Uncertain Science . . . Uncertain World

Why can't science answer, once and for all, the major questions that make up our headlines:
Is the world warming because of the greenhouse effect?
What would be the dangers associated with a terrorist release of anthrax spores?
What action should be taken against an outbreak of foot-and-mouth disease or BSE?
Why can't we predict the occurrences of earthquakes?

Scientific uncertainty puzzles many people. The puzzlement arises when scientists have more than one answer and disagree among themselves. *Uncertain Science . . . Uncertain World* will help people to find their way through a maze of contradiction and uncertainty. By acquainting them with the ways that uncertainty arises in science, how scientists accommodate and make use of uncertainty, and how they reach conclusions in the face of uncertainty, the book will enable the reader confidently to evaluate uncertainty from their own perspectives, in terms of their own everyday experiences.

Advance praise for *Uncertain Science . . . Uncertain World*

'*Uncertain Science . . . Uncertain World* gives the layman an excellent inside look at how science works and flourishes even though it is immersed in uncertainty. Pollack analyses the paradox that society is unable or unwilling to address environmental problems of global scale – often under the pretence that there's not enough scientific certainty to take action – while at the same time the insurance industry and other businesses routinely hedge the risks attendant to an uncertain future. It's my hope that this very clearly written book, devoid of both polemics and equations, will be widely read by the general public and policy-makers.'
Paul Crutzen, Winner of the 1995 Nobel Prize for Chemistry for work on the ozone hole

'*Uncertain Science . . . Uncertain World* is certain to clarify one of the most fundamental popular misconceptions about science – that it is exact and

certain. Henry Pollack demolishes the mythology about certainty in science with short and clear examples of how uncertainty is both endemic to science and not a cause for paralysis or inaction. This well-written book is a welcome antidote to the misrepresentations of special interests, who misuse scientific uncertainty to stall public policy and advance their own agendas.'
Stephen Schneider, Professor of Environmental Biology at Stanford University and author of Laboratory Earth: The Planetary Gamble We Can't Afford to Lose

'This excellent book will serve as a blast of common sense to counter two dangerous attitudes. One is the desperate search for impossible certainties in a complex world where few comprehend the meaning of probability. The other is a belief that scientists are the magicians of today who can deliver certainty by 'scientific tests'. Pollack writes with vigour and clarity about big issues such as global warming, and reading this book ought to help us to become better judges when 'facts' conflict. There are few more important attributes we need for the twenty-first century.'
Aubrey Manning, Professor Emeritus at the University of Edinburgh and author of An Introduction to Animal Behaviour

'Public policy debates are constantly getting stuck in the mire of perceptions about scientific uncertainty and risk. Yet science is no different to many other areas of human experience in that uncertainty and risk are inevitably present. In a readable, entertaining presentation, Henry Pollack removes some of the mystery surrounding scientific uncertainty by placing it alongside examples from everyday life.'
Sir John Houghton, Co-chair of the Intergovernmental Panel on Climate Change and author of Global Warming – The Complete Briefing

'At last we have a solid, scientific look at the vexing subject of uncertainty. You may not be more certain about some subjects when you finish this book, but you'll understand why.'
James Trefil, Professor of Physics at George Mason University, and author of A Scientist in the City

'Too often, scientists fall into the quicksand of technical jargon and fail to communicate important information to the general public. In *Uncertain Science . . . Uncertain World*, Henry Pollack uses plain English and engaging examples to explore uncertainty both in science and everyday life.'
Neal Lane, Professor at Rice University, former Science Advisor to President Clinton and former Director of the US National Science Foundation

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HENRY N. POLLACK

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To Lana, John and Sara . . . the loves of my life

Contents

Acknowledgments

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About the author

No book can be free of the background and experiences of the author, so let me tell you a little about myself.

I was born and schooled in Nebraska, in the agricultural heartland of America. My mother was a traditional homemaker, my father raised livestock on the family farm. As a young boy in Nebraska, I thought the world was made of dirt, good rich soil that with a lot of hard work yielded good things to eat. In 1954, at age eighteen, I went off to college at Cornell University in upstate New York, a long way from my midlands home. At Cornell, the bedrock is well exposed in deep gorges carved by small streams tumbling down to Cayuga Lake, one of the spectacular glacially sculpted Finger Lakes of New York. There I learned that the soil was only a thin veneer on top of layers and layers of rock, the real *terra firma*. And in those layers were fossils, the record of life on Earth in ages past. I was awestruck by the vastness of time so revealed, and in virtually no time I was firmly hooked on geology as a career choice. The entire Earth was my field of study, and in a sense I never returned home: "How can you keep 'em down on the farm, after they've seen the Paleozoic?"

I did return to the University of Nebraska for a master's degree (lured by an excellent faculty in geology and the bargain tuition of $90 per semester) and then went on to the University of Michigan to study for a PhD and to Harvard for a postdoctoral research position. Between Michigan and Harvard, I married Lana Schoenberger, a Michigan girl, and when a teaching position was advertised at the University of Michigan a few years later, I interviewed and was delighted to be selected for the job. Lana and I have been in Ann Arbor, home of the University of Michigan, ever since. We had two

children, Sara whose life was cut short by an accident at age 14, and John who is an author and writer living in Washington, DC. As a family we twice lived abroad, in Zambia in 1970–71, and in England in 1977–78.

At the University of Michigan, I have taught at every level of the curriculum, from introductory undergraduate Earth Science courses for non-scientists to specialized graduate seminars, and I have taught in virtually every setting: lecture, laboratory, seminar, and in the field. In my department, unlike some others, responsibility for introductory courses is placed in the hands of the more experienced faculty, and consequently I have increasingly taught courses for undergraduates who will not be pursuing scientific careers. The challenge in such courses is to develop in students an awareness of the ways science interfaces with their lives, and to enable them to understand both the strengths and frailties of the 'scientific method'. I have taught the generic first course in geology, 'Geology 101', and other courses with titles like Geology of the National Parks, Climate and Mankind, Geology and Climate of the Planets, and Science and Politics of Global Warming.

My principal research efforts for many years addressed Earth's internal heat and how that heat is lost over time. The Earth's heat is the fuel for the big 'engine' that drives plate tectonics and continental drift, yielding earthquakes and volcanoes as a byproduct. Those large-scale processes that shape Earth's surface are actually manifestations of the internal processes that enable the planet to cool slowly. For many years, my students and I made field measurements of the heat loss from the Earth's interior in Africa, South America and in the USA. In simple terms, when people ask me to describe that process, I often reply that I go out and take the Earth's temperature in wonderfully remote places around the globe.

Over the past decade, my geothermal research has taken a new direction. My colleagues and I came to recognize that the temperature profiles of the outer few thousand feet of the Earth's crust comprised an archive of the planet's changing climate over the past millennium. The underlying principle is that if the surface of the Earth is

warming (or cooling for that matter) the rocks below the surface will feel it and record it. The longer the change at the surface persists, the deeper the warming will penetrate into the subsurface. In the context of the important debate about global warming and its probable causes, the thermal information contained at these depths in the Earth's crust enables a comparison of the Earth's surface temperature in both the industrial and pre-industrial era, and it provides an estimate of the size of the human contribution to climate change.

In an academic career of this duration, I have also had the opportunity to gain administrative experience. I led the Department of Geological Sciences as Chairman for a period, and I also served the college administration as the Associate Dean for Research. In the national scientific community, I have had the opportunity to serve on several advisory panels for the US National Science Foundation's Division of Earth Sciences. These panels evaluate research proposals from scientists around the country who are seeking funding for their research programs. I also served four years on the American Geophysical Union's Committee on Global and Environmental Change, which among other tasks has been responsible for preparing the position statement of this professional organization on the subject of global climate change.

As is the custom at many universities, the faculty, in addition to their primary responsibilities in teaching and research, engage in service activities for the university, community, state, and nation. In my department, I spearheaded the development of our alumni relations program. Aside from the obvious benefits that financial contributions from alumni bring to the students and faculty of the department, there are the more subtle benefits that come from regular interactions with graduates out in the workaday world, an awareness of circumstances and constraints, problems and solutions that these people face in their professional lives, and their perceptions of science-based issues such as water quality standards, environmental cleanups, and global climate change. These interactions help academics to assess the relevance and effectiveness of their curricula and programs.

Over the past decade, I have frequently had the opportunity to discuss scientific issues such as global warming, radioactive waste disposal, and earthquake prediction with many groups outside the University. These discussions are generally with mature, thoughtful, educated people with non-scientific backgrounds. The venues for these discussions are diverse, but include meetings with University of Michigan alumni groups around the country and the world, talks to community service organizations such as Rotary and Kiwanis, workshops with professional journalists, expeditions to Antarctica with groups of eco-tourists, testimony before a US Senate committee, briefings at the White House, seminars for legislative staff at the state and federal level, interviews with the press and on radio and television, and call-in shows on public radio. Through these diverse activities, I have learned of the many misconceptions that educated people from all walks of life harbor about the scientific enterprise generally. Perhaps at the head of the list of misconceptions is the concept of uncertainty.

Scientific uncertainty puzzles many people, not because they have a hard time accepting that scientists do not have answers to every pressing question. The puzzlement arises when scientists have more than one answer and disagree among themselves. I have found that one of the principal contributions that I make as a teacher is to help people to find their way through a maze of contradiction and uncertainty. By acquainting them with the ways that uncertainty arises in science, how scientists accommodate and make use of uncertainty, and how they reach conclusions in the face of uncertainty, I have enabled them to evaluate uncertainty confidently from their own perspectives, in terms of their own experiences. This book has developed because I wish to share these views more widely.

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