The Post-Normal Science of Precaution

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Our present situation

We are now losing the comforting image of science that has long been so important for the Western optimistic view of humanity's prospects. Science is undoubtedly the great driving force of modern global civilisation. In the conventional understanding of science, curiosity-driven research discovers nuggets of fact, and beneficent application then shapes them into tools that enable the conquest of nature for the improvement of human welfare.

At every phase of the process, science now becomes problematic and compromised. Priorities for research are set not by scientists but by the external interests that supply funds. The research community is itself elitist; those disadvantaged by gender or otherwise (as by non-English native language) are left behind. The work of research on sentient beings raises ethical problems that cannot be answered by science alone. Control of the intellectual property embodied in the products of inquiry is increasingly expropriated, either from the scientific researchers or from the rightful owners of traditional knowledge abroad. Applications are directed to the furtherance of profit and power; issues of safety and ethics are seen as secondary. Regulation, on behalf of humanity and the environment, comes after the event, is always counted as a cost on 'growth', and is therefore characteristically too little and too late. And the degradation and destabilisation of the natural environment as a result of globalised science-based industry increasingly threatens the survival of civilisation itself.

Up to now our industrial society has developed on the principle that innovations are safe until proved dangerous. Turning it round to the adoption and implementation of a 'precautionary principle' is an enormous task, which many vested interests will resist and are already resisting. But change is inevitable, for the old, secure order does not hold. When environmental and health policies involving science are debated, in place of facts we have uncertainty and even ignorance. We can no longer separate ‘nature’, ‘science’ and ‘society’; the combination of lifestyles and markets drives innovation in the science-based industries, and their cumulative effect is to further disrupt the complex natural systems on whose stability we all depend. But the environmental effects are downstream, and so are often delayed and diffuse. Even global climate change does not have a simple ‘cause’ that can be identified and eliminated. Hence the old belief in scientific certainty is lost; in place of objective facts, we have an open clash of interests and world-views.

The economy's need for a skilled and sophisticated workforce has given rise to a sophisticated public, where 'consumers' also see themselves as critical 'citizens'. The steady growth of public support for officially disapproved 'alternatives', as in nutrition and medicine, is a reminder that the consent of the governed can no longer be taken for granted in science-related issues. And there is a rapidly growing sector of environmental and 'community' research with a local, populist base, that explicitly addresses the problems ignored by mainstream science and its commercially-driven applications. (Community Research Network 2002)

The collapse in the state's monopoly of scientific expertise has consequences for its authority in the governing of society. For the ideology of modern science (deriving from Hobbes and Locke as much as from Descartes and Galileo) has become the rationale and justification of modern government. Scientific expertise has gradually replaced divine authority, birth, and wealth as a source of legitimacy for governance. But as that whole system was developed in a context of triumphal conquest and material growth, it now faces a crisis of confidence, of legitimacy and ultimately of power. We need to go back to the Reformation to find parallel crises of equal depth.

Two approaches to science

Now we can discern the emergence of two approaches to the understanding and management of the scientific enterprise. The first is what might be called “mainstream science,” which carries on with inherited attitudes and assumptions of inevitable and irrestable progress, in spite of the drastic changes in the new conditions. It proudly maintains the reductionist tradition of Western science, in which complex systems are assumed to be capable of being taken apart, studied in their elements and then reassembled. In this old paradigm, systemic properties are deemed incapable of scientific study and are therefore to be ignored. The leading, cutting-edge science now is molecular genetics, with applications in the engineering of life itself. The private sector is increasingly dominant, either converting academic researchers to contractual out-workers, or doing all the work on a speculative commercial basis and therefore needing an immediate return on capital. The ruling paradigm has become 'one gene = one disease = one drug = one patent = one monopoly'.

The social processes of research have become transformed. Discoveries are frequently classed as inventions, in order to secure patent rights; and 'public knowledge' exists only on the margins, displaced in the important areas by 'corporate know-how'. Independent research has become hazardous, owing to the threats of litigation over claimed patent infringements. In the rush to 'progress', the problems of safety and ethics are unloaded onto national regulatory bodies, with the warning that there are always less restrictive locations to which the research could run away. The leading area of science, biomedicine, increasingly invades the domains of the private and the sacred. Public compassion for the sick is regularly enlisted in the service of corporate imperatives. Since there will always be a heartrending story of medical need, the arguments against any proposed development, however dangerous or grotesque, must contend with real cases of human suffering for which relief is unfailingly promised.

This new industrialised science, combining scientists' hubris in discovery with corporate greed in commercialisation, presents novel hazards to civilisation. The ruling assumption is that anything that can eventually be done, will then certainly be done, whether it be (for example) human clones or xeno-transplants. This is, after all, the spirit of 'progress' that seemed so successful until a mere half-century ago.

The contrasting approach to science, still in the very early stages of development, could be called 'precautionary', since it is usually concerned with reacting to the unintended harmful effects of progress. Its style is 'post-normal'; it lies at the contested interfaces of science and policy. It addresses issues where, typically, facts are uncertain, values in dispute, stakes high and decisions urgent (Ravetz 1999). The post-normal style of problem-solving has matured first in some areas of medicine and public health, where there are large, well defined constituencies with a high personal stake, and also where methodological issues are explicitly political. Thus we have had AIDS and Gulf War Related Illnesses; even the fundamental definition of the problem, whether it is a disease to be researched and treated, or an illness to be experienced and managed, can be crucial for policies at every level (Zavetoski et al 2002).

A good example of the sort of issue where the post-normal approach is urgently needed is the study of environmental toxicants. We are living with the effects of the myriad pollutants that have been (and are still being) dumped into the environment at such a rate that prior testing would be a significant extra expense and retrospective testing is impossible. This has arisen because our industrial economy has hitherto operated on the assumption that all innovations are safe until proved dangerous. When human health effects are discovered, they are frequently long-delayed and are masked by other causes. The processes may well be synergistic among different toxicants, and causes are extremely difficult to prove by the criteria and procedures of lab-based science. There will be powerful vested interests, industrial, regulatory and professional, who would rather not know that such problems exist. Yet eco-toxics, including endocrine disrupters, are already causing palpable damage to wildlife in the form of sex changes; and their eventual effects on humans, although perhaps more subtle, could be profound in their consequences. Thus the facts are inevitably uncertain, the values in dispute (between populations at risk and the pollutors), stakes are very high, and decisions urgent - a perfect case if post-normal science.

The traditional twin goals of science, the advancement of knowledge and the conquest of nature, are insufficient to guide inquiry in these post-normal situations. There is instead a medley of issues from ethics, society and ecology, which might be summed up in two terms: safety and sustainability. Both of these involve science and technology, but at their core are positive visions of humanity, its welfare and its destiny. In this sort of science there is no neat overarching theory that is to be tested precisely under the unnaturally stable and controlled conditions of the laboratory. This new science does not have the luxury of abstracting from the complex problems encountered in the real world; it must cope with them directly. These include not merely the complex interactions at the level of the natural world, but in addition their synergies with profit, bureaucracy, poverty, exploitation and war. For comprehending all this, a science needs clarity and self-understanding; the isolated puzzle-solving approach of traditional 'normal science' is self-defeating here.

In this new sort of science, problems become salient as a result of a broad public debate. Issues are forced into public and official consciousness by campaigns involving activists and the media, which reveal suspected scandals and disasters. Once public trust is lost, experts' authority become very difficult to maintain. Persons involved in these debates discover that scientific prestige or official status is no guarantee of credibility or even of assured honourable behaviour. Scientists' claims of preserving independence, or of avoiding conflict of interest, are weakened when their research necessarily involves collaboration with institutions identified as those who are making the problem rather than solving it. For the researchers themselves, engagement with policy is a very different type of career; the traditional rewards for successful puzzle-solving on tame abstracted problems do not apply here. Indeed, there is no Nobel Prize for safety; up to now, the academic research community has not yet adopted precaution in its criteria of excellence. By contrast, some political institutions, notably the European Commission and the European Environment Agency, are struggling to integrate the Precautionary Principle in their programmes; and in this they also recognise the issues of the democratisation of expertise (European Commission 2001)

In the course of a dialogue that includes the 'extended peer community', lay participants show their competence in scrutinising research reports in relation to their quality in this extended setting. The public has discovered that the claimed scientific facts can be as controversial as the underlying ethical and political principles. This realisation fosters greater clarity about perspectives and assumptions than was hitherto the case in 'normal science'. Since uncertainty cannot be tamed by statistical techniques whose value-commitments are concealed, debates will explicitly involve the participants' different agendas and perspectives. These produce conflicting criteria of quality and hence different principles of experimental design; scientific methodology itself becomes politicised. Regulatory principles like 'absence of evidence of harm is not evidence of absence of harm' are regularly invoked in public debate.

After many generations of propaganda for science proclaiming its freedom from values, the secret has leaked out that all statistical tests are value-loaded, necessarily designed to avoid one or another sort of error (Shrader-Frechette et al. 1997) Without going into technicalities, we may say that any test might be overly selective, rejecting correlations that are probably real; or it might be overly sensitive, accepting correlations that are probably accidental. This distinction is most frequently expressed through a 'confidence limit', where a high confidence limit protects against over-sensitivity but makes the test vulnerable to over-selectivity. What is appropriate for a laboratory experiment, where the main concern is protecting the research literature from spurious results, may be quite inappropriate for exploratory or monitoring research, where weak signals of harm may be all that we have.

It is impossible to design a statistical test which avoids both types of error; there must be a choice, made by someone, somewhere. Even if 'normal science' practitioners have no knowledge of the source of the particular value of the confidence limit that is standard for their field, they are involved in making a choice between the two types of error. The result of that value-laden choice shapes both our knowledge and our ignorance. For if a weak correlation representing a warning of harm is rejected as ‘not significant’, the research goes down the memory chute and hardly anyone knows that it was ever tried. It is ironic that those who proclaim the necessity for old-fashioned 'sound' science, accepting only orthodox research designed against over-sensitivity, are actually giving aid and assistance to those who demand the right to pollute the planet until it is rigorously proved that they are doing harm.

The presence of values in all research is a reminder of the related impossibility of eradicating uncertainty. Centuries of indoctrination have led us to blieve that real science achieves certainty, preferably in numerical form. Anything else is ‘soft’, girlish and of low status as knowledge. This ingrained prejudice has had two deleterious effects, both of which harm the prospects for a precautionary science. First, any research that has quantitative inputs and mathematical arguments, is accepted as inherently scientific even if it is totally nonsensical. The vast industry of computer modelling, much of whose output is essentially vacuous, benefits from this illusion (Ravetz 1998). In addition, fields of inquiry with severe uncertainties are dismissed as worthless. Since precautionary science operates just in such areas (otherwise it would not be necessary), all its work is at risk of being despised or neglected by the mainstream elite scientists. The great lesson of post-normal science is that the quality of results does not depend on the elimination of uncertainty. Rather, the skilled management of uncertainty, along with the recognition of decision stakes, is the key to quality, especially in the precautionary fields. (See Funtowicz and Ravetz 1990)

The products of the work of precautionary inquiry are generally in the public domain, but are likely to be found outside the typical elitist published literature. In this sort of science, quality-control, or more generally quality-assurance, is very different from that in mainstream science. Here the 'peer community' is extended beyond research colleagues and industrial sponsors. Since the products of research are deployed in policy processes, all concerned members of the public are involved. And when such work is done well, there is a process of mutual learning among those with different perspectives and commitments, including the scientists themselves. The very idea of 'science' expands beyond stylised inquiries done within artificially controlled conditions, and comes to include effective problem-solving in all societal and cultural milieus.

Of course the two sorts of science are not of totally distinct. All policy-relevant research is now subject to public debate, and is sometimes regulated for its ethical and safety standards. Many prominent research scientists, and editors of leading journals, have come out against the unbridled commercialisation of their fields of inquiry. And on the other hand, much ‘normal’ research is deployed in the course of developing ‘precautionary’ science and appropriate technologies. Examples are to be found in global climate modelling, on the one hand, and alternative energy technologies on the other. Further, those large firms that are adopting the 'sustainability' agenda will promote research that to some extent is precautionary in intent. Given all of those encouraging trends, we must still recognise that up to now the overwhelming bulk of resources, and of prestige within science and technology, have been devoted to 'progress' rather than 'precaution' Moreover, the ongoing tendencies to the commodification of the scientific process, and its incorporation in the concerns of private and state institutions, make real change even more difficult. So long as the major institutions, state and private, are committed to continued material growth with privatized knowledge at its base and with 'sustainability' merely as an afterthought, there will be little chance of accommodation between mainstream and precautionary science.

Precautionary Science as Post-Normal

How we describe this new sort of science is to some extent a matter of convenience. In the context of the conference that stimulated this essay, 'precautionary' is appropriate. In others, we might think of 'sustainability', or perhaps 'community' or 'citizens'. Is there any concept that lends unity to all these separate perceptions, each valid and illuminating in its own way? We have suggested 'post-normal', as it is not restricted to any particular function or aspect of the new sort of science, and it also suggests some very important features. There is a general sense in which these times are no longer 'normal', in that the comfortable assumptions about science and progress, so long established in Western thought, have been seriously weakened. The title is a reminder that science itself must adapt to this new situation. And there is an important concept in the recent philosophy of science, that of 'normal science', which serves as a contrast to the sort of science that we are describing and proposing. The philosopher T.S. Kuhn described 'normal science' as the sort of research that is devoted to 'puzzle-solving' within a 'paradigm' that must be accepted uncritically (Kuhn 1962). As he put it graphically, it is the sort of thing that all scientists do most of the time, and most scientists do all the time. He argued that in spite of its anti-humanistic tendencies, this style of research has been successful in creating the great edifice of scientific knowledge. We argue that such a conception of science has now become part of the problem; and that if science is to be organised around precaution, sustainability, safety, community or some related goal, then that style must be replaced by another. Such a change would constitute the sort of ‘paradigm-shift’ that Kuhn associates with his concept of ‘scientific revolution’; and so if ‘precautionary science’ may be considered revolutionary in Kuhn’s sense.

In the post-normal approach, the essential feature of this new, appropriate sort of science is its methodology. Unless this is understood, then all the desired applications of science to its new tasks will be frustrated and misdirected. There will be no way to refute the claims of established expertise to control the definition and solution of these new problems along traditional lines. The post-normal approach focuses on the central dogmas of old-fashioned scientific methodology, its supposed perfect objectivity and certainty. In traditional, 'normal' scientific practice, value-commitments were concealed to the point of being unknown to most practitioners, and uncertainties were recognised only if they could be tamed by statistical techniques. By contrast, under the conditions of post-normal science, both 'systems uncertainties' and 'decision stakes' can be high, to the point of dominating the strategies for problem-solving. By ‘decision stakes’ we mean the investments and commitments, personal as well as commercial and institutional, that are at stake in the inquiry. A participant with very high stakes will naturally exploit all systems uncertainties in the argument in the defense of their interest. Under these conditions, a narrowly trained expertise can be irrelevant or even counterproductive. Then an 'extended peer community' must be involved. That new community will have 'extended facts', far beyond the peer-reviewed published literature (itself elitist in effect although not necessarily so in conscious intention); and these may include 'housewives' epidemiology', local knowledges, and investigative journalism.

We show the relation between the new and the old sorts of science by means of a diagram. This includes a transitional case, which helps to explain the difference between old and new sorts of science. In relation to policy issues, where both systems uncertainties and decision stakes are low, we have 'applied science', the equivalent, in the policy context, of Kuhn's 'normal science'. There is an intermediate case, where either aspect is significant. For significant uncertainties, we may think of the engineer, coping with nature not completely tamed; and for significant decision stakes we may think of the surgeon, whose error may cost a life. Both sorts of professionals may well use science in their work, but their task cannot be reduced to the application of science.

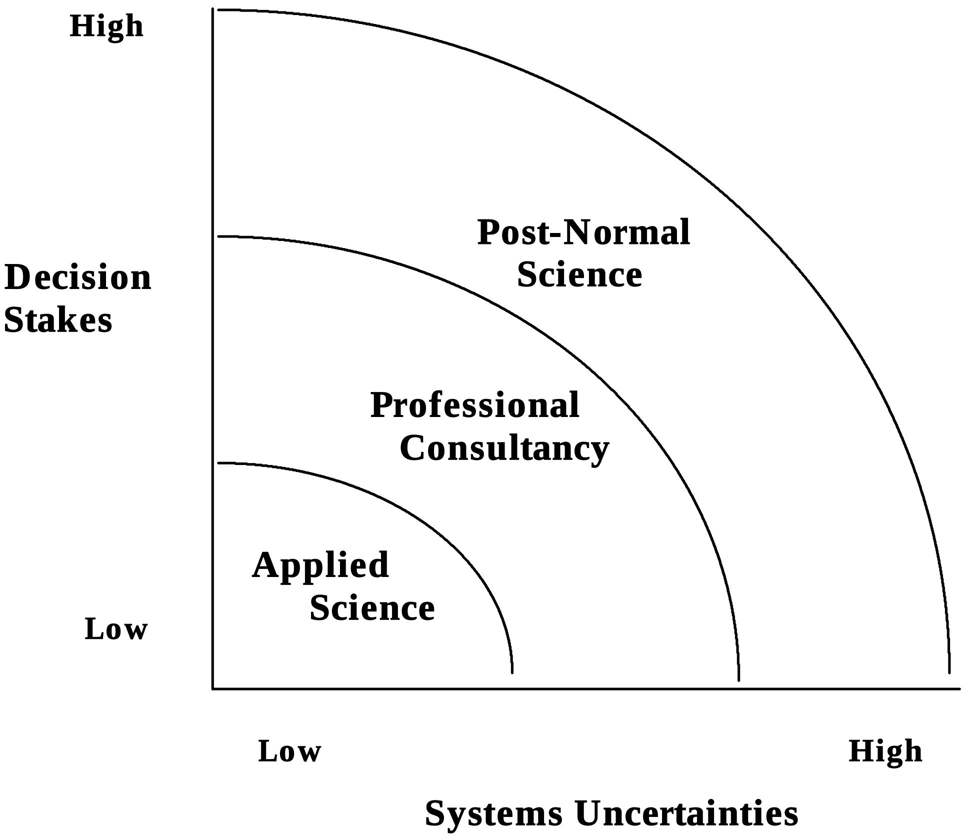

Figure: Post-Normal Science

Then furthest out we have the sorts of problems for which even the professionals' skills and commitment are insufficient; where deep uncertainty or even ignorance swamps our knowledge, and where the value-commitments of participants set incompatible frameworks for the policy issue in dispute. Resolving such issues requires new skills and attitudes. Dogmatic scientific demonstration gives way to open-ended dialogue. All participants learn to respect the others' approaches, so that there can be a creative process of resolution. None of this is easy, and success is far from guaranteed. But it is the only way forward, in the challenges we facing in coping with the problems that our inherited socio-technical system has created.

Cultural perspective and issues of quality

These sudden and broadside changes in the situation of science amount to a serious culture shock. For many generations science had been the main embodiment of visions of progress for humanity; those who opposed the advance of science had become increasingly marginalised. Now, over the course of a mere half-century (starting with the atomic bomb and then *Silent Spring*) all the earlier verities have become contested and compromised. Science is no longer plausibly conceived as an obedient servant of humanity; and instead of conquerors of nature we may seem rather more like the sorcerer's apprentice. But the existing institutions of science are not at all well prepared for bringing about the change in consciousness that will be required for developing a 'precautionary' science alongside the dominant mainstream sort.

In retrospect it appears that, in spite of all the traditional propaganda about science and the freedom of thought, in many ways science inherited the dogmatism of the literalistic religious world-views that it supplanted. Students spend all their formative years being force-fed incontestable facts. There is no place for judgment, still less independence of thought, in the traditional science curriculum. The idea of error in science, which enters so crucially when science is deployed in the policy process, has no place whatever in the received views of science. Within this system of ideas it is unimaginable for a well-conducted scientific inquiry to produce an erroneous result. The cases where this has actually happened to great scientists, such as Newton's denial of the wave nature of light and Lavoisier's assimilation of combustion to acid-formation (hence 'Oxy-gen' rather than 'Pyro-gen'), are suppressed (Ravetz 1996 p.115). This dogmatic approach could not be transmitted successfully unless the teachers themselves still believe in it; and who will teach those teachers who will re-train the current teachers? The reform of science education may itself become politicised, so that the new understanding of 'precautionary science' can be integrated into the education of the next generations of scientists.

All such reforms bring a real danger of loss of quality. It is not merely that traditional, restrictive criteria of quality must be revised, as by extended peer review. It is possible that in the turbulence of change, all standards will be lost, and then any charlatan or demagogue can successfully claim to be a scientist. But it is equally possible that in the absence of new understandings, quality in mainstream science itself can become compromised and corrupted. The old system of colleague peer-review for projects and publications is now in serious difficulties. Commercial pressures affect funding, and results may be kept concealed in order to give funders a commercial advantage. Increasingly, the announcement of key results by-passes the research quality-control system. They appear either as patents for which users must pay, or as newspaper stories devoid of peer-review of any sort.

Criticism is at the heart of science; in the absence of effective external quality-assessors (such as consumers in the case of marketed products), quality in specialised, esoteric research science holds itself up by its bootstraps. For the objective public knowledge of science is in the last resort the product of individual craft work, conditioned by style and subjectivity of each worker. For any product of work in this very enclosed world, only colleagues can fully assess the quality of its craftsmanship and its significance as potential knowledge. Hence the research quality-assurance system requires morale and commitment all around. In their absence, quality becomes a ritual (for the obedient majority) or a game (for those who have no illusions). Recalling that high-quality research has been possible only in a minority of fields in a minority of milieus, we see that quality in science is in fact a very delicate cultural product, which could quickly decay beyond recognition. And when, as has started now, researchers can be threatened with lawsuits to intimidate them from making critical comments, the quality-assurance process is under direct and immediate threat (Ho 2001).

The dangers to quality in 'precautionary' science must also be addressed. There is a systematic problem here: if traditional research science required collegiality and a shared idealism for its maintenance, how can quality survive in the adversarial atmosphere of policy-relevant science. The great cautionary tale from literature is Dr. Stockman of Ibsen's *Enemy of the People.* Was he a brave reformer who was destroyed by the corrupt small-town establishment, or was he also a naive megalomaniac who came to believe that he would single-handedly root out all the corruptions of society? (For a critical analysis, see Ravetz 1996, p. 428) To be sure, when violent debate is dominant, then accusations of 'junk science' will fly in all directions. But the process of post-normal science is one of mutual learning. It first requires respect and then appreciation, of the perspectives and commitments of other parties in the extended peer community. Trust can be built, and then extended peer review can be done successfully. For this there is the example of the 'Cochrane Collaboration' for the evaluation of medical treatments by co-operating expert and lay persons (Cochrane 2002). In such a process, quality is not a matter of a committee consensus, but of a process of common discovery of creative solutions to complex situations. Then 'compromise' becomes not so much a surrender of a prior advantage, as a sharing of benefits from an arrangement of mutual aid. (For a full discussion of this new sort of governance of science-related policy issues, see Fisher 2000)

Democracy

The relation of science to democracy is less straightforward than it might seem. Although there are no formal barriers to participation in science, in practice that is restricted to those with the background and inclination for a long initiation of jumping through intellectual hoops, extending through childhood, adolescence, and beyond. The resulting constraints on becoming a scientist cannot be devoid of connections to class and culture. With its restricted recruitment and close involvement with the state as advisors and experts, the corps of scientists has had functions analogous to those of the priesthoods of traditional societies.

Under post-normal conditions, citizens can participate in science in many ways. In policy processes they can act rather as they do on juries, not needing a full technical indoctrination, but capable of effectively using their common sense on issues of strategy and the relevant aspects of quality. The rapid rise of community based research in America, and its integration with education and local politics, shows another significant way forward. The development of alternative, more appropriate technologies, for production, safety and health, both in the colonised countries and at home, is yet another sign of genuine progress. Further enhancements of participation will arise through the Internet. This revolution in access to resources, and in exchange of information worldwide, must lead to new conceptions of knowledge and its uses. We can look forward to 'science' changing its meaning from a specialised, esoteric sort of activity and knowledge to something closely related to ordinary life and its problems. Utilising the Internet for this constructive activity may be one of the great tasks of the post-normal age of science.

In historical perspective, we can understand post-normal science as a contribution to an extension of democracy that is appropriate to our own age. Previous epochs in modern civilization saw the elimination of tyranny and barbarism from the judicial and penal systems, the abolition of slavery and child labour,the extension of the franchise, and the winning of rights for trade unions and for women. More recently we have had the enlargement of compassion to include special groups of people, including children and the disabled, and also to non-human intelligent and sentient beings. Now that science must be modified if we are to have a chance of survival and sustainability, the remedy is at hand, in the broadest possible participation of citizens. For the necessary changes in lifestyle can be brought about only by the active and creative participation of people in using and adapting technologies for benign ends. Sustainability and safety cannot be forced by governments. In these terms we can imagine the new 'extended peer community' of science to comprise all of humanity.

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References

Cochrane Collaboration. 2002. http://www.cochrane.org/ .

Community Research Network. 2002. crn-list <crn-list@igc.topica.com>

European Commission. 2001. Report of the Working Group "Democratising Expertise and Establishing Scientific Reference Systems" (Group 1b). http://europa.eu.int/comm/governance/areas/group2/report_en.pdf .

Fisher, Frank. 2000. Citizens, Experts, and the Environment. The Politics of Local Knowledge. Durham NC: Duke University Press.

Funtowicz, Silvio O., and Jerome R. Ravetz. 1990. Uncertainty and Quality in Science for Policy. Dordrecht: Kluwer. See also www.nusap.net .

Ho, Mae-Wan. 2001."Independent Scientists: An Endangered Species?" Splice (September):4-6. For details of the case discussed there, see the websites: http://www.ucsf.edu/pressrel/2000/11/110101.html .
http://www.hsph.harvard.edu/ats/Nov3/ .

Kuhn, Thomas S. 1962. The Structure of Scientific Revolutions. Chicago: University of Chicago Press.

Ravetz, Jerome R. 1999. “What is Post-Normal Science?.” Futures 31(7): 647-654.

Ravetz, Jerome R. 1996. Scientific Knowledge and its Social Problems. (New edition). New Brunswick NJ and London: Transaction Publishers.

Ravetz, Jerome R. 1998. "The Emperor's New Models?" Impact Assessment and Project Appraisal 16(2):79-80.

Shrader-Frechette, Kristin, Carl Cranor and John Lemons. 1997. "The Precautionary Principle: Scientific Uncertainty and Type-I and Type-II Errors," Foundations of Science 2: 207-236.

Zavetovsky, Stephen, Phil Brown, Meadow Linder, Sabrina McCormick and Brian Mayer. 2002. "Science, Policy Activism, and War: Defining the Health of Gulf War Veterans," Science, Technology & Human Values 27(2):171-205.