

SCIENCE and ANTI-SCIENCE in AMERICA:
belief and knowing

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This is a new experience for me. Typically, when I address a conference, I get to refer to my graphs and tables and figures. This is the first time I am speaking in a public venue about my thoughts on science and anti-science in America for which I have no graphs. I think of this as a kind of editorial. And I thank you for this opportunity.

I am a biologist and teacher and while I have worried about the public understanding of science from time to time, I can recall how it came to capture my attention with the urgency it now has for me:

I was listening to President Bush on the news and I frankly can't remember what he was addressing specifically, likely some vague comments about how the jury was still out on evolution or global warming, but whatever it was, it made me angry and frightened. And I began to push myself to articulate **WHY** I was so distressed. And each time I answered myself, I pushed again: so what? and as I answered, again, well so what and again so what?

And I finally reached the most powerful answer to the general question, so what if science doesn't inform the decisions we make as a country, a people, a world?--The consequence--is that people suffer.

Well, what do I mean by that? And how many examples can you think of? Here are just a few of mine:

--the absence of an understanding of how the AIDS virus is transmitted has led to countless deaths and the millions upon millions of children orphaned in Africa.

--in the 1960's, data began to emerge linking cigarette smoking with heart disease and lung cancer. The volume of these studies has only increased and yet for years the industry tried to suppress or dismiss the link between cigarette smoking and health problems.

--scientists had been predicting that a Katrina-like storm was bound to hit low-lying areas in the U.S. and we now know the consequences of having ignored that prediction.

--and now that the scientific community is convinced that global climate change has been set in motion as a consequence, at least in part, of human activities, Frances Cairncross of the British Association for the Advancement of Science has said that "We need to think about policies that prepare for a hotter, drier world, especially in poor countries."

But part of the difficulty in the public's understanding of science is that people are *first*, eager to accept claims of **direct causality** and *second*, they want **certainty** and science doesn't always confirm the former and can't always provide the latter.

--we don't know when the next Katrina-like storm will occur

--or when or what the next pandemic will be, if any

But these assumptions about direct causality and certainty speak to a misunderstanding of science.

So let's deal with the causality piece first:

People seem predisposed to infer causality. I have wondered how this predisposition might have come about? In other words, how might it have served our biological fitness in our evolution.

--Well, which is more risky: attending to a false negative (*Uncle Bob ate that mushroom and died but it had nothing to do with the mushroom*) or a false positive (*I saw a yellow butterfly and then lightning struck nearby*).

--Well, or course, attending to a false positive likely won't hurt me (that is, worrying about a lightning strike after I see a yellow butterfly and perhaps seeking shelter is not particularly detrimental to me) but a false negative? (oops, I ignored the fact that Uncle Bob died after eating the mushroom, and I ate the mushroom and died). So we seem to be predisposed to infer causality--it serves us to make associations: if we happen to goof on a false positive (the butterfly) we can still reproduce. But if our "causality button" is off when someone eats a mushroom and dies and we DON'T make that association, then we may die, too. So on average, it probably helped us to infer causality.

But what's the harm in inferring causality at the least provocation? Well, how many children have to contract polio because their parents have inferred a causal relationship between the immunization and contracting the disease? UNICEF has reported an increase in the incidence of polio among children in Indonesia. I saw a news report in which a mother had brought her child to be immunized and a day later he had polio. Of course, this child already had had the virus incubating in his body prior to the vaccination and he was vaccinated too late. But without understanding how the disease is contracted and how the vaccine works, the mother's logic made sense. She has discouraged her neighbors from having their children immunized, and thus the disease spreads.

Yet science relies on the association of events to make sense of the universe. Once we find an association or a correlation, we can begin to look for causality, that is, the mechanisms underlying a phenomenon. Scientists noticed an association between smoking and heart disease and lo and behold, we are beginning to uncover the causal relationship between smoking and particular physiological consequences in blood vessels.

And now I come to the next piece of confusion about science: the absence of certainty. Every human being who smokes cigarettes will not get lung cancer; we can't even know (yet) who WILL. So what do we know: of thousands of people who smoke, some proportion of them will die prematurely as a consequence. We can only get closer to the truth of how the material world works through the play of large numbers and thus, probabilities. People have some sense of this. If I asked my students, is it possible for me to flip a coin and get 4 heads in a row? Yes. Is it possible for me to flip 10 heads in a row, yes. Is it POSSIBLE for me to flip one million heads in a row, possible yes, but so improbable as to be as to be virtually impossible (if I did, we might doubt our assumption that the coin actually had a tail side).

We all know that science is a way of asking testable questions about the material world. It is a process by which one goes from noting association or correlation to unlocking mechanisms by attention to evidence.

One of the things that makes science such a powerful process is that it is self-correcting: an hypothesis not supported by evidence doesn't hang around long--scientists

are constantly testing their ideas and those of others and the bar is set pretty high for what it takes to be persuaded.

Science is powerful because it DOES accurately predict events, from the virtually certain:

-if I drop this ball from the building it will fall to earth
to the probabilistic:

-people who don't smoke are likely to lead healthier lives than those who do.

Again, my concern about the misunderstanding of science is that the insights of science can enhance the quality of people's lives.

I suspect that many of you have bumped up against what I call anti-science: a mistrust or a misunderstanding of science. The way it can be institutionalized can shape how we see and act in our world.

Well, what sorts of institutions?

Alas, I am sorry to say that segments of the University contribute to a misunderstanding of science:

Some academics have argued that there is no truth and anyone's view of how the world works is as legitimate as anyone else's (a view with which some of my students have sympathy).

Andrew Ross, Professor of Social and Cultural Analysis at NYU has written, "How can metaphysical life theories and explanations [i.e. New Age theories and explanations] taken seriously by millions be ignored or excluded by a small group of powerful people called 'scientists'?"

Ah, so because millions subscribe to it, it must be so. Tell that to the "witches" who were burned in the 17th century. Oh, but we are so much more sophisticated than that now. Are we, indeed?

I have also heard academic colleagues who describe themselves as radical feminists dismiss the practice of science because logic is a tool of male domination.

Now, is it possible that a scientist's gender can affect how she or he asks a question? Sure. All of our experience affects our phenotype and has bearing on how we approach the world.

--did Barbara McClintock's gender influence how she approached her genetics research?

Well, some would say yes. I honestly don't know what role her gender played. Do I think that scientists would have eventually figured out that genes jump? Yup, they simply might not have figured it out as soon as McClintock did and her particular experiences, including her gender may have influenced how she conceived her experiments.

But I have well-earned confidence in the process of science, we would have gotten there.

And finally and perhaps most disturbingly, science professors at colleges and universities who present science as a disembodied collection of facts are culpable. How many of us had science classes that failed to have us engage in the enterprise of science, to confront the process and history of a field, and the meaning of evidence?

Let's think about another institution which can shape the public's understanding of science: the government.

In the Soviet Union of the 1930's, a bureaucrat named Lysenko eschewed genetics and spouted theories of heredity that were consistent with Stalin's view of the world. Real scientists were jailed or even killed for disputing the validity of what is now referred to as Lysenkoism.

Well, perhaps you all see where I am going with this. In February of 2004, 62 leading scientists (which included Nobel laureates, National Medal of Science recipients, Crafoord Prize winners and advisors to the Eisenhower and Nixon administrations) wrote a statement entitled "Restoring Scientific Integrity in Policy Making" which begins:

Successful application of science has played a large part in the policies that have made the United States of America the world's most powerful nation and its citizens increasingly prosperous and healthy. Although scientific input to the government is rarely the only factor in public policy decisions, this input should always be weighed from an objective and impartial perspective to avoid perilous consequences. Indeed, this principle has long been adhered to by presidents and administrations of both parties in forming and implementing policies. The administration of George W. Bush has, however, disregarded this principle. When scientific knowledge has been found to be in conflict with its political goals, the administration has often manipulated the process through which science enters into its decisions.

Here is just a short list of measures documented to have been taken by the Bush administration:

- the administration interfered with a discussion of climate change in an EPA report until the EPA simply eliminated that section;
- the administration distorted findings of the National Academy of Sciences on climate change;
- there are recent reports from NASA scientists detailing pressure from political appointees to alter or delete climate change findings;
- after Bush took office, the Department of Health and Human Services deleted website references to the efficacy of condom use in the fight against the spread of AIDS;
- the administration "dropped independent scientists from advisory committees on lead poisoning and drug abuse in favor of ones with ties to industry." (*editorial from sci am*)
- one wonders how much more progress could have been made in our efforts to ameliorate Parkinson's Disease or diabetes if stem cell research had been encouraged by the administration.

So what if science doesn't inform our decisions?
People suffer.

Industry is another culpable agent encouraging a misunderstanding of science. Is there no connection between industry and the almost grotesque consumerism of the U.S. and global climate change? At least cigarette manufacturers have finally owned up to the harmful effects of smoking.

Well, everyone loves to take a poke at the media so now it's my turn. You may recall that in the fall of 2005, this story hit the media: the Dover, Pennsylvania Area School Board of Directors passed by a 6-3 vote the following resolution:

Students will be made aware of gaps/problems in Darwin's theory of evolution and of other theories of evolution including, but not limited to intelligent design.

They further required that science teachers read a kind of evolutionary disclaimer to their biology classes. The school board was sued by a group of parents who were upset by this decision and the case was widely reported for some time. I checked various print, TV, and internet media and saw how they reported this story. Typically, they interviewed one person who was in favor of the resolution and one who was not. NO where was there a statement of the validity of evolution and why it is so widely accepted among scientists. At the time, I was teaching my course Science and Anti-science in America and I gave my students the following question to address:

The media claim that it is their job to report the news rather than suggest a particular point of view. In their effort to remain unbiased, they try to describe varying points of view on a topic. This is often true for their reporting of scientific issues (and then I gave some examples). In discussions of what should be taught in our schools the media might interview a proponent of the teaching of evolution and a proponent of the teaching of intelligent design. Comment on this tendency of the media to represent all sides (or more typically, "both sides") of an issue particularly as it pertains to scientific questions.

By and large, my students thought that that was an appropriate way to cover an issue in order "to be fair." I asked them, suppose the story was about teaching that the world was flat versus round? Oh, that's different. I said that the preponderance of evidence for the FACT of evolution is as robust as that for a round earth.

Science is about the preponderance of evidence. Perhaps 30 years ago an article about the role of human activity in climate change could have presented "both sides." (or better yet, what the questions, data and uncertainties were). But now the preponderance of evidence suggests that humans have a role in climate change and the consequences of climate change are that people will suffer.

And now I come to another institution that has had a huge impact on the misunderstanding of science in this country and as I describe this institution, I watch my chances to become president of the United States evaporate: I refer to certain religious groups. It is no secret that certain fundamentalist Christian groups oppose the teaching of evolution because they see it as a direct challenge to the revealed word of God as described in Genesis. The opposition to the teaching of evolution has a long history in the United States as I am sure you are aware. In my own lifetime, it has continued to reinvent itself even as it is dismissed by the courts (as a violation of the establishment clause).

-first creationism was to be given equal time

-then creation science

-and now, intelligent design in which God is not mentioned by name.

This last attempt was dismissed in 2005 as Genesis in sheep's clothing by Judge John E. Jones III in the Dover, PA case (he is, by the way a Republican and was appointed to the court by Bush). His decision found in favor of the plaintiffs who opposed the teaching of intelligent design and the distortion of evolution.

Now let's flip back to my students in my science and anti-science class. They had no difficulty disparaging the folks who eschewed evolution, oh, those ignorant people. But some of them bristled when I suggested this: dismissing science as simply a vehicle for continued male domination is equally problematic. When you begin your inquiry with the answer rather than the question, whether the answer is "God did it" or "western intellectual thought is simply a way to insure the power of white men," then it isn't inquiry at all; it's dogma.

Science requires, at once, an openness to possibilities and a skepticism as to how things work. What was your question? How did you gather your data? What do your data mean? What are other hypotheses that might be consistent with your data?

Some of my students also had a tendency to dispense knee-jerk black and white pronouncements about certain issues. In fact, a colleague of mine has suggested that the most difficult thing about teaching environmental science is getting the students to be more skeptical about particular claims. For example, "Genetically Modified foods are bad." Why? "They are not natural." Well, what does that mean?

My students have said that they are worried about global warming. When I push them with my now hated "so what if there is global warming" they posit various scenarios in which organisms become extinct. So I push them, so what if every organism on the planet becomes extinct?

Ultimately, not just students, but all of us need to invoke some aspect of who we are other than science. Science can help us predict the consequences of our actions but our own sense of ethics or humanity or aesthetics or, yes, faith, must be invoked in order for us to DECIDE whether those consequences are acceptable.

Science can predict that people will suffer if we don't attend to various problems. We, as human beings, need to say that that suffering is unacceptable.

Lastly, I come to what is perhaps of greatest concern to me as a biologist but more as a citizen of earth: So what if roughly half of Americans don't subscribe to evolution? (I don't like to use the phrase "believe in" evolution--it's like choosing whether or not to believe in gravity--you can choose not to believe in it but if you jump off a building...)

Evolution has occurred and continues to occur. There are particular problems for which an understanding of evolution can provide important insights: the appearance of new and antibiotic resistant strains of bacteria was and continues to be both predicted and explained by evolutionary theory. And, at long last, physicians have taken this understanding into their practice by not unnecessarily prescribing antibiotics, which have become a selective agent in the evolution of bacteria.

But more than that, this denial of evolution speaks to an anti-intellectualism, a brand of anti-science that, as I said leads to suffering.

Science is a way of asking questions about the material world; the knowledge we have gained is imperfect, provisional, and can be derived only through the play of large

numbers. And yet, it is the best we can do in addressing certain problems. Perhaps Einstein said it best:

All our science, measured against reality, is primitive and childlike-and yet it is the most precious thing we have.

And finally, an understanding of evolutionary science can only enhance our sense of awe and wonder and gratitude for the natural world. Our soul is enriched. As Darwin said, "There is grandeur in this view of life."

Thank you.