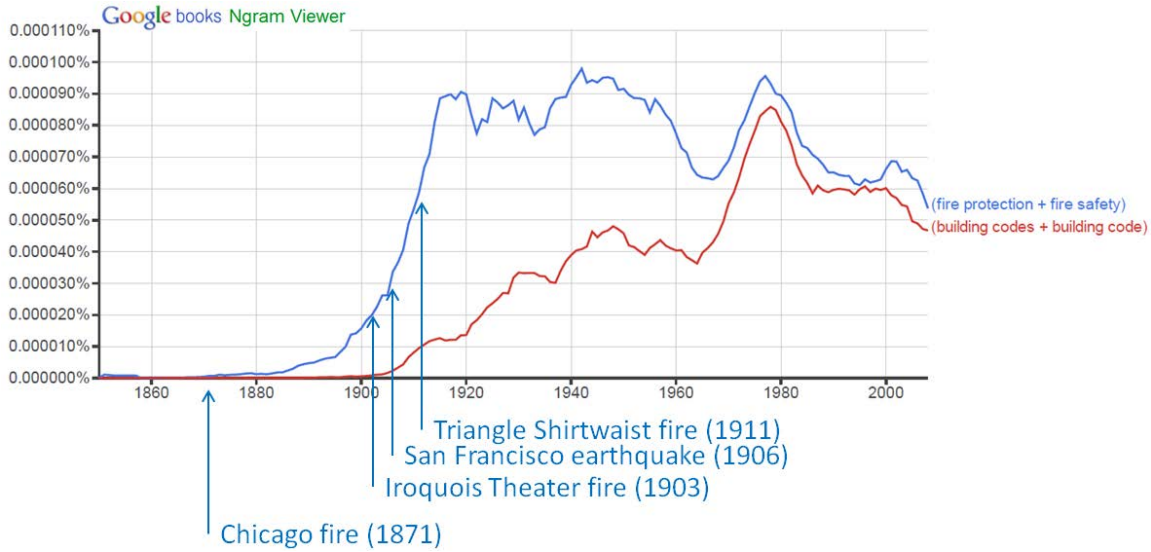


The corresponding figure (below) with examples from Storyline No. 2 (mitigation of hazard) looks somewhat different to my eye. As full disclosure, I did play around a bit with what phrases to use, e.g., "smoking is dangerous", so the two figures should be taken as somewhat subjective. Still, Storyline No. 2 seems to generate a different pattern: An issue becomes controversial and rises to a peak of public interest. Action is taken. Subsequently the issue is less in the public eye. The issue becomes a solved problem. By contrast, topics from Storyline No. 1 ("electronics", say) never become solved problems. They are inventions or technologies that remain active in the public eye.



For this talk, I am particularly interested in issues of type Storyline No. 2. Where, in such cases have scientists like us succeeded in galvanizing public action in a direction justified by science, and where have we failed?

As a case study, it is useful to pick an issue that is truly a solved problem, today without any political baggage. We go back a century to an example that, today, we might not even recognize as science, although at the time it was so considered: fire protection and fire safety. Today, this is so built into our infrastructure that we don't even think about it: exit signs, adequate numbers of doors, fire resistant materials, fire extinguishers, and so forth. A hundred and fifty years ago, however, we built cities with virtually no regard to fire risk.



In 1870 Chicago burned down. Little happened, however, until a series of infamous fires at the beginning of the 20th Century: The Iroquois Theater fire (also in Chicago) in1903; the San Francisco earthquake in 1906 (where the destruction by fire was vastly more than that of the earthquake itself); and the Triangle Shirtwaist fire in New York City in 1911.

According to the N-gram plot, this was the epoch when the public actually did become interested in fire safety. (Correlation doesn't imply causation, but in this case, historians leave no doubt in our minds.) Government took action, not just on fire protection, but on infrastructure safety generally. One sees in the N-gram a rise of the term “building

codes" somewhat lagging "fire safety" by perhaps 20 years. (I am curious about the secondary peaks of both terms in the late 1970s, but have not delved into the data.)

What made fire safety a successful "technology intervention" into public policy? This was an immense undertaking, essentially the rebuilding, as codes became enforced, of every city in the country. The cost today, in today's dollars, would be many trillions.

As I study this example, I see four relevant characteristics:

1. The hazard was one familiar to the public. People knew what fire was and understood its potentially disastrous consequences.

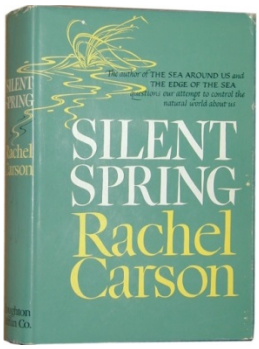
2. There were catalyzing events, as I have already mentioned, widely and sensationally reported.

3. There were effective and affordable mitigating technologies. In 1890, Frederick Grinnell invented the glass disk sprinkler head, in use and virtually unchanged today. (The idea is that water can be released only when the low melting-temperature glass disk softens and loses its structural integrity. The likelihood of accidental triggering is thus made extremely small.)

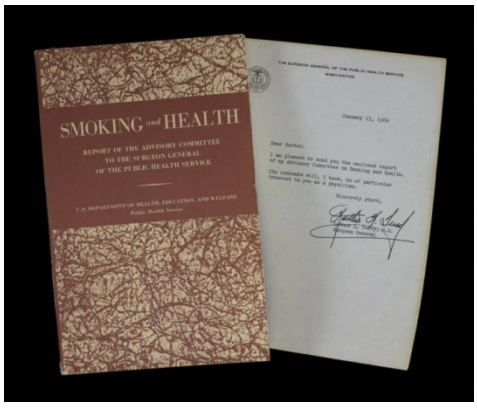
4. Economic interests were not exclusively on one side. This might be the most important characteristic of all. The insurance industry was a strong proponent of fire safety and, in 1894, founded Underwriters Laboratories for the purpose of safety research and certification of products, continuing to today, when the UL logo is still recognizable (if obscure to younger generations).

A measure of the success of this Storyline No. 2 example is that fire deaths today (say per 100,000 people per year) are about a tenth of what they were in 1920. As an issue of public policy, fire safety is a solved problem.

Let's see if these same characteristics can also be found in other case studies. Rachel Carson's 1962 publication of Silent Spring was a catalyzing event: Historians directly trace a path from this book to the establishment of the Environmental Protection Agency (with the support of President Nixon, incidentally).



The publication of the 1964 Surgeon-General's report on the danger of smoking—seemingly just another report in the large mass of documentation of the danger—somehow "took fire" with the public as a catalyzing event. Smoking rates in the U.S. soon began to drop. Currently, smokers are about 17% of the U.S. population, down by a factor on the order of 3.

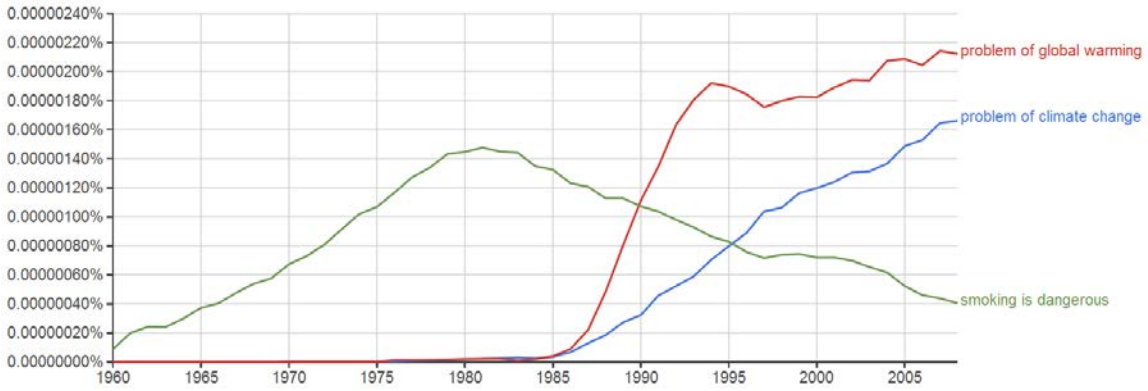


The N-gram for the phrase "smoking is dangerous" rises from near zero in 1960 to a peak in 1980, and has declined since. In terms of convincing the public of the facts, smoking is a solved problem. (We may be less sanguine about nicotine addiction in other forms, for example electronic cigarettes. The fight between public health and the tobacco industry is by no means over.)

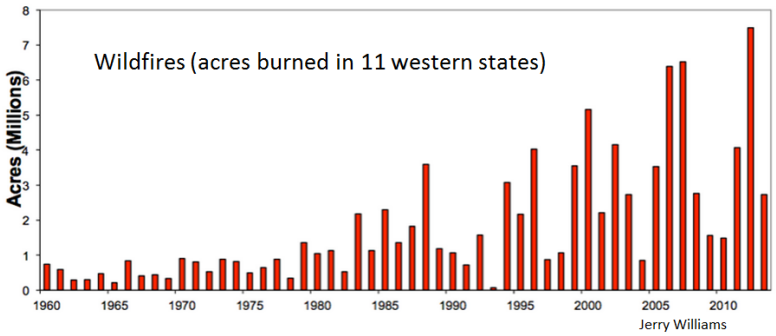
What about the rest of the checklist of four questions? Was smoking an activity that the public was familiar with? Yes, of course, everyone either smoked or knew someone who did. Were there effective and affordable mitigating technologies? Yes, either just stop smoking, or substitute another means of nicotine delivery (patches, etc.).

Were economic interests not exclusively on one side of the issue? My reading is that this was the final thing to fall into place. As the result of the Surgeon-General's report, the medical profession was soon anti-smoking. (Before, people could smoke in their doctors' waiting rooms or their hospital beds!) Life insurance companies began to charge smokers higher premiums than nonsmokers. Employers sponsored anti-smoking efforts as an employee benefit, in support of reduced absenteeism. So significant economic interests changed sides, or at least changed from tolerant of smoking to discouraging it. (The 1990s brought another fundamental shift in public opinion against passive or second-hand smoking.)

I haven't said the word "climate" yet, but I'm sure that you have guessed that it was coming. In the sense that fire safety may have been the big issue of a century ago, and smoking was the issue half a century ago, certainly climate change is today's big issue. All these examples share the same Storyline No. 2 paradigm: A scientific cohort convinced by the evidence confronts an initially skeptical public. In the N-grams, contrasting the rise and fall of "smoking is dangerous", "problem of climate change" (and related phrases) continue to be very much on the rise, however. I read this as indicating that the task of effective communication is not yet finished.



What about the four questions? Are there effects of climate change that are familiar to the public? I think that this has changed a lot recently, and that the answer is now yes. Have there been catalyzing events? Yes, also quite recently. Hurricane Sandy in 2012 is an example (independent of whether or not any particular storm can be ascribed uniquely to secular changes in climate). For many people living in the western U.S., the rapid increase in the number and intensity of destructive wild fires (see figure below) has been catalyzing—not least because pictures of houses burning make effective TV news footage.



Are there effective and affordable mitigating technologies in the case of climate change? This is a complex question beyond the scope of this talk. When the climate community speaks of mitigation, they mean reducing CO_2 emissions. Some mitigation technologies (e.g., conservation and energy efficiency) are not merely affordable—they actually pay for themselves and then some. Switching from coal to natural gas is a low-cost mitigation, thanks to the low cost of natural gas from fracking technology. The cost of some other mitigations remains a matter of debate. For many years, the climate science community was distinctly—one might say, doctrinally—silent on the desirability of (so-called) adaptation, that is, technologies for mitigating not the rise in CO_2, but the economic and human consequences of that rise. Attention to adaptation might distract from the importance of mitigation, it was argued. Personally, I think that this was short-sighted, and I am happy to see that it has largely changed. Mitigation (in some forms) and adaptation (in others) will both be a part of the long-term solution. In the context of this talk, mitigation and adaptation technologies may both be necessary to convince the public that effective and affordable strategies for countering climate change exist. *Convincing the public* that effective and affordable strategies exist may well be, in my view, the rate-limiting step for progress on the climate change issue.

Finally, are economic interests not exclusively on one side of the climate issue? On this, I think that we are at about the same point as, for smoking, just after the Surgeon-General's report. Insurance companies see the risks of climate change as real. Large corporations are starting to do forward planning on their supply chain vulnerabilities. Risks to agriculture are real and are spurring the commercial development of drought-resistant crops (an example of adaptation as one element in a strategy).

This isn't a talk on climate change, but, going through the four-point checklist, I find myself cautiously optimistic that we have turned the corner in terms of convincing the public that action on climate is necessary—as necessary as it was for fire safety and building codes a century ago. Indeed, the two examples are in many ways analogous, one about the constructed environment, the other about the natural one.

However, I want to return to the more abstract discussion of the two storylines. What happens when the two get blurred or confused? To remind you where we left that discussion, Storyline No. 1 was the one where research delivers new products and industries. Storyline No. 2, was the one about mitigatable hazards that should, thus, be mitigated.

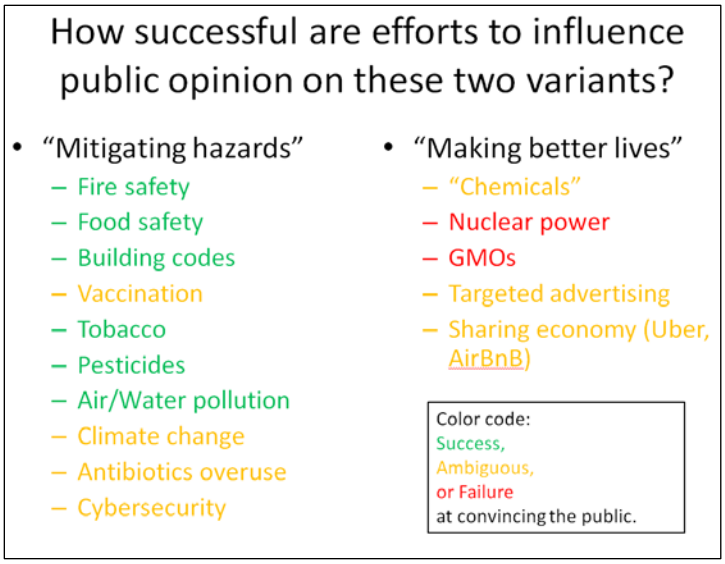
What about a story that go something like this:

> Storyline No. X. A cool new technology exists. It can make lives better, so it should (in the sense of "ought to be") be widely adopted.

Which storyline is this? It sounds a bit like number 1, where better lives are made possibly by new products. But, I claim, it is actually a variant of number 2, because of that word "should". Should is a very tricky word. Let's look at some examples of the effectiveness of convincing the public that they "should" accept the advice of scientists on Storyline No. 2 (mitigating hazards) versus this new No. X (making better lives).

These are all judgment calls, but on mitigating hazards, I think that calls for public action by the scientific community have been largely successful on these issues: fire safety, building codes, food safety, tobacco, pesticides, air and water pollution. I judge partial or incomplete success on: vaccination (currently backsliding from what appeared, a generation ago, to be success), climate change (hopefully gaining ground), inappropriate use of antibiotics (significant economic interests continue to align against the scientific evidence, especially as regards use in animals), cybersecurity. By and large, however, this picture looks good. We are having at least some success on all of these issues.

What about making lives better? Here the picture ranges from at best partial success to complete or near failure. DuPont's one-time slogan, "better living through chemistry" sounds sarcastic to today's ears, although I don't doubt that it remains factually true. The benefits of chemistry are enormous. (I began this talk with an example of bad communication from the industry-sponsored American Chemistry Council, however.) Does the public believe Google (and other information-rich companies) that Big Data, gathered from the personal lives of consumers, makes their lives better? Success in making this case is partial at best, and similarly, I think, for the technology innovations that give us the sharing economy (Uber, AirBnB, etc.). Nuclear power and genetically modified organisms (GMOs) exemplify almost complete failures at convincing the public that the named technologies will make their lives better and enormously benefit society.



The figure above summarizes these judgments on the effectiveness of our communication with the public on these public issues. The underlying issue, of course, is: Who gets to choose what "better" means? Is it that scientist in the white lab coat pointing his (rarely her) finger at the public?

Nor is the scientific community itself always of one mind on these issues. You may not agree that consumer Big Data is as obviously good as childhood vaccination, for example. Or, consider these two possible positions on the question of labeling GMO food products:

> A. GMO labeling is scientifically misleading. It creates externalities with identifiable costs, such as higher food prices, and poorer nutrition in the developing world. It sets a precedent for anti-scientific public policy. Governments should discourage GMO labeling.
>
> B. GMO labeling is a matter of consumer preference. As long as a GMO label is not designed to be intentionally confused with a safety label, science and scientists have only a limited special role in this debate.

I have asked audiences of scientists to vote, by show of hands, on which position is closer to their own. The tallies have been about evenly divided between A and B. The point:

This is not a debate on science, it is a debate about *values*. If we pretend otherwise, we can at best confuse the public, at worst, alienate them.[1]

The word "should" carries a lot of baggage. It is a matter of judgment, not scientific fact. But whose judgment? The public asks, are people "like me" a part of the process? Do scientists have, or claim, a special role in judging? If so, why?

"Should" has an economic dimension: At what cost and to whom? Is the proposed action disruptive of established economic interests? Does it imply a redistribution of resources or wealth? (Almost all actions do, at some level.) Does it imply a perturbation on political relationships or influence? (Again, almost all actions do.)

And by whose moral compass are we to decide? My values, priorities, and beliefs may all be different from yours. Most important, my tolerance for change may be vastly different from yours.

When we chose to become scientists we became part of "the scientific enterprise". My thesis is that we have actually bought into two, quite distinguishable, enterprises that are conflated—more than they ought to be—as a matter of history and practice, not necessity. I should make clear that I am proud of being a part of both enterprises, but I nevertheless want to tease them apart.

First, science is a fact-discovering enterprise. The elements of that enterprise have evolved and been optimized over time (e.g., since Galileo). They include quantification, experimental validation, and repeatability—itself requiring the existence of underlying natural laws. Statistical inference, mostly unknown before the time of Carl Friedrich Gauss, is an important element. Certain social processes have proved themselves necessary to the fact-discovering enterprise. Open publication, peer review, and career advancement by merit come to mind as three important ones. The fact-discovering enterprise is a methodology, one that is able to discover facts about the natural world and generate translational paths to applications, often unexpected ones.

Second, distinguishably different, science is a rationalist approach to life. Scientists believe that human decisions can and should be based on data—on weighing pros and cons. We are skeptical about the use of untestable "facts" or assertions based on authority only. The vast majority of scientists believe in some version of a utilitarian metric—that the better decisions are those that produce the greater good for the greater number of people. Of course none of this would be useful if we did not also believe in the efficacy of action—that the future can be different and better than the past. (This may also inform our tolerance for change.) Widely shared beliefs like these are not a methodology, like the fact-discovering enterprise. Instead, they are a value system, something quite different. As Mr. Spock in Star Trek could have at some point said, "Scientists are logical, rationalist lifeforms."

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[1] If you want to know about my values, I am strongly for position A. Golden Rice, genetically modified to contain vitamin A, could save the lives of half a million children per year in the developing world. However, many developing countries won't allow it to be sold because of the high visibility of opposition to GMOs in the developed world.

1. Science is a fact-discovering enterprise.
2. Science is a rationalist approach to life.

- Quantification
- Experimental validation
- Repeatability
- Underlying natural laws
- Statistical inference
- Processes
  - open publication
  - peer review
  - advancement by merit
- Translational path to applications

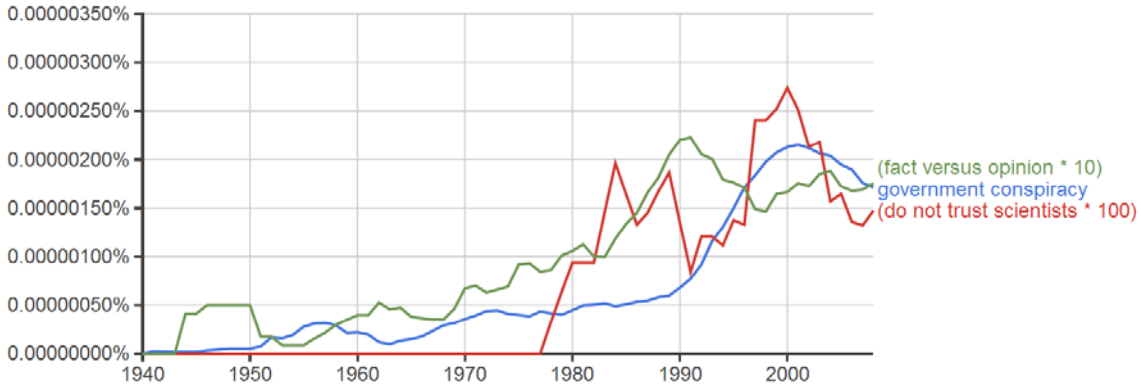
This is a methodology.

- Decisions based on data
- Weighing pros and cons
- Skepticism about the use of
  - untestable "facts"
  - assertions based on authority only
- Some version of a utilitarian metric
- Some belief in the efficacy of action
  - the future can be different and better

This is a value system.

There is no reason that we should not seek public support for both enterprises, but, for effective communication, we need to keep them distinct. The public may readily grant us our "methodology" without much debate or concern; but they have the right, if they wish, to be critical of our value system. Not all of the public want to be like Mr. Spock.

In recent decades, the mistrust of science has increased in a way that does not appear to be merely cyclical. The N-grams for phrases like "do not trust scientists", "government conspiracy", and "fact versus opinion" show rapid increases since about 1980. Sadly, a significant part of this mistrust has been financed by contrary business interests, a marketing strategy first employed and perfected by the tobacco industry. (The book *Merchants of Doubt* by Naomi Oreskes and Erik Conway documents many such examples.) In the 1970s, roughly, large economic interests discovered that they could make money, or maintain market positions, by bad-mouthing the scientific enterprise. Previously, this had not been the case. (I wonder if future historians will record this discovery as a critical event in the decline of our civilization.) Unfortunately, this is the new reality for current and future science-based issues.



What can (or "should") we do in the present situation? The following would be my list.

We should make greater efforts to clearly separate fact-based conclusions from value-based judgments, even when both are useful. In my opinion, journals should publish *more*

opinion *labeled as such*, but they should be correspondingly *more* rigid in excluding explicit and implicit value judgments from refereed scientific publications.

We should be more active in communicating the merits of a rationalist approach to decision-making, most effectively, I think, by our own example in the public space. In education at all levels, we should encourage students to think, "How would a scientist approach this policy decision?" We should not claim that this is the only approach, but it is one that has proved its usefulness broadly and for a long time. It is an approach worth, at the very least, understanding.

In general, we should be careful and selective in invoking science as a privileged platform. Assertions of the form, "This data shows that we need to..." should always be suspect. We should say, "Speaking for myself..." more often than now, but we should also not be shy about saying, when justified, "It is an accepted scientific fact that..." or "The evidence demonstrates that…."

We should be less dismissive, I think, of value systems that we see as being unscientific. The first rule of marketing is sometimes said to be that knocking the competition destroys credibility—yours. But, at the same time, we should be more assertive in reacting to threats to the integrity of science. We should be more publicly critical of poor quality science, even when its conclusions happen to support our values. The "irresistibly true"—but actually flawed—finding is a grave danger to the integrity of science. Too many such papers get published.

I think that journals should require, as a condition of publication, meaningful disclosure of all funding sources. By meaningful, I mean the ultimate source, not an opaque front. Some argue that researchers do not always have access to such information. However, if the information was required by journals, then reputable organizations could easily provide it. So the ball is in the publishers' court for action on this.

Meretricious balance ("there are two equal sides to every issue") is often an excuse for poor quality journalism. Scientists should be more active in calling it out, both publicly and by communicating privately with editors. Likewise we should call out "merchant of doubt" campaigns when we see them.

In the long run, I see convincing the public as a long, two-step process. Before we can do Step 2, the communication of well-established scientific results (something that we often do well), we need to lay the groundwork of Step 1, the communication of a rationalist approach to decision-making (something that we often do badly).

We need to be better, separately, at both kinds of communication.