In risk assessment, one has to admit ignorance

Explaining there are things we can't know could improve public confidence in science.

Sir — The risks and benefits of novel technologies such as genetically modified foods continue to be fiercely debated. Risk assessment is at the crux of these conflicts, as shown, for example, by the report of the United Kingdom's Agriculture and Environment Biotechnology Commission last September, *Crops on Trial* (www.aebc.gov.uk/aebc/reports.html). Yet it is often overlooked that scientific risk assessment is fundamentally limited by ignorance.

Naturally, scientific knowledge refers to known processes and their influence upon known state-variables. Within this domain of reproducibility and control, uncertainty can be explicitly stated and reduced by reproducible experiments under controlled conditions. However, the domain of ignorance, characterized by the interaction between unknown processes and/or unknown state-variables, tends to be implicitly neglected in risk assessment. As the well-known examples of dichlorodiphenyltrichloroethane (DDT) and chlorofluorocarbons (CFCs) suggest, our ability to assess novel risks is primarily limited by the fundamental difficulty of taking these interactions into account.

In the case of DDT, the increase in concentrations of this insecticide resulted in (among other things) fragile egg-shells, threatening the survival of rare species of birds. Here we are dealing with interactions between a known process (increase in DDT concentration) and an unknown, thus neglected, state-variable (egg-shell thickness); between this neglected state-variable and a neglected process (population dynamics); and between this neglected process and the neglected state-variable of bird population. All of these interactions fell within the domain of ignorance for the contemporary environmental risk assessments of DDT. As long as egg-shell thickness was not understood to be a relevant state-variable, there was no reason to monitor it. Therefore, it was exceedingly difficult at the time to identify the unknown effect of bioaccumulation.

In the case of CFCs, risk assessment was initially limited to human toxicity. The highly stable nature of CFCs was considered desirable because it was thought to indicate the very low reactivity of these novel compounds and thus their suitability as non-flammable refrigerants. Vertical transport of CFCs into the stratosphere was not then considered a relevant process; their concentration in the stratosphere was not monitored (neglected state-variable). Nobody suspected a connection between stratospheric CFC concentrations and stratospheric ozone concentration (neglected photochemical processes in the stratosphere). Once again, these state-variables and interactions were neglected because they belonged to the contemporary domain of ignorance.

The impossibility of taking unknown processes and variables into account may be a more fundamental obstacle to credible risk assessment than our inability to describe the known interactions accurately. Yet the current discussion on uncertainty tends only to deal with the latter.

The possible consequences of ignorance are a major concern among the public regarding new technologies: time and again, people ask who will be in charge of responses to inevitable future surprises, and whether they can be trusted.

The policy response to these concerns has typically been to recommend further research on known uncertainties, with the intention of creating greater certainty and hence reassurance that risks are controlled. This response fails to reassure the public since it mistakenly assumes their concerns to be inspired by a demand for zero risk.

To overcome mutual misunderstanding by scientists, policymakers and the public, it is important for all to acknowledge that unanticipated effects of novel technologies are not just possible but probable — and that potential harmful consequences cannot reliably be established by further research since they fall into the domain of ignorance.

Risk assessment and policy need to emphasize uncovering the limits to knowledge, rather than proving existing knowledge to be correct. Multiple interacting perspectives should be encouraged, as each can be useful in pointing to limitations of the others. Lay knowledge, in particular, can be a valuable addition to expert knowledge, because it is based on different experiences.

Both the UK Office of Science and Technology guidelines on scientific advice for government (www.dti.gov.uk/ost/aboutost/scientific_advice/index.htm) and the European Union communication on the precautionary principle (europa.eu.int/comm/dgs/health_consumer/library/pub/pub07_en.pdf) laudably advocate greater inclusiveness, transparency about uncertainties, and accountability in scientific inputs to risk policy. But they also need to recognize and address the crucial distinction between uncertainty and ignorance. Otherwise, they may inadvertently contribute to the continuing confusion of the pretence of control with the reality of unanticipated consequences. Failure to address this predicament may unintentionally encourage further erosion of public confidence in science.

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Favouritism in physics?

Sir — In his Correspondence (*Nature* **415,** 472; 2002), a response to your Opinion article (*Nature* **414,** 829; 2001), L. Maiani states that, in comparing CERN with DESY, "you fail to take into account the significant cost-of-living differentials between Geneva and most other European locations". Most CERN employees do not suffer from the high cost of living in Switzerland because they live and do most of their business a few kilometres away in France. They get the best of both worlds: high salary with excellent benefits, and a relatively low cost of living. In this sense, if no other, they are 'more equal than others'.

For decades, particle physics in Italy has been very well funded. It has been able to attract excellent students and researchers with the prospect of an exciting career, opportunities for travel, and salaries even while studying for their *laurea* projects (equivalent to a master's degree), in stark contrast with those in other disciplines. This dominance of particle physics is probably due to the legacy of Enrico Fermi, who started the school that became Italy's national institute of nuclear physics, of which Maiani was president before becoming director general of CERN.

Thanks to this institute, which receives some 250 million euro (US$216 million) a year from the Italian government, and to the roughly 100 million euro a year that Italy contributes to CERN, Italian particle physics has been receiving more research money — by orders of magnitude — than any other Italian basic scientific discipline. (The Italian research budget is a meagre 1% of its GDP.) This perhaps helps to explain why Italian research has higher standards in particle physics than in other scientific disciplines.

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