Real progress in understanding how the natural world works only truly began with the Enlightenment, with its guiding principle that the truth is to be found not by appeal to authority but by experimental tests and evidence. Unfortunately, but understandably, science is too often seen—in school, in university and especially on quiz shows—as certainty. In fact, science (including social sciences, engineering and medicine along with the more narrowly defined physical and biological sciences) is better seen as organized scepticism: a journey, over time, toward contingent understanding guided by experimental tests and sceptical questioning. Essentially all such journeys are beset by uncertainties of various kinds. This article sketches some of the consequent problems, particularly in relation to science advice, policy making and public engagement.

1. Introduction

While most previous generations believed their own time to be special, humanity’s current predicament is truly singular. By various measures (e.g. WWF 2010) our combination of total numbers and average environmental impacts per person now has a magnitude comparable with—perhaps a bit above or below—that which is globally sustainable. And yet populations are still growing, greenhouse gas emissions are still increasing, threats to biological diversity are growing, available supplies of fresh water are decreasing relative to demand, and much else. The need for effective use of scientific advice in governments’ policy making, and more generally for public understanding of and engagement with such advice, has never been greater.

In what follows, I will first emphasize that science—especially at the frontiers of research—is rarely the unambiguous certainties we encounter in school exams or quiz shows, but rather is a process best seen as organized scepticism or as a way of asking the right questions. I then indicate some consequent implications for science advice in policy making, interpreting science in the widest sense to include social sciences, medicine and engineering, along with the physical and biological sciences. This catalogue of ideal processes for making wise choices is, however, easier to articulate in theory than to execute in practice. Hence the concluding section discusses some of the barriers that intrude between the ideal and the actual.

*robert.may@zoo.ox.ac.uk

One contribution of 15 to a Discussion Meeting Issue ‘Handling uncertainty in science’.
2. Science as a way of knowing

The widespread misapprehension that ‘science’ is essentially always about unambiguously factual answers is both understandable and unfortunate. It is understandable because the science taught in primary and secondary school, and in much of tertiary education as well, deals with topics we really understand very fully. It makes for sensible curricula and easily-marked exam papers. *A fortiori* the answers to ‘science’ questions on quiz shows cannot admit debate, and therefore promote the illusion that science consists of boring trivia about the technical names for things, or definitions memorised by rote.

This is deeply unfortunate. Although many areas of science are extremely well understood, a lot of the topics that have attracted public attention in recent times lie at or beyond the frontiers of the currently known: might GM crops hybridize with other plants to create superweeds; how soon might stem cell research lead to major medical benefits; to what extent might a generic H5N1 vaccine provide protection if and when avian flu becomes transmissible among humans; and much more.

Much, perhaps most, of scientific advice to government policy makers is routine, based on well-explored areas of science. When this happens, public expectations—‘tell us the facts’—can be fulfilled. To the contrary, there are many topics of concern, both currently and in the recent past, which lie in areas where there is still significant scientific uncertainty. When this happens, it is essential that we understand and acknowledge that science is as much a way of asking illuminating, testable questions, as it is a collection of tidy and certain answers.

It is easy to say there are areas of science where assured answers can be given, and on the other hand areas where uncertainty still reigns. The critical question, however, then becomes: who decides whether a given question lies in the area of certainty or uncertainty? Or, more accurately, who decides where along the usual continuum, from initially recognizing a problem to eventually having a fairly confident understanding of it, we lie at any particular time. All this leads to the antecedent problem: who decides the deciders?

This is not an abstract philosophical question. It is the crux of many recent and contemporary quarrels. One can, for example, assemble a lot of evidence to show how implausible it is that any of the many GM crops grown in recent years will cross-pollinate with some other plant species to produce an invasive weed, but those opposed in principle to GM crops can justifiably argue a lack of certainty.

So what is meant by ‘certain’ in science? I answer this question narcissistically, with an extended quotation from my 2002 Anniversary Address (May, 2003): ‘The question arises, albeit in rather trivial form, with some of the correspondence that the President of the Royal Society (among others) customarily receives, seeking sponsorship or patronage for an idea which ‘the establishment’ has dismissed. Commonly, such letters describe perpetual motion machines. I do not read them. However ingenious, not to say incomprehensible, the mechanism of such a machine may be, it violates the Second Law of thermodynamics. The Second Law is a cornerstone of physics, and if it goes, so does most of modern physics. In common with most colleagues, I regard the Second Law as being pretty much as certain as that day will follow night (which, of course, is itself not certain in the sense that $2 + 2 = 4$ is certain)."
‘By this time, other biologists and I regard the essentials of Darwin’s explanation of how living things evolved, by ‘descent with modification’, as having much the same status as the inverse square law. However, you can find literally thousands of people with PhDs in the USA who believe the world was created, literally as described in Genesis, some time in October 4004 BC. This illustrates, in telling fashion, the difficulty in giving a crisp answer to what is certain.

‘And, of course, there are innumerable areas where virtually all agree that uncertainty still reigns.’ As just one example, we lack any widely-agreed explanation for why the interval between infection with HIV and the onset of AIDS (in the absence of drugs which suppress viral replication) is so long and so variable; several groups believe they may have the essence of an answer, but, despite the huge importance of HIV/AIDS and much work, this problem is not yet solved.

More generally, on any scientific issue, there is, at any one time, what might be thought of as a landscape of opinion. In the early stages of research, various ideas are proposed, producing lots of little clusters of opinion, like little hillocks on the landscape. As questions are raised, observations noted, and experiments designed to discriminate among possibilities, some of the bumps shrink to zero, others attract support and grow. As things progress, we tend sometimes to find two ‘schools’ or hilltops, rarely of comparable size, or perhaps many hilltops, with some growing and others fading. Ideally, over time, confident understanding emerges, and appears as one tall, triumphant peak on an otherwise vacant landscape.

In practice, this rarely happens. Pockets of aberrant opinion may hold out, with proponents either ignoring decisive evidence and experiments, or alternatively inventing ever more baroque ways of modifying their views to accommodate such facts. And, of course, such situations arise even more implacably if some fixed ideological position commits an individual to a position, transcending any data.

In general, however, the historical landscape of any major scientific question has its own evolution, from pimply plurality, through contending hillocks, to a single and narrowly-spiky mountain in maturity. It is important—although often difficult—at each stage in the evolution of such a landscape to maintain a clear sense of its geomorphology. Unfortunately, the media’s praiseworthy aim of always presenting a ‘balanced’ account can have difficulty tracking such an evolving landscape. The temptation, whether in print, radio or TV, is to seek to present the ‘two sides’, as if reporting a sporting event.

A particularly topical example of this is to be found in the recent debates about the extent to which human activities—burning fossil fuels and putting greenhouse gases into the atmosphere—are causing global warming, as distinct from warming deriving from natural causes. Early warnings were suggested over a century ago. But we are dealing with a hugely complicated and nonlinear dynamical system, and even three decades ago there were very significant uncertainties associated with our quest for understanding. With computational power doubling every eighteen months, things have greatly advanced since then, and the basic facts are now unambiguous enough to be agreed (although there do remain significant uncertainties about the speed of some processes—ice caps melting, or permafrost thawing, or oceans becoming more acidic, and so on). The basic facts are now clear enough that in 2005 the G8 science academies along with China, India and Brazil asked that we ‘identify cost-effective steps that can be taken now
to contribute to substantial and long-term reduction in net global greenhouse gas emissions [and to] recognize that the delayed action will increase the risk of adverse environmental effects and will likely incur a greater cost. These academies created the process of organized scepticism which we call ‘science’, and their recognition that we are well past the point where we should doubt the serious consequences of climate change deserves attention. But this virtual unanimity within the community of relevant scientists is bizarrely at variance with a recent opinion poll in the UK, which found 56% tending to agree (11% of them strongly agreeing) that ‘many leading experts still question if human activity is contributing to climate change’.

3. Science advice and policy making

Against this background, seeing the quest for scientific knowledge as a journey guided by organized scepticism, how do we give scientific advice for policy making? How do we make sound choices in ways that engender public confidence?

The recipe for arriving at scientific consensus on a given issue—climate change; the evolutionary origin of species; safety of the MMR vaccine; GM foods; you name it—is relatively easily stated. Bring together the appropriate experts, consulting widely and deliberately seeking and considering dissenting opinions. Identify conflicts of interest, but do not necessarily use them as grounds to exclude individuals. And, above all, do all this openly. In many practical circumstances it is most important, yet most difficult, to separate the scientific facts and uncertainties—which must serve as a constraining background—from policy choices. In addition, one should aim to assess the magnitude of risks, whenever possible, and to manage them proportionately. When real or perceived uncertainties remain, give people choices whenever possible (e.g. label GM food).

This relatively simple list of precepts was set out in the Protocols for Science Advice in Policy Making issued by John Major’s Government in 1996. They have subsequently been reviewed and reaffirmed by Tony Blair’s Government in 1997 and 2000 and by Gordon Brown’s Government in 2006 (at each iteration they have grown bulkier, but their essentials remain unchanged). Independent support for such rules also has been provided (with acknowledgement of the originating 1996 document) by the Phillips Inquiry into BSE in 2000 and the House of Lords Science & Technology Select Committee in 2000 (the Jenkins Report).

Enunciating an ideal process is one thing. Embedding it as standard operating procedure is another. Eloquent testimony to this sad fact is provided by the recent episode of Professor Nutt’s dismissal from the Chair of the Advisory Committee on the Misuse of Drugs (ACMD). Indeed, given the apparent need to reincarnate such protocols for science advice in policy making at regular intervals, I suspect similar rules were enunciated prior to 1996 and that I am guilty of being unaware of them!

Quite apart from this ‘embedding’ issue, there are other major problems in implementing such guidelines for good practice.

For one thing, the scientific facts are simply not relevant for many individuals and groups whose views are determined by fixed, unquestioning ideologies (religious beliefs, political doctrines, and so on). For such individuals, no observed fact or experimental result can ever prevail over the apodictic ‘truth’ of a

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fixed belief or canonical revelation. Rather than engage with the scientific facts and uncertainties, such ideologues and extremists will pick and choose among them—or deliberately misrepresent them—in support of immutable beliefs. It is a category error to call such people ‘sceptics’.

In the tumult of voices that can arise in such disputes, the media—print, radio, TV—are often unhelpful, for two reasons. First, their primary aim, which is not at all unreasonable, is to get your attention—to be read, listened to, watched. Only secondarily do they aim to inform; indeed, they cannot hope to inform if they do not attract your attention. Second, the media’s praiseworthy desire for ‘balance’ in reporting too often leads to presenting ‘two sides’ as if reporting a soccer match. But this can, and often does, seriously misrepresent the state of the scientific evidence, where ‘one team’ is the consensus view of the science community and the ‘other team’ is a tiny minority. For example, consider the debate about whether HIV causes AIDS. A research community of order 100 000 has by now established this as a fact. But a small travelling roadshow, including one Nobel Laureate, can still be assembled to deny it. And there are many other examples: from MMR vaccination in the UK to the essential reality of anthropogenic climate change (albeit with remaining uncertainties about the timescales and magnitudes of some nonlinear processes).

Furthermore, it is often difficult to make an accurate assessment of risks, and even when an accurate assessment can be made, many people’s subjective assessment is very different from the objective facts. Such subjective attitudes can create their own reality and impede effective policy actions.

Even a policy of ‘label and let the consumer choose’ has its problems. For one thing, there is a question of individual risk versus collective risk (e.g. an individual may choose the health risk of smoking, but there remain associated risks of ‘passive smoking’ for family or in public places; other examples abound, particularly in relation to vaccination policies and herd immunity). For another thing, there is the question of individuals making bad choices for dependent people, such as young children.

4. Coda

The first paragraph highlighted the global environmental problems we currently face. It might seem that I have wandered far from this opening theme in focusing on guidelines for science advice in policy making by Government and other organizations, and the many, varied and as yet unsolved difficulties in implementing them. But I believe these difficulties lie at the heart of our failure to confront the problems of tomorrow’s world with sufficient urgency. Clarity of fact-based understanding is increasingly important for effective action to address this range of environmental and social problems. But such clarity of basic understanding has to be matched by broad public engagement with the issues and consequent motivation to endorse necessary actions. It is for this reason that the tensions between the organized scepticism of the scientific process and the comforting certitudes of dogma and belief are particularly unfortunate.