If Science is to Save Us

Martin Rees

CONTENTS

Praise for *If Science is to Save Us*

‘Reading this book is like cosying up to a fireside chat where one of the greatest minds in science distills the complex interface between science and the welfare of society. Even better, no fire required!’

Marcia K. McNutt, President of the National Academy of Sciences

‘This is a powerful humane argument for science. Martin Rees draws on his long and wide range of experience to show how science works – and how it can be done better.’

David Willetts, President of the Resolution Foundation and Chair of the UK Space Agency

‘Sometimes it can feel like we’re stumbling from one global challenge to another. At the same time, we rightly worry about the pace of technological advances. But we cannot afford to turn our backs on science for, without a scientific understanding of our world, we are doomed. Rees puts the case for placing our trust in science compellingly and with a rare honesty.’

Jim Al-Khalili, University of Surrey and BBC Broadcaster

‘This timely and absorbing book issues a clarion call to scientists, policy makers, and citizens everywhere to join forces so that the extraordinary advances in science will be directed towards solving pressing global challenges. Whether we live in the best of times or the worst of times in the future is up to all of us.’

Shirley M. Tilghman, President Emeritus of Princeton University

‘The future of humankind depends on science and on fully integrating that science into human culture and society. In this erudite yet accessible book, Martin Rees makes a compelling case for supporting science and making it an integral part of our democracy and political decision making.’

Paul Nurse, Nobel Laureate, Director and Chief Executive of the Francis Crick Institute

‘Delight along with me as Martin Rees describes his world of science and what it will take to ensure that we not only survive but prosper in the Anthropocene Era.’

Charles F. Kennel, Scripps Institution of Oceanography and former Chair of the NASA Advisory Council

‘This lucid and compelling book by one of the world’s foremost and far-seeing scientists shows why we ignore science at our peril. The book should be required reading for scientists and is an accessible “must read” for everyone interested in the critical and existential challenges facing humanity.’

Ian Goldin, Director of the Oxford Martin School, University of Oxford

‘Martin Rees is unique in combining achievement at the very highest echelons of science, an almost cosmic perspective on humanity’s risks and prospects, and the ability to communicate complex ideas in vivid ways. Here he shows how much we need science, in a tour rich in personalities and history, fusing comments on the frontiers of science with appreciation of their political and ethical dilemmas, giving the reader the pleasure of learning in the company of a sparkling intellect.’

Geoff Mulgan, University College London, and former Chief Executive of the National Endowment for Science, Technology and the Arts

‘Are science and its organization fit for purpose as society faces 21stcentury challenges, from climate change to dominance by AI? As clearly demonstrated in this masterpiece, no one is better able to answer this crucial question than Martin Rees.’

Tim Palmer, Royal Society Research Professor, University of Oxford

If Science is to Save Us

MARTIN REES

polity

First published in 2022 by Polity Press

Polity Press
65 Bridge Street
Cambridge CB2 1UR, UK

Polity Press
111 River Street
Hoboken, NJ 07030, USA

ISBN-13: 978-1-5095-5421-8

Library of Congress Control Number: 2022934662

A catalogue record for this book is available from the British Library.

For further information on Polity, visit our website:
politybooks.com

Preface and Acknowledgements

My prime thanks are due to my editor, Jonathan Skerrett. He persuaded me (and his colleagues) that an accessible work on the themes of this book would be appropriate for Polity Press, and he invested a great deal of time and effort into shaping the book and offering helpful suggestions on both style and content. I'm most grateful also to Ian Tuttle for his careful copy-editing and for suggesting numerous improvements, as well as to Neil de Cort and Emma Longstaff, who helped to see the book smoothly through to publication.

It will be plain from the book's contents – spanning wide-ranging themes where I can't claim special expertise – that I owe a lot to what I've learnt, and advice I've received, from a huge number of friends and colleagues with whom I've collaborated or interacted. I cannot mention them all, but I wish to offer special thanks to Partha Dasgupta, Mario Livio and Steven Pinker, whose collaboration has influenced my coverage of some topics.

I also thank the BBC for permission to include in Chapter 2 some updated material adapted from my 2010 Reith Lectures on 'Scientific Horizons'.

Introduction

In our responses to Covid-19 we were told to ‘follow the science’ – and there’s never been a time when ‘experts’ have had such public prominence. At the time of writing, this pandemic is still, after more than two years, an overwhelming challenge. But it’s not the only one: politicians need also to confront a whole array of policy issues – on energy, health, environment, and so forth. Indeed, the choices our governments make in the coming decades could determine the Earth’s future. Politicians must take cognizance of expert advice, but in reaching decisions this advice must be tensioned against other factors: the feasibility and public acceptability of particular measures, and their economic and human costs.

Such choices – decisions on how science is applied – should be preceded by an informed public debate. But for the debate to rise above the level of tabloid slogans, we all need a ‘feel’ for the key ideas underlying modern technology, and an understanding of the natural world (including humans). Science isn’t just for scientists. Equally important, we need to be mindful of how incomplete and provisional our knowledge actually is. Moreover, these ideas are not only the basis of everyday technology, but they’re of sufficient intrinsic interest that they should be part of our common culture. The great concepts of science – or at least the flavour of them – can be conveyed using non-technical words and simple images. Or so I believe.

In this book I won’t elaborate on the actual findings of science. Nor will I extol it as the greatest collective achievement of humanity – though it surely is. My focus will instead be on how the sciences impinge on our lives – and on the hopes and fears for the future. I shall offer thoughts

on what distinguishes science from other intellectual activities, how the entire scientific enterprise is organized – nationally and globally – and on how to ensure that scientists and their innovations mesh into society, so that applications are channelled in accordance with citizens' preferences and ethical judgements.

The stakes have never been higher. The Earth has existed for 45 million centuries, but this is the first century in which one dominant species can determine, for good or ill, the future of the entire biosphere. Over most of history, the benefits we garner from the natural world have seemed an inexhaustible resource; and the worst terrors humans confronted – floods, earthquakes and diseases – came from nature, too. But we're now deep in what some have called the 'Anthropocene' era. The human population, now approaching 8 billion, makes collective demands on energy and resources that aren't sustainable without new technology and threaten irreversible changes to the climate. The threat of nuclear war still looms over us. And other novel technologies – especially bio and cyber – are socially transformative but open up the possibility of severe threats if misapplied. The worst threats are no longer 'natural' ones: they are caused (or at least aggravated) by humanity itself. There remains a huge – and widening – gap between the way the world is and the way it could be. Inequalities within countries, and between countries, are vast.

Despite the concerns, there are powerful grounds for optimism. For most people in most nations, there's never been a better time to be alive, thanks to advances in health, agriculture and communication – dependent on earlier scientific discoveries – which have boosted the developing as well as the developed world. And this optimism need not be eroded by the pandemic. Indeed, in dealing with this globe-spanning plague, science is our salvation: the

response has shown the scientific community at its best – a colossal worldwide effort to develop and deploy vaccines, combined with honest efforts to keep the public informed.

Creativity in science and the arts is nourished by a wider range of influences than in the past and is accessible to hugely more people worldwide. We're embedded in a cyberspace that can link anyone, anywhere, to all the world's information and culture, and to most other people on the planet. Everyday life has been transformed in less than two decades by mobile phones, social media, and the internet – we would have been far less able to cope with the recent shutdowns without these facilities. Computers double their power every two years. Gene sequencing is a million times cheaper than 20 years ago: spin-offs from developments in genetics could soon be as pervasive as those we've already seen from the microchip.

These rapid advances, and others across the whole of science, raise profound questions. Who should access the 'read-out' of our personal genetic code? How could lengthening lifespans affect society? Should we build nuclear power stations, or wind farms, if we want to keep the lights on? Should we use more insecticides, or plant GM crops? Should the law allow 'designer babies'? How much should artificial intelligence (AI) be permitted to invade our privacy? Are we prepared to accept a machine's decisions on issues that matter to us?

All these questions require engagement of 'experts' with politicians and the wider public. The public and governmental challenges posed by the Covid-19 crisis were unprecedented (at least in peacetime) in their urgency, impact and global scope. Some threats – global pandemics and massive cyber attacks, for instance – are immediately destructive and could happen at any time. The worst of them could have consequences that cascade and spread

devastatingly. And their probability and potential severity is increasing. Covid-19 must be a wake-up call, reminding us – and our governments – of our vulnerabilities.

Looming over the world this century is the threat of climate change. This is potentially a ‘global fever’, in some ways resembling a slow-motion version of Covid-19. For instance, both crises aggravate the level of inequality within and between nations. Those in the megacities of the developing world can’t isolate from rogue viruses; their medical care is minimal, and they’re less likely to have access to vaccines. And likewise, it’s those countries, and the poorest people in them, that will suffer most from global warming and the effects on food production and water supplies. Climate change and environmental degradation may well, later this century, have global consequences that are even graver than pandemics – and longer term (indeed irreversible). But a potential slow-motion catastrophe doesn’t engage public and politicians – our predicament resembles that of the proverbial boiling frog, contented in a warming tank until it’s too late to save itself. We’re well aware of them, but fail to prioritize countermeasures because their worst impact stretches beyond the time horizon of political and investment decisions. Politicians recognize a duty to prepare for floods, terrorist acts and for other risks that are likely to materialize in the short term – and are localized within their own domain. But they have minimal incentive to address longer term threats that aren’t likely to occur while they’re still in office – and which are global rather than local.

The case for effective action to address long-term threats is compelling. But unless there’s a clamour from voters, governments won’t properly prioritize measures crucial for future generations. So scientists must enhance their leverage, by involvement with non-governmental organizations (NGOs), via blogging and journalism, and

enlisting charismatic individuals and the media to amplify their voice and change the public mindset. It's encouraging to witness more activists – especially among the young, who can hope to live into the twenty-second century. Their campaigning is welcome. Their commitment gives grounds for hope.

Without earlier scientific insights, we'd be denied all the everyday benefits whereby our lives differ from those of our forebears – electricity, vaccines, transport and information technology (IT). We should be evangelists for new technology, not luddites – it's essential if the world's expanding and more demanding population is to have enough food and enough energy in a sustainable form. But many are anxious that it's advancing so fast that society may not properly cope with it – and that we'll have a bumpy ride through this century.

And, of course, most of the challenges are global. Coping with Covid-19 is plainly a global challenge. And the threats of potential shortages of food, water and natural resources – and transitioning to low-carbon energy – can't be solved by each nation separately. Nor can the regulation of potentially threatening innovations – especially those spearheaded by globe-spanning conglomerates. Indeed, a key issue is to what extent, in a 'new world order', nations will need to yield more sovereignty to new organizations along the lines of the International Atomic Energy Agency, World Health Organization, etc.

Scientists have an obligation to promote beneficial applications of their work in meeting these global challenges. Their input is crucial in addressing the downsides: helping governments to decide wisely which scary scenarios – eco-threats, or risks from misapplied technology – can be dismissed as science fiction and how best to avoid the serious ones. And we need the insights of

social scientists to help us envisage how human society can flourish in a networked and AI-dominated world.

My own research field is astronomy and cosmology. Before concluding this introduction it's perhaps appropriate to ask: are there special perspectives that astronomers can offer to this book's theme? I think there are. Astronomers are disclosing insights that New Agers would welcome and be attuned to. Not only do we share a common origin, and a common 'genetic code', with the entire web of life on Earth, but we are linked to the cosmos. All living things are energized by the heat and light from the nearest star, our Sun; and the atoms that we – and indeed our entire Solar System – are made of were forged from pristine hydrogen, billions of years ago, in faraway stars.

But, more significantly, astronomers can offer an awareness not only of the immensity of space but of the immense time spans that lie ahead. The stupendous time spans of the evolutionary past are now part of common culture (apart from in creationist circles). We and our biosphere are the outcome of about four billion years of evolution. But most people still somehow think we humans are necessarily the culmination of the evolutionary tree. That hardly seems credible to an astronomer, aware of huge time horizons extending into the future as well as into the past. Our Sun formed four and a half billion years ago, but it's got six billion more before its nuclear fuel runs out. And the expanding universe will continue – perhaps for ever – becoming (according to the best current long-range forecast) ever colder, ever emptier. So, even if life were now unique to Earth, there would be scope for post-human evolution – whether organic or electronic – on the Earth or far beyond. It won't be humans who witness the Sun's demise: it will be beings more different from us than we are from a bug. We can't conceive what powers they might have.

This book has of course a narrower theme than the cosmos. The focus is on our Earth, and mainly on the present century: an instant in cosmic perspective, but sadly longer than the planning horizon of business and politics. My focus is on scientists – their communities and their interaction with society, the economy and politics rather than on what their work has revealed about nature. Indeed, I'll be using the term 'science' – as is common practice in public discourse – to embrace technology and engineering as well. 'Problem solving' motivates us all – whether one is an engineer facing a novel design challenge or an astronomer probing the remote cosmos. And having myself had a career focused on academic science, I want to emphasize that, despite their symbiosis with 'pure' science, it's the 'applied' activities that engage far more brainpower and resources. The message of an old cartoon that resonates, quite rightly, with my engineering friends shows two beavers looking up at a giant dam. One beaver is saying to the other 'I didn't actually build it, but it's based on my idea.'

* * *

Chapter 1 highlights three areas where science is transformative – and indeed where the whole future of our species depends on its deployment for societal benefit. These are climate and environment, biomedicine, and computers and machine learning. I argue that science and technology – optimally applied – will be crucial to our collective flourishing. But we need to be mindful of the downside; some technologies are advancing so fast that we may not properly cope with them – and their misuse, by error or by design, can lead to catastrophe. There will always be a trade-off between risks and benefits, and it's therefore important that public concerns are respected, and that these aren't distorted by unbalanced perceptions.

Chapter 2 describes what scientists are like – emphasizing that rather few actually resemble traditional stereotypes, in personality or work patterns – and how their ideas are communicated, to become part of our culture as well as the underpinning of our modern (and future) world. I address the structure and sociology of the scientific enterprise; science's scope and limits, and its relation to culture and politics; and how to improve the public's capacity to make informed choices of how it is applied. Scientists must acknowledge that the applications of their work resonate far beyond their expertise; citizens and politicians must be reassured that new discoveries aren't applied unethically or dangerously.

In chapter 3, I describe the institutions within which scientists work – some of which have serious weaknesses. Nations differ in the extent to which their scientists can engage with their governments as advisors, or directly with the public via campaigning and the media. The role of international organizations and academies needs strengthening, especially as the challenges we face increasingly require a coordinated international response. Science is a truly global culture, and we need deeper international contacts among professionals, and in universities and colleges.

Being a scientist is a career choice – it's crucial that enough talented people should opt for this choice. Those that do require sufficient incentives and appropriate education and opportunities. So chapter 4 addresses educational issues, not only from the perspective of potential professionals, but in the wider context of ensuring that all of us understand enough to feel at home in our high-tech world and can participate in debates on how science is applied. Formal education – throughout the school years, and in higher education as well – is one of the most sclerotic aspects of UK society; the US offers greater

flexibility, but at school level the whole Anglo-Saxon world can learn from Scandinavia and the Far East. The world is changing so fast that learning must be a lifelong process: it needs to be inclusive and flexible, not restricted to a privileged minority; it should take optimum advantage of the internet. Some words of H. G. Wells a century ago resonate even more strongly today: we're in 'a race between education and catastrophe'.

Chapter 1
Global Mega-challenges

The ‘plague years’ of Covid-19 have imprinted two contrasting messages. First, our entire world is interconnected: a catastrophe in any region can cascade globally; no nation is truly safe until all are. Second, international science can be our salvation – as in the development of vaccines. Let’s hope that, when this crisis has passed, nations can focus on ensuring that we’re better prepared for the next pandemic. Moreover, it has been a ‘wake-up call’ that should deepen concern about other future threats that could be even more catastrophic; it should stimulate effective actions to confront all the longer-term challenges the world faces.

I’d highlight three interlinked mega-challenges:

1. Providing food and energy for a rising and more demanding population, while avoiding depletion of the biosphere and dangerous climate change.
2. Coping with the ethical and security challenges posed by ever-advancing biotechnology while harnessing its benefits for health and agriculture.
3. Enabling artificial intelligence, the cybernet and social media to transform our economy and our society, despite vulnerability to malfunctions (natural or malicious) that could cascade globally.

The alarm having sounded, these are items which have long been on humanity’s collective agenda but which we now need to consider anew.

1.1 Threats to the biosphere: population growth and biodiversity loss

The backdrop to current geopolitical challenges is a world where humanity's collective footprint is getting heavier. There are about 7.8 billion of us on this planet – twice as many as in the 1960s. Nonetheless, despite doom-laden forecasts by Paul Erlich (1968)[1] and the Club of Rome (1972),[2] food production has, thanks largely to advances in plant science (the 'green revolution'), kept pace with rising population. Famines still occur, and many people, especially children, remain undernourished; but the most distressing episodes, such as those in Afghanistan, Yemen and Ethiopia, are mainly due to conflict or maldistribution, not overall scarcity.

Population growth has now slowed. Indeed, the number of births per year, worldwide, is now declining: in most countries it has fallen below the 'replacement level' of 2.1 births per woman; for instance, it is 1.5 in Japan, 1.56 in Canada, and 1.64 in China, leading to concerns (especially in Japan) about an over-dominance of the elderly. But world population is nonetheless forecast to rise to around 9 billion by 2050.[3] That's partly because most people in the developing world today are young, owing to persistent high fertility in recent decades and welcome falls in infant mortality. These young people are yet to have children, and they will live longer. Moreover, the transition to low fertility hasn't happened everywhere – particularly in rural parts of sub-Saharan Africa.

Most of the 7.8 billion people on the Earth today are still impoverished by the standards of the 'Global North' – though, according to the World Bank, the proportion below the official 'extreme poverty' threshold, which currently

stands at $1.90 per day, has dropped from around 60 per cent in 1950 to 10 per cent today.[4] World food production needs to double again by 2050, not only to cope with the rise in population but to ensure that all those in the Global South (where the main population growth in the coming decades will be) become as well nourished as most people in Europe and North America.

It's true that food production has doubled in the last 50 years; but a further doubling is more problematic. There will be constraints on energy, on the quantity of fertile land, and on the supply of water. This will require further improved agriculture – low-till, water-conserving and genetically modified (GM) crops – together with greater efforts to reduce waste (via refrigeration, for instance) and improve irrigation. We need modes of farming that can produce crops efficiently in a changing climate, and avoid encroaching on natural forests. The buzz-phrase is 'sustainable intensification'.[5] There will be consequent pressure to enhance the yield from the oceans, without allowing over-fishing to drive species to extinction. There will certainly need to be changes in the typical 'Western' diet: for instance, we can't all consume as much beef as present-day Americans.

Some dietary innovations are feasible without deployment of 'frontier' science: for instance, converting insects and maggots into palatable food, and making artificial meat from vegetable protein. 'Beef' burgers (made from wheat, coconut and potato, moisturized with beetroot juice) are now being marketed in the US by companies called Beyond Meat and Impossible Foods. It will be a while, though, before these 'pseudo-burgers' will satisfy carnivorous gourmands.

These novel foods are best characterized as clever or exotic cookery rather than entailing advances in a laboratory. But