EMBO reports

preface

Degrees of risk

For those of us who are lucky enough to live in the developed world, life has never been better. Thanks to modern medicine, sanitation and agriculture we can expect to live up to or beyond the age of 70. The threat of infectious diseases—a major curse of mankind only 60 years ago—is nearly a thing of the past. We can board a plane and land almost anywhere on the globe in less than 24 hours. Thanks to television and the internet, we have more access to information than ever before. Modern science has brought about radical changes to our environment that allow us to live more safely and comfortably than did our ancestors; historians may look back on this time as the 'golden age' of Western civilization. Of course, for the more than five billion people living outside the developed world, some, if not most, of these blessings are yet to come.

But why is it, then, that we still see threats and hazards lurking around every corner? Why do we fret about risks of all kinds when our lives are so much better than our grandparents'? Rather than enjoying the blessings of modern technology, we—as individuals and as societies—seem to be obsessed instead with their risks. We love our mobile phones, but stage protests against new antennae being erected in our neighbourhoods. Smallpox, polio, measles, mumps and rubella—all great scourges of the past—are virtually conquered thanks to vaccines, but we refuse to have our children inoculated for fear that they could suffer nearly improbable side effects. We enjoy an abundance of food but worry about the risks of genetically modified (GM) crops to our health and the environment. At the same time, we eat too much, needlessly putting ourselves at risk of obesity, heart disease and diabetes. Nobody in his or her right mind wants to do away with computers or the internet, but we fear their effects on job markets. It is a schizophrenic situation: while science and technology have made our lives so much safer and richer, we fear their threats—real and imagined—and become increasingly wary of new technologies, demanding ever increasing protection against their negative effects.

It was not always this way. In fact, in the 1960s and 1970s fear of science and technology and demands for risk assessments and moratoria were largely unknown. The accidents at the nuclear power plants in Three Mile Island, PA, USA, and Chernobyl, Ukraine, changed all that. Their effects continue to ripple through our societies to this day, sometimes turning into tidal waves that flood debates such as those about global warming, biotechnology or globalization. As a result, citizens demand ever greater safeguards against the unwanted side effects of new technologies. In the same way, the notion of risk—the probability that an unforeseen accident could happen or that a feared hazard could be realized—is now more important to our societies and has slowly spread from nuclear energy to biotechnology to almost all new technologies and other advances of modern science. The result is that non-governmental organizations and citizens mount protests and campaigns, politicians react by introducing new laws and regulations, the media pick up on and magnify the impact of inevitable failures—and science is caught in a dilemma of providing new advances on the one hand, and ensuring that they are 100% safe for human and environmental health, on the other.

But science cannot and does not provide all the answers to how new developments can be safely implemented. Uncertainty is as much a crucial component of the scientific enterprise as it is in probability theory, the mathematical basis of risk assessment. Instead, science can only anticipate potential problems from experiment and experience. This creates a growing dilemma for policy makers and regulators, who must make decisions based on inadequate knowledge. It has given rise to the precautionary principle, which has now assumed a central role in risk assessment and is enshrined in many environmental and health legislations. The principle adds another layer of caution by demanding that, in light of insufficient scientific knowledge, precautionary measures should be taken if an activity raises a threat of harm to human or environmental health. Again, it is an ambivalent tool: it may have helped to prevent some accidents in the past, but critics believe it is being misused by interest groups to halt, or at least postpone, the application of new technologies by raising new risk claims. But this is a logical result of a democratic society in which citizens want to have their say in political decisions.

Scientists do not necessarily like this. Many argue that science and development should not be hindered by too much red tape if we, as a society, want to reap the benefits of technological advances. It has also created tensions between science and society at large, with scientists finding themselves defending against claims that their latest invention is a potential Frankenstein—as the debate over GM organisms has shown. At the same time, technology and risk assessment have blossomed into research fields with the mandate to anticipate negative effects of new technologies and devise countermeasures if the worst case should happen.

As José Mariano Gago—Professor of Physics at the Instituto Superior Técnico in Lisbon, Portugal, and former Portuguese Minister of Science and Technology—points out in his Introduction (page S4), the central role that society has assigned to risk poses major challenges to

science. But this also presents huge opportunities for the future of science and technology. Indeed, if research institutions and individual scientists can assume the role of disinterested providers of knowledge and advisors on risk governance for new technologies, Gago argues, it may thus lead to a new relationship with society and better acceptance of the scientific enterprise. This new role would be not only as a producer of new knowledge but also as a provider of expertise on how best to use this knowledge. In this way, science could also overcome some of its current problems, namely the possibility of shrinking public investments into research and a decreasing interest in science and scientific careers among the younger generation.

The other 13 articles of this special issue, from a wide range of experts, contribute to this topic by looking at risk from various angles. John Ross, a former editor of *Smithsonian* magazine, sets the stage by going back into history to describe the origin of probability theory, which over time evolved into risk research with all its current specializations and subdivisions. In an entertaining way, he also describes what this new idea of risk means for our daily lives ('Pascal's legacy', page S7). Tikki Pang and G. Emmanuel Guindon, from the World Health Organization's Department of Research Policy & Cooperation, then take a step back and look at health risks in a globalized world, in which people, goods and services can move almost limitlessly ('Globalization and risks to health', page S11). Other articles highlight more specific risks in our modern world. GM crops have caught the attention of the public and the media, probably more than any other technology in the past ten years. They have thus become a textbook example of how a new development can become entangled in public opposition, risk assessments and demands for protective regulations borne out of a fear for human health and the environment. The story of GM crops and their consequences for science and society is told by Helge Torgersen—from the Institute of Technology Assessment at the Austrian Academy of Sciences in Vienna—in 'The real and perceived risks of genetically modified organisms' (page S17).

Over the next few years, we will probably see further advances in elucidating the causes of common diseases, such as cancers, diabetes and heart disease, and hopefully we will be able to identify those at higher risk and provide treatment at an earlier stage. Wayne Hall, Katherine Morley and Jayne Lucke—from the Institute for Molecular Bioscience at the University of Queensland and the Queensland Institute of Medical Research, Australia—critically assess whether and how biomedical research and modern genetics will be able to provide every one of us with an individual risk assessment for common diseases ('The prediction of disease risk in genomic medicine', page S22). They also question if such developments—with all their social and medical implications—are in fact desirable, or if the old-fashioned methods of public health are more efficient than indiscriminately screening whole populations. But it is also up to us as individuals to modify our behaviour in order to diminish our chances of developing these diseases. We all have to eat and drink to survive, but we often do not realize that this in itself can be dangerous. Susan Wilkinson, Gene Rowe and Nigel Lambert—from the Institute of Food Research in Norwich, UK—spell out 'The risks of eating and drinking' (page S27) and explain why many people still ignore them, putting themselves at a higher risk of developing many of the diseases that Hall and his colleagues highlight in their article.

Our concerns—some might even say obsessions—about mitigating risks have spawned new research fields that analyse risk in different ways. Most notably, risk research and risk assessment rely on a broad range of sciences, from toxicology to engineering, and from environmental biology to climate research. In addition, the social sciences have contributed a large amount of new knowledge on risk and the perceptions of risk among the general public. The second part of this special issue thus deals with the various aspects of risk research. Armin Grunwald, Director of the Institute of Technology Assessment and Systems Analysis at the Research Centre Karlsruhe in Germany, first argues that we need a novel approach to assess the risks of new technologies ('The case of nanobiotechnology', page S32). According to Grunwald, in the past risk claims were immediately rejected, whether unfounded or not, but this approach may be as damaging in the long term for the future acceptance of a new technology as is fierce opposition from the public or special interest groups. Instead, by acknowledging that any new technology or product harbours risks, it may be possible to overcome suspicion and avoid some of the pitfalls and resistance that characterized the fate of other technologies, notably nuclear energy and biotechnology. Grunwald uses nanobiotechnology—a relatively new field with many exciting prospects—to explain how such a strategy, that takes into account both positive and negative utopias, could succeed.

Other areas where risk assessment has been a natural component for decades are toxicology and pharmacology. This is not surprising, given that researchers in these fields have a mandate to protect the public from any toxic side effects of a wide range of chemicals and pharmaceuticals. But as Edward Calabrese—from the University of Massachusetts's School of Public Health in Amherst, MA, USA—argues, it is also a perfect example of what happens if risk managers and regulatory authorities err too much on the side of caution, causing serious consequences for environmental protection, public health and the economy ('Hormesis: a revolution in toxicology, risk assessment and medicine', page S37). Not only do the standard models used to assess the toxicity of a given compound rely on unverified and unobservable assumptions and extrapolations, he claims, they also do not reflect reality. Instead, Calabrese presents the 'hormetic' model, based on biological research, which has the potential to make toxicological risk assessments more reliable and to enable risk managers to make better decisions.

Risk research and risk managers would be overwhelmed if they had to devise a new strategy to deal with the possible threats of each emerging technology. That is why Ortwin Renn and Andreas Klinke from the Department of Environmental Sociology at the University of Stuttgart, Germany, introduce the concept of systemic risk ('Systemic risks: a new challenge for risk management', page S41). They first define all possible risks that come from new technologies and developments and assign them to six risk clusters, named after Greek mythological figures. Such a characterization of risks, according to their probability and the potential hazards they pose, allows risk managers and regulatory agencies to

classify a new technology, choose the appropriate method of introducing it to the public, as well as devise effective measures to counter any risks.

But it is not only risk itself that has come under intense scrutiny. In fact, an underlying theme of nearly all the articles in this special issue is risk perception, that is, the way in which the public views risks and why its views often differ from experts' analyses. Given that it has been perceived, as opposed to real, threats that have made some technologies and products—from GM crops to electromagnetic radiation emitted by mobile phones—unacceptable to the public, research on how normal citizens perceive and value risks in their everyday lives has gained much interest in recent years. Lennart Sjöberg from the Stockholm School of Economics in Sweden takes a closer look at this field, based on his research on how the Swedish public views biotechnology ('Principles of risk perception applied to gene technology', page S47). His results show that it is not only a lack of knowledge, a general distrust and a 'feeling of dread' at being faced with new technologies that drives public attitudes, but also other moral and social factors.

The notion of risk is now so deeply embedded into our societies that it is not possible to go back to the old days when only scientists and engineers decided whether a new technology or product was safe. In addition, potential risks have been largely expanded beyond human health to include risks to the natural environment, social risks and political implications. As a consequence of this expanded mandate, risk research has become a fully fledged research field. At the same time, science, which was once an independent and disinterested enterprise, has become entangled in politics and public debates. This in turn has an impact on science itself, one that Peter Weingart—Director of the Institute for Science and Technology Studies at Bielefeld University in Germany—analyses in 'Science in a political environment' on page S52. The advent of risk research has brought science under greater public scrutiny and consequently, scientific advances must now meet social acceptance before they can be translated into new technologies or products.

There are other consequences to our obsession with risk. David Ropeik, Director of Risk Communication at the Harvard Center for Risk Analysis, Boston, MA, USA, describes how worrying about risks becomes a risk in itself, with repercussions for public safety and health ('The consequences of fear', page S56). He concludes that risk assessors must analyse and consider the consequences of people over- or underestimating risks, in order to prevent hazards worse than those posed by the original risk itself. Risk assessment requires improved ways of communicating risk to the public to make citizens understand how new technologies and products affect their daily lives and thus enable them to make better—and healthier—decisions. This is the topic of Katherine McComas's article, 'When even the best-laid plans go wrong' (page S61). McComas, from the Department of Communication at Cornell University, Ithaca, NY, USA, analyses situations in which risk communication becomes necessary and presents new methods on how to effectively talk to the public in order to create a more positive awareness of new technologies.

Of course, communication is not the only way in which risk research trickles into society. Equally important are the laws and regulations that aim to protect us from risks and implement new technologies as safely as possible, without doing away with their benefits. 'Risk and the law' (page S66), by Julian Kinderlerer—from the University of Sheffield's Institute of Biotechnological Law & Ethics, UK—describes how scientific research in risk is translated into law. Using biotechnology as an example, he explains the rationale behind various national and international laws to protect public health and the environment.

Ever since probability theory and risk assessment became available as scientific tools, the notion of risk has become an integral part of our existence that extends to nearly every aspect—financial, scientific, social, economic and personal—of modern life. In democratic societies with unhindered access to information, it is clearly no longer possible for a small group of experts alone to make decisions about new technologies that could potentially affect a large number of people. Instead, we have to accept that people's demands for safer products and risk mitigation are valid, and that risk research is therefore necessary if we want to use science and technology to improve the quality of human life in a sustainable and socially acceptable way. We hope that this special issue on risk will therefore be an enlightening and interesting collection of articles on this important topic.

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