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Introduction

Science and technology play major roles in our lives. We directly and indirectly make decisions about what we think to be true, likely to be true, exaggerated, or false. This may involve decisions to spend extra to purchase "totally organic foods," choose to inoculate children against disease, or how to power one's house. We vote on policy by supporting candidates and government initiatives on incredibly complex issues, including climate change, federal regulation of food and drugs, nuclear power, and off-shore oil drilling. The present essay discusses the need to critically assess the avalanche of information we receive on a daily (even hourly) basis from a wide array of sources having a wide array of credibility.

Information overload has been recognized for many years and called by one author "Data Smog."[1] Technology writer Nicholas Carr worries that we may be losing our abilities to focus, concentrate, and be serious in evaluating information as the Internet seems to be "…tinkering with my brain, remapping the neural circuitry, reprogramming the memory."[2] In 1960, the ratio of "media supply" to "media demand" was assessed at roughly 98.[3] The corresponding ratio was estimated by researchers at nearly 21,000 in 2005.[3] These researchers worry: "The digital citizenry may be content with the information it retrieves, but is it any better informed?"[3] In my view we *should* worry: a March 2009 Gallup Poll indicated a bare majority (53 %) of *college graduates* believe evolution theory to be correct.

"Nay-Sayers": Are We Now All Experts on Vaccines?

In the preblog era, information was received from those recognized as having some degree of authority as experts. Families regarded medical doctors as authorities on medical matters. Debates in print or on TV usually occurred between recognized experts.

The Internet has democratized news and opinion in ways desirable and undesirable. A sensationalistic claim can instantly attract a large following. If the claim is later debunked, there is little notice and residual confusion may reign for years. One result is what writer Michael Spector terms "Denialism"[4]—the irrational rejection of rational science and technology. An example is the continuing fiction that vaccinations cause autism.[5] In 1970, only 1 child in 2,500 was diagnosed with autism while the number today is closer to 1 in 150.[5] In 1998, the respected English medical journal, *Lancet,* published a study by Dr. Andrew Wakefield that connected late-onset autism, as well as intestinal lesions, to the Measles-Mumps-Rubella (MMR) vaccine. The blogosphere went into full-active mode. In the U.S., the National Academy of Sciences (NAS), as authoritative an organization as exists, initiated a thorough study of the claimed causal relationship and, by 2004, concluded that none existed. Next, an alleged relationship between autism and the vaccine preservative thimerosal, which contains mercury, "went viral" on the Web.[5] In spite of advice to the contrary by well-informed physicians, many thousands of U.S. and U.K. families elected to avoid vaccinations, thereby placing large populations at risk. Family physicians were no longer seen as allies and medical experts but, to the contrary, stooges for Big Pharma.

The causal relationship between the MMR ("triple") vaccine and autism is totally baseless.[5] In England, Dr. Wakefield had been engaged by a lawyer looking for an opportunity to sue companies manufacturing the "triple" vaccine. A strategy was devised and the 1998 *Lancet* study was published by Wakefield with 12 coauthors. In 2004, 10 coauthors withdrew their names from the published paper and *Lancet* retracted its conclusions. Disclosure that Dr. Wakefield had taken out a patent on a "single" vaccine to prevent measles suggested another obvious conflict of interest. In February 2010, *Lancet* completely retracted the 1998 paper. In May 2010, Dr. Wakefield's license to practice medicine was revoked.[6] How many years will it take now to completely remove the fabrication from the public consciousness?

Emphasizing Doubt and Uncertainty for Politics and Profit

Rigorously speaking, it is correct that a scientific theory can never be absolutely proven true. Unfortunately, business, government, and political and religious organizations often exploit widespread lack of understanding of science to exaggerate such uncertainties. Despite overwhelming evidence of the causal relationship between cigarette smoking and cancer, for decades the tobacco industry emphasized uncertainties in these studies (e.g., animals vs. humans, realistic dose, limitations on human studies, environmental causes).[7] A clever political ruse is to call for tens, even hundreds of millions of dollars to study an issue until the science is "proven beyond a reasonable doubt." That day, if it ever arrives, is likely to be in the very distant future. Millions of dollars for research are certainly much cheaper than billions of dollars for policy and regulation.

Today, the overwhelming scientific consensus is that the Earth's atmosphere and oceans have been warming due primarily to the combustion of fossil fuels and the greenhouse gas carbon dioxide produced. Virtually universally-accepted data establish: (a) the rapid increase in atmospheric carbon dioxide starting in the industrial revolution, (b) the mechanism of warming by greenhouse gases, and (c) the increase in temperatures during this period. Although Democrats and Republicans seek the favor and largesse of powerful industries, the relationship between the administration of George W. Bush and industry, especially the energy industry, led to unprecedented efforts to subvert good science.[8] Former Republican Governor of New Jersey, Christine Todd Whitman, administrator of the U.S. Environmental Protection Agency (2001–2003), resigned in frustration over the efforts of the Bush administration to distort her agency's scientific efforts. It also attempted to discredit and silence Dr. James Hansen, chief of the NASA Institute for Space Studies, who warned, starting in the 1980s, of global warming.[9] These efforts backfired when Hansen was interviewed on the CBS program *Sixty Minutes* (March 19, 2006). Philip Cooney, chief of staff of the White House Council on Environmental Quality, a nonscientist and former lobbyist for the American Petroleum Institute, infamously edited a report by federal scientists on climate change by inserting "significant and fundamental" before "uncertainties" and many other similar modifications.[9]

The "Yellow Rain" Controversy

During the 1970s, tales emerged from Laos, Kampuchea (Cambodia), and Afghanistan concerning "Yellow Rain," employed as a weapon causing sickness and death. In September 1981, Secretary of State Alexander M. Haig publicly accused the Soviet Union and its proxies of employing chemical and biological agents and offered physical evidence. The stakes were extremely high: alleged violations of the 1925 Geneva Protocols (outlawing use of chemical and bacteriological weapons) and the 1972 Biological Weapons Convention (banning possession of biological and toxin weapons). If the Soviets could violate these agreements, then why sign any new treaties with them? The alternative—modernize weapons, stock up, and be ready for total war.

In the January 9, 1984 issue of *Chemical & Engineering News*, the weekly magazine of the American Chemical Society, Lois R. Ember, later awarded a Pulitzer Prize for this work, published a long and highly detailed analysis of the yellow rain controversy.[10] In great detail she described the chemical composition of spots said to be yellow rain, analyses of fungi toxins, fungi ecology, limitations of chemical analyses, and much more. The highly readable and accessible, if challenging, article exposed very serious flaws in the State Department arguments concerning this deeply serious issue.

What Are Some Solutions to Managing TMI in Science and Technology?

1. Perhaps the most important need is for students (and the general public) to become "Information Literate." Of five recognized Information Literacy skills,[11] the ability to critically and ethically apply information is fundamental in the Age of TMI.

2. It is vital that the public understands how science is accomplished and evaluated. Although scientists are conservative in terms of defending established theory, once a scientist can revise or even overturn a theory by applying data that have been thoroughly and impartially reviewed, that scientist will be honored by the community, not treated as a heretic. Honesty is critical. A highly successful scientist may have a research budget of a few million dollars per year. These funds will be lost quickly if dishonesty is discovered. Fresh dollars will dry up quickly if there is even a perception of dishonesty. In this hyper-competitive arena, there will always be far more excellent research proposals than funds to support them.

Modification and revision of theories does not discredit them. Atomic theory, introduced by John Dalton over 200 years ago, was never a target for religious controversy and the types of criticisms hurled at evolution theory. Yet, while Dalton's fundamental theory

remains the same, given its modifications over the past century, he might not recognize his own great concept today. Similarly, when Darwin published evolution theory in 1859, there was no knowledge of genes, DNA, proteins, or enzymes. Yet today, knowledge of homologies (similarity relationships) among proteins and DNA fully support evolution. Thus, the protein hemoglobin is more similar between humans and chimpanzees than between humans and horses. These were effectively predictions made by evolution theory that Darwin could never have imagined 150 years ago. The fact that there have been significant modifications—for example, rapid changes in species at variance with Darwin's view that evolutionary change only occurred very slowly over time—is not a weakness in Darwin's synthesis.

3. It has been argued[12] that scientists should be less diffident in presenting knowledge. To differentiate scientific knowledge from articles of faith, scientists might replace "We believe" with "Scientific evidence supports the conclusions that"; similarly,[12] replace "theory of evolution" with "law of evolution" since the notion of theories as "unprovable" has been used for political purposes. Why not use the term "paradigm" where merited? It is the atom paradigm that underlies our total understanding of chemistry. The evolution paradigm is the scaffold without which modern biological science would collapse.

4. Scientists must be impartial in their research and avoid arrogance. However, scientists are human and it is inevitable that a few well-funded "frequent flyers" will display hubris. Hubris was evident in e-mails intercepted at the Climatic Research Unit (CRU) at the University of East Anglia (UEA) that led to "Climategate." Climategate was gleefully exploited to question the integrity of global climate change research. A March 31, 2010 report, ordered by the U.K. government,[13] and an April 12, 2010 report, by a nonpartisan international group of experts ordered by UEA,[14] fully support the quality of the climatology research while advising increased openness in providing public access to data. Predictably, climate-change deniers claim the reports are whitewashes.

5. A complex science/technology debate needs appropriate clarification and simplification to educate its intended audiences. As a Ph.D. in organic chemistry, I might have done nearly as credible work as Ember in analyzing the "yellow rain" controversy had I devoted six months exclusively to this effort. Her service and skill was to make these complex arguments accessible to me. In turn, I successfully "distilled" key points and presented them to a class of high school and middle school teachers. These teachers were then capable of presenting key points to their students. This "four-level" approach furnishes a model for reasoned public discussion of complex scientific issues.

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