Borrowed Time

Facing the hidden vulnerabilities of modern civilisation

by

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for

Robert Soul

the first teacher to care what I thought

Francis Hall

whose rope preserved me and whose chance remark gave birth to a shared obsession

and above all for my wife

Rebecca

whose support included never asking why I kept coming back to bed with cold feet and who, as a touch typist, will imagine what pains all this must have cost me

C O N T E N T S

PART ONE

BUILDING OUR HOUSE OF CARDS

Nineteenth century science revealed a world that was older, to an almost incredible extent, than previous generations had imagined and showed that our appearance on it was explicable without any divine intervention. It seemed safe to conclude that ours was a fortunate planet; that our species had grown to be well matched to its environment, and that we would be secure here for as long as it took to meander towards universal happiness and fulfilment. However, late twentieth century science abruptly stood that cosy assumption on its head. The Earth, it turns out, though certainly old, is rather a dangerous place; our survival for so long a near miracle, and we might need to adjust our attitudes before our luck runs out. But what twentieth century science didn't acknowledge was even worse news: if mankind does succumb to one of the many lurking catastrophes, the problem won't be just to ride out its immediate effects but to recover at all. Our prolific breeding, lazy thinking and headlong pursuit of material progress have left a planet denuded of easily-won natural resources and a population passively reliant on an intricate balance of sophisticated technology that most of us don't understand and which the looming shortage of resources would prevent survivors from either maintaining or reconstructing. If our present civilisation, whose many comforts bring an illusion of invulnerability and permanence, were to collapse now, it would almost certainly be forever. And our survival as a species, even for a few hundred thousand years, is no guarantee that calamity won't strike within a generation: such probabilistic reasoning might be valid for the familiar doomsday asteroid scenario, but many aspects of modern life make us thousands of times more vulnerable than our ancestors, who lived and died in ignorance of any impending external cataclysms or of the stresses they were themselves building up for future generations.

Chapter 1

Risk perception and real dangers

A short history of worrying – Is history really bunk? – A Catalogue of Conceivable Calamities – Don't panic! – Loading the dice – Looking on the bright side

A short history of worrying

'May you live in interesting times' is widely quoted as an ancient Chinese curse and, though it's almost certainly apocryphal, today almost every citizen is its victim. Times have never been so interesting, either in being so full of intellectual excitement or – the sense presumably intended by an uninquisitive peasantry for whom any change was likely to be bad news – so dangerous.

Presumably we'd all tacitly agree on the first of these assertions? Admittedly, from time to time individual cities, courts and seats of learning have nurtured or attracted such exceptional talent as to blaze up suddenly and, for a generation or so, seemingly outshine the rest of the civilised world as a supernova can briefly outshine its parent galaxy. I'm thinking here especially of fourth century Athens; of Baghdad during the first Caliphate; of Florence under the Medici and of London at the birth of the Royal Society, though you'll probably have your own candidates. Nevertheless, never before has the large mass of the population enjoyed ready and affordable access to so much accumulated knowledge and so many shades of opinion, plus the means to comment on and debate them. The Internet has brought about at least the possibility of a new Golden Age and, for the first time, one not restricted to leisured elites but open to all. It is the assertion that our age is more dangerous that seems likely to divide people along cultural lines.

It's certainly not the majority view. For about four decades after 1950, all our lives were shadowed by the threat of imminent nuclear annihilation but that concern has now faded, leaving only the slowly accumulating effects of humans on the climate to engage the general public, and then as a matter of no universal conviction or particular urgency. Nevertheless, experts in every field have taken to issuing dire warnings and pessimistic forecasts and you might have noticed that the prophets of those kinds of doom come overwhelmingly from the sciences. Indeed, Antonia Byatt wrote[7] in the *Guardian Review* in 2011:

> *Almost all the scientists I know think we are bringing about our own extinction, more and more rapidly.*

It's increasingly true. If any household-name scientist utters a word of optimism these days, it seems they are immediately awarded the Templeton Prize[8]! Recently, several gifted science communicators have produced books that warned of the risks humanity is storing up for itself, like Martin Rees's *Our Final Century,* Clive Hamilton's *Requiem for a Species* and Ward and Brownlee's *The Life and Death of Planet Earth* (though Rees was equivocal enough – or perhaps far-sighted enough – to leave scope for his own later Templeton)[9].

However, any historian, I'm sure, would be impatiently dismissive of such nonsense, perhaps pointing out that, had it not been for internal Mongol politics, the heirs of Genghis Khan would probably have brought civilisation (in Europe at least) to its knees in around 1250. Also that, a bare century later, the Black Death apparently killed at least one third of that continent's entire population. Today, we seem to have tamed infectious diseases – even to have eradicated one or two – and we've certainly prolonged average life expectancy

beyond the dreams of our ancestors (again, looking only at Europe) so how can we possibly be in greater danger?

Our historian might further propose that an individual's capacity for worrying tends to expand to fill the time available, so that Western civilisation has become steadily more risk-averse even as its citizens enjoy longer, safer and more comfortable lives. That is all true. Today, perhaps we even know rather too much for our peace of mind? To the unfortunates in the path of the Mongols or the Plague, there can have been little warning of impending disaster while, if one of these seemingly cosmic calamities had struck the next village but missed their own, they'd not even have known the risk they'd run until it had passed. These days, of course, they'd be able to follow the day-to-day progress of each threat via TV news bulletins. It would be surprising if our individual perception of risk could have escaped being magnified and distorted by this insistent twenty-four hour coverage, highlighting the most sensational events even though these directly affect relatively few of the world's inhabitants. Individually we are undoubtedly safer than ever before.

Is history really bunk?

So who is right; the alarmist scientists or the sanguine historians? Sadly, we can be pretty sure it's the scientists but to understand why we need to look at where their warnings are coming from.

The disagreement doesn't reflect any competing systems of short-term prediction. Neither science nor history makes any claim to infallibility there and such modesty is completely justified, because both use the same, deeply flawed approach. This is simple extrapolation from past events, and basically it's all we have, although it's been thoroughly and repeatedly discredited. History is wonderful at showing any society the deeply buried origins of its present-day traditions, prejudices and anxieties but it could deliver reliable predictions only in an unchanging world. Those who base their prognostications on the past are forced to neglect science and technology, whose relentless advance really does change our world irrevocably, while those who predict technological advances sometimes seem to neglect everything else. Clearly we are not yet travelling to work for just a few hours a week, strapped to personal jet-packs, living to be 200 or renouncing the pleasure of hot meals for the convenience of a daily polynutrient tablet: indeed I'm not sure we really even have the paperless office yet. As the Nobel laureate Niels Bohr remarked, 'Prediction is very difficult, especially about the future'[10]. Extrapolation will always miss the key developments like gunpowder, printing, the steam engine and the electric telegraph, smartphones, satnavs and the World Wide Web, simply because they arrive unheralded, with no detectable precursors. If the past is a foreign country, the future is surely more like some alien and bizarre exoplanet.

So it's with longer-term prediction that science emerges triumphant. It's all to do with assembling a representative dataset or, if you like, a long enough baseline for meaningful extrapolation. It has often been remarked that history is always written by the victors but of course a more fundamental and inescapable shortcoming is that it can only ever be written by the literate. Thus we know more about ancient Sumeria, over 5000 years ago, than we do about Scotland 1200 years ago, simply because the Sumerians left ample written records that we are able to decipher while the Picts didn't. History can only take us back to the invention of writing, beyond which we have the alternatives of myth and science. The latter offers first archaeology, whose reach is limited by the earliest known artefacts (perhaps ten times as far back as the invention of writing), and then the breathtaking sweep of palaeontology, uncovering evidence from the start of the fossil record almost a billion years ago (and today wonderfully buttressed by analytical genomics).

But that's all airy generalisation. To further disentangle these two views and to examine a specific global threat, let's recall the well-known calamity that overwhelmed the towns of Pompeii and Herculaneum and their inhabitants in 79 CE[11]: an eruption of Mount Vesuvius that produced what we would now recognise as a classic pyroclastic flow and was described in a surviving letter from Pliny the Younger. To historians, it's a fascinating episode but, to a geologist, both more illuminating and more worrying. That unexceptional eruption reminds us that our world's apparent solidity is an illusion: the rocks themselves are in torment, with seething magma and pent-up, super-hot gasses lurking just beneath the fragile crust we tread. The young science of plate tectonics (which explains volcanoes and much else, though unfortunately it can't yet predict individual eruptions) rests entirely on this fluidity. Larger eruptions than any in history would be capable, by altering the reflectivity of the atmosphere, of wiping out not just the occasional unfortunate city but the food supply of the entire planet for successive growing seasons. And that fact underlines the superiority of science for making long-term forecasts: there have certainly been no such supervolcano eruptions in recorded history but there is ample evidence from geology both of their occurrence, and of their devastating impact on life, at irregular intervals throughout the remote past[12].

While such global threats lie beyond our direct experience, they deserve our consideration because we know humans have not yet been on the planet for anything like a representative fraction of its existence. Human history therefore, while certainly not bunk[13], is frighteningly selective: *Homo sapiens'* tenure of 100,000 years or so is dwarfed by the unchallenged 130 million-year reign of the dinosaurs, yet they in turn became victims of just one such rare disaster. You might chuckle at that, because I'm sure our species would gladly settle today for a guaranteed dominance of 130 million years but unfortunately, that's not quite what's on offer: the dinosaurs didn't depend on alternating current and antibiotics; they didn't even need fertilisers, shelter or complicated food distribution networks. The main lesson I think we can take from their story is that evolution can cope well with slow changes but, if you have a small brain (or perhaps even a large one but refuse to use it), you can become quite comprehensively extinct in the course of perhaps only a single generation.

While traces of many hitherto unsuspected long-term threats (like those supervolcanoes) have now been uncovered by pure science, its slightly tainted partner, technology, has actually delivered some of its own[14]. With no parallels in recorded history, these were not just unimagined but unimaginable only a generation ago, and perhaps we have to accept that Earth might be a more dangerous place than it previously appeared. But we haven't yet proved that these threats are likely to be more frequent or more damaging in the immediate future than they have been over the last four thousand years, say. I shall do so, and a few scientists go even further: not content to predict novel but plausible disasters brought down on an unprecedentedly overcrowded and interconnected world, they claim (somewhat counter-intuitively) that modern lifestyles and technology are undermining rather than strengthening our defences and even that resource depletion makes it less likely with every passing year that humanity could ever recover from the worst that might happen. We'll examine that contention in Chapter 10.

If we concede that history is an untrustworthy guide to likely futures, perhaps the wisdom of crowds might be? The great mass of people clearly suspect the risks are overstated, but when you contrast the motivations of those encouraging that view with the reluctant and disinterested conclusions of the scientists, it's hard to be persuaded. It's not as though these novel threats are being dispassionately considered and then discounted: instead, they're being dismissed in advance as self-evident scaremongering, and the most confident dismissal comes from those with a vested interest in maintaining the status quo. Most newspapers and many TV channels encourage the suspicion that, over climate change, say, there is a worldwide scientific conspiracy, perhaps abetted by governments, to maintain an unrealistic level of alarm. This certainly represents an odd reversal of earlier conspiracy

theories that scientists and governments were complicit is *suppressing* alarming knowledge (about UFOs for example).

It's also hard to see how such a worldwide pretence might be sustained when the slightest departure from scrupulous open-handedness is instantly seized upon and publicised, as has happened twice recently in the world of climate science. The first was the 2009 'Climategate' crisis, which involved the suppression of inconvenient data by the beleaguered Climate Research Unit at the University of East Anglia (all of whose staff were subsequently exonerated from any imputation of misconduct by the House of Commons Select Committee on Science & Technology). The second was the 'Glaciergate' controversy[15]: the suggestion in the Intergovernmental Panel on Climate Change (IPCC)'s *Fourth Assessment Report* of 2007 that all Himalayan glaciers might have melted by 2035! The first fall from grace arose because mischievously insistent demands for detailed information by climate-change deniers threatened to prevent the Unit from doing any useful work but the second was in fact the result of a simple typographical error – the original draft had read 2305 – but nevertheless both helped to undermine public trust in climate science.

Sadly, those whose meat and drink is conspiracy never uncover any of the real scandals perpetrated by governments or criminal organisations: their limited imaginations and naive trust in hearsay (and often in recondite sources like ancient prophecies) invariably lead them in the wrong direction. In the real world, we rely on whistle-blowers finding, first, enough inner courage and second, some sympathetic media somewhere, prepared to publicise the disgraceful conduct they reveal. Even setting aside systematic disinformation, distraction and denial from those with clear monetary and political motives, when it comes to dangers, the sheer sweep of unfolding possibilities is a problem for the general population. Crowds (and also, sadly, politicians) like to focus on one problem at a time and to try alternative solutions sequentially. That won't work when threats suddenly multiply and grow complex interconnections. It will of course be one task of this book to try to isolate the more serious challenges, and tentatively to suggest a few workable defensive strategies.

In case your attention is wandering, during the interminable wait to see some specific threats enumerated and validated, perhaps I can distract you with a contradiction? I've claimed we know too much – for continued peace of mind or mature risk assessment – but in another sense we still know far too little: too little to solve emerging problems quickly, and too little of the amazing interdependence of the climate and the biosphere and the delicate mechanisms underlying our survival to solve them wisely. The illusion of power over Nature – really no more than an ability to tinker with local environments – has left us arrogantly persuaded that we are masters of our destiny, yet we have been slow to see how our actions in one field impact another. One and a half centuries after Darwin pointed out our utter reliance on the honeybee[16], we are still recklessly denuding the planet of vegetation that replenishes the very oxygen we breathe. Not only that: faced with the unquantified threat of global warming, a number of enthusiasts are proposing the release of stratospheric sulphur aerosols to enhance the reflectivity of the atmosphere and hence cool the Earth, freeing us to continue as irresponsibly as before. This heedless and perhaps hubristic attempt to correct one symptom while leaving all the other deleterious effects of anthropogenic climate change to worsen is especially alarming when you consider that, once assumed, there could be no end to our responsibility for 'managing' the whole planet's meteorology. Yet it is being seriously considered while our knowledge of this most complex and vital of all Earth systems remains massively incomplete.

Society has already wisely imposed limits on some technology (especially weapons like landmines and nerve gases) and even on some scientific experiments (such as human cloning): just because we *can* do something, it doesn't mean we *should*.

A Catalogue of Conceivable Calamities

It's time to bravely face (or at least bravely survey on paper) the major threats that confront us, before assessing what collectively they imply for our future as a species. These will include some of the modern successors to the Mongols and the Plague (like nuclear war and global pandemics) but first we need to set aside the myriad terrifying but localised disasters that have always visited humanity: those, like the 79CE Vesuvius eruption we've already mentioned, which the insurance industry used rather disrespectfully to classify as Acts of God. We can exclude them because clearly they are not – and have never been – sufficiently general in their destructive power to threaten us all. Though their frequency varies across the inhabited world, there have always been floods and cyclones, earthquakes and volcanoes, pestilence, drought and famine, while the inescapable arithmetic of our steadily increasing population guarantees that, if their overall frequency remains unchanged, their destructiveness in terms of lives lost will still rise, roughly in proportion.

However statistics only show trends; they can't predict individual cases. The greatest natural calamities of this young century, the Haitian earthquake of 2010 and the Indian Ocean tsunami of Boxing Day 2004, are estimated to have claimed around 315,000 and 230,000 lives respectively but both were far less costly than historic floods in China in 1887 and 1931, each of which may have killed over two million people. China too holds the dubious distinction of recording both the most lethal earthquake (way back in 1556) and the worst famines. But to the Grim Reaper, records exist to be broken: the World's population passed a billion a long time ago (sometime before 1820) and seven billion in October 2011 so, on average, when disaster strikes, there are simply going to be more of us in the line of fire.

Even such localised disasters though are still unusual: most of us have always left this world not with a bang but a whimper. Through all the ages, untold billions have died of simple malnutrition, while smallpox, measles and malaria may each have killed over 250 million people in the twentieth century: the infamous 1918–20 Spanish flu (H1N1)[16] pandemic, perhaps 100 million in a couple of years. Yet even the most virulent of these established diseases invariably leave some survivors. Our concern here is with potential disasters unprecedented in recorded history, about whose probability we nevertheless now have some evidence: the kinds of occurrence that might threaten our entire species.

Before becoming an indexer, I worked as a librarian, so my first instinct when confronting multiple threats is… to classify them. But even that's not straightforward. We routinely collocate books by author or subject, as being more significant and helpful than by binding colour, publication date or size, and with threats too there are several criteria (they're called 'characteristics of division' in the library world) that we might select to govern the initial split. Four that come immediately to mind are by avoidability, by likelihood, by urgency and by causality. Some of the risks that we bring upon ourselves, and a few of the others, are preventable, given the will: for many, we can perhaps only trust in statistics and hope we stay lucky, at least until a proportion of them might yield to improving technology. Some are quite likely to arise within the next few years; others only once in countless millennia. Some will develop gradually; others might strike suddenly with little or no warning. Some result directly from our own behaviour: others are coldly indifferent to whether or not any planet in their path is even inhabited. Here's a preliminary list to take the flavour out of your breakfast coffee:

- Astronomical threats: impacts from asteroids and comets, disruption by black holes, irradiation by nearby supernovae or gamma ray bursts, or by suddenly unshielded solar radiation; blockage of that essential radiation by changes in the Earth's atmosphere or in the interstellar medium
- Geological threats: global environmental disruption by exceptional earthquakes or supervolcanoes

- Biological threats: pandemics of diseases to which humans have no immunity or whose causative organisms are fully antibiotic-resistant (whether cross-species infections or escaped laboratory pathogens) and lethal diseases affecting other species on which we depend (e.g. food crops and their pollinators; photosynthetic organisms)
- Human carelessness or ignorance: runaway climate change; exhaustion or irretrievable pollution of essential resources
- Human ineptitude (as at Chernobyl) or arrogance (making laboratory black holes or uncontrollable changes to the structure of matter, or what I shall call 'the Cassini Effect')
- Human malevolence: globalised war, terrorism or deliberate acts of destruction – whether an updating of the fashionable nihilism of the nineteenth century or a targeted expression of lurking religious fundamentalism, nationalist grievance or racial intolerance
- Technological threats, like a robot revolution (beloved of science fiction authors) or failure of some strategic system on which we've allowed ourselves to become totally reliant

It will need regular updating, of course, as changing technology delivers or science reveals new challenges. The now familiar risk of nuclear annihilation is still only a few decades old; general awareness of anthropogenic climate change is even more recent. Admittedly, some serious threats, like the weakening of the planet's defensive ozone shield by refrigerant gas emissions, were seemingly dealt with quite effectively soon after they were recognised but they were for a while both new and troubling. The list will certainly change… but only a determined optimist would expect it to grow shorter.

Don't panic! Well, not yet…

Before we dissect these individual threats, it might be worthwhile to pause and address some predictably sceptical reaction to the list itself, if only because I don't anticipate recruiting so many readers that I can afford to alienate any of you as early as Chapter 1. If I'm right, the reasons you might lose patience here will lie somewhere along a spectrum whose two ends we can address similarly. One end is totally subjective and can be characterised as: 'Why should I uselessly depress myself by reading about a host of possible calamities, every one of which I am totally powerless to prevent?' The opposite end is more objective, as in: 'If our civilisation were really in such danger, surely it would be showing clear signs of strain, whereas it actually appears to me to be in vigorous health?' Both can, I think be countered by comparing threats to civilisations with the more familiar threats to us as individuals.

In connection with the first though, your understandable reluctance to plough through perhaps a hundred pages promising various kinds of disaster might perhaps respond to some emollient assurances? *Fifty Shades of Black* would seem an unlikely crowd-pleaser but, more tellingly, if any one of these fates was indeed either certain or inescapable, my writing about it would be a lot less fun even than your reading about it. Of course luck may enter into some calculations but it would be foolish to discount Man's almost limitless resourcefulness and adaptability. Indeed, I see many grounds for hope, if few yet for optimism. The third part of the book will examine the attitudes and interests standing in the way of our responding effectively to global threats with the last proposing approaches that might put us in a stronger position. So it's not all gloom, let alone doom.

Returning to impotence in the face of a multitude of threats, we know that as adults we shouldn't respond to danger by hiding from reality. With low-probability/high-risk threats like, say, killer diseases, traffic safety or lightning, we normally assess our vulnerability and

calmly take such defensive and corrective measures as are available, affordable and proportionate[18]. Collectively, as we've already conceded, twenty-first century humans are more risk-averse than their grandparents, while confronting fewer real dangers, but we'd all think it morbid to dwell too obsessively, say, on the myriad forms of cancer or expressions of extreme violence in our world. We know most of us will still live and die without experiencing either (though fewer will altogether escape vicarious exposure through a partner, friend or relative). So most of us neither obsess, nor retreat completely into fatalism: we just allocate sufficient time to acquaint ourselves with known risk factors and take such precautions as seem prudent to adjust the odds in our favour. Once immunisation and smear testing, seatbelts and crumple zones, lightning conductors and smokeless fuels were devised, we didn't just come to embrace them but altered our expectations of our leaders to include making them available (something that is usually easier in democracies).

Similarly with these global calamities: not only is each far from inevitable but humanity has clearer strategies for avoiding or mitigating most of them than does the individual over disease or accident. As we've remarked, the problem is that they are seldom discussed, let alone soberly evaluated. Our popular news media – on the rare occasions when they put aside escapism or salaciousness – present a wildly misleading perspective on personal risk, and few governments encourage much long-term thinking either so the invitation to consider them is generally all too avoidable. It's almost as though the authorities had tried to control public fear of cancer, say, by suppressing any mention of this particular 'C word'. And, even as individuals, I believe we can all contribute to a change of heart. Not all human progress depends on persuading some political party to adopt a manifesto commitment; it can happen when our leaders simply detect and respond to changed public attitudes. The collective will is no more than an amalgam of the sometimes conflicting interests of individually-powerless minorities: our possible futures change every microsecond and, while influencing the massive enterprise of human civilisation can seem as daunting as trying to divert a surging supertanker, we can each contribute some tiny momentum towards a more sustainable and rational course.

The second sceptical reaction however (questioning the evidence) is superficially perfectly logical, because at least quantitatively, human civilisation does indeed seem to be prospering. Since you are reading about these pessimistic possibilities, then clearly the world has *not* yet ended, from which one can presumably conclude that each threat is individually improbable. Ah no, not necessarily: past record is no guarantee of future performance, remember, while predictions from a sample of one tend be less than completely reliable. We can again usefully compare the fate of our species with our individual fates, because your reading this also means you have yourself survived, but soberly you must know that this happy situation cannot last forever! The facts that various recent predictions of calamity were unfulfilled, ranging from the misinformed assertion that the Mayan calendar ended abruptly in 2012 to the exaggerated concerns over the Y2K bug in 2000[19]; that none of the recent scares over disease pandemics has yet resulted in any significant change in overall mortality, and that rogue asteroids keep on missing us, are no real comfort. For a civilisation as for an individual, The End only has to happen once.

Loading the dice

If I've persuaded you to keep reading for a bit, there are a few other general issues worth addressing before we move on to the detail. One serious point is that some of these risks are evidently new or recently discovered but that, in other cases, I am claiming either that their probability has increased, or that our society has somehow become more susceptible. The first of these is the more obvious: our Victorian forebears may have been more vulnerable to cholera, tuberculosis and reckless food adulteration but they didn't have to worry about nerve

gases or nuclear weapons: their steam-powered economy couldn't be paralysed by an Internet worm and most of them remained blissfully unaware of the impact their mania for collecting was having on biodiversity.

It may not be wholly self-evident though how our twenty-first century lifestyle can be making us especially vulnerable to what Martin Rees called 'threats with no enemy', especially since we have agreed to exclude the obvious fact that increasing human numbers offer a larger pool of potential victims for any particular limited catastrophe. After all, common sense suggests the chances of an asteroid impact, say, are the same next year as they were last (or, to be pedantic, just infinitesimally lower as such debris is gradually being mopped up by other planets) but there are a number of subtle ways in which our growing reliance on technology is increasing our vulnerability even to threat levels that are themselves stable over time, some of which we can all think of. For example, the spread of the railways in the mid-nineteenth century and of the internal combustion engine early in the twentieth were hugely liberating social phenomena, but they introduced previously unrecognised dependencies. Were fuel oil, by some unforeseen circumstance, very suddenly to become unavailable, we should quickly find ourselves (in developed economies) without enough heavy horses and other draft animals to sustain even medieval levels of subsistence agriculture, a fact that underlines the UK's national dependence on fossil fuels[20]. The doors opened by technology often reveal such enchanting prospects that we fail to notice another door softly closing behind us.

For a more dramatic instance, let's look at solar flares and coronal mass ejections (CMEs), the seemingly unpredictable occurrence of magnetic storms on the Sun that can send intense bursts of radiation or huge jets of superhot plasma (ionised gas) surging toward us. The Sun is nearly five billion years old so let's assume that, at least over the medium term (say the six million years or so over which recognisably humanoid primates have been around) the most severe of these might have occurred with essentially constant average frequencies. But only now have they really begun to hurt us. Even a thousand years ago, a severe CME might have resulted in an especially awesome auroral display but nothing more: impressive enough to the Inuit near the magnetic pole certainly but completely imperceptible to dwellers in the tropics. Now though, the same event would damage electricity transmission systems, plunging our cities into darkness (as happened to Quebec in March 1989) and our machines into inactivity while disrupting radio communications. Its magnetic effects could fry the electronics of our satellites, wrecking telephony and the Internet, while its heating of the atmosphere, by causing it to expand briefly into the zone of low earth orbit[21], could increase friction on those satellites sufficiently to bring them prematurely to Earth (as happened rather spectacularly to NASA's Skylab in July 1979, following enhanced solar activity in 1977).

By themselves, you might think flares and CMEs are unlikely to constitute a lethal threat to civilisation though ironically, at the height of the Cold War, one outage caused by a solar storm was suspected of being due to enemy action, so conceivably this phenomenon could frighten someone into 'getting their retaliation in first' and precipitating disaster in a future world both nuclear-armed and nervous. More worryingly, as with volcanoes, we have uncertain evidence of occasional much more severe CREs in both historic and prehistoric times[22]. A truly massive one would leave us all without domestic electricity for years, for the horribly prosaic reason that we simply couldn't replenish the many thousands of transformers that would be simultaneously burned out in any shorter time. The key secondary vulnerability here reflects the fact that, with Capitalism almost everywhere triumphant, emergency planning is now subordinated to the demands of the market. Competing electricity companies simply cannot afford to commission and store sufficient equipment to reconnect even key industrial, let alone domestic, customers in the face of a possible universal malfunction. So might such an event perhaps qualify as moderately serious?

In another case that seemingly concerns few people, digitising human knowledge has delivered it to our desktops and mobile phones, but disposing of libraries of hardcopy records as redundant and putting all our eggs into the digital basket would seem short-sighted if civilisation were to be brought even temporarily to its knees. You can keep a printed book safe for a thousand years in a reasonably dry cave but you can't read a CD-ROM just by daylight or repair an integrated circuit in a thatched hut. The knowledge accumulated since the invention of writing is a resource we assume to be indestructible but the legacy of unreadable microforms and computer media – magnetic tape (including VHS cassettes), aperture cards and microfilm, various sizes of 'floppy' and 'laser' video disks – provides embarrassingly recent evidence to the contrary. And the obsolescence isn't restricted to hardware: sometimes the early programs needed to access legacy data are can no longer be supported. With hindsight, the rush to replace paper records with unstandardized digitised equivalents was a fit of collective hysteria uncomfortably reminiscent of the South Sea Bubble or the Darien Scheme. IT itself, of course, is an area whose professionals are notorious for avoiding excessive introspection, and recent widespread adoption of cloud computing techniques is adding another dimension of abstraction and risk to an insidiously spreading dependence.

Sometimes the vulnerabilities are even deliberately introduced, as when manufacturers of GM seeds introduce terminator genes, which make the resulting plants yield only sterile seed and effectively tie farmers not only to the supplier – as is intended – but also to a particular supply chain[23]. More often, a technological fix to one problem, whether or not it works, creates others that nobody predicted (notoriously so in the biological control sphere, where we have often clumsily intervened in systems that turn out to be far more complex than our preferred models could predict). We'll look more critically at the costs and benefits of technology in Chapter 7 but, for now, can we at least agree that some progress comes with a hidden penalty in terms of new dependencies and dangers?

Of course, we'd be unlucky to have to face more than one potential calamity at a time but the point is, there are an awful lot of them on offer and one might be enough. Also, they're not necessarily independent in their probabilities or their consequences. For example, the loss of stratospheric ozone, had it progressed unchecked to the point where we became really vulnerable to incoming high-energy radiation, would have intensified the effect of a second threat, geomagnetic pole reversal, since that disables a different protective mechanism (deflection in this case, rather than absorption) against radiation damage. In another instance of interaction, some scientists believe that the eruption of supervolcanoes may itself somehow be triggered or rendered more probable by global warming.

Looking on the bright side?

Before examining each of my listed threat categories, I think we need to pause to ask one final basic question: whether it really matters. Because, even if you are persuaded that at least some threats are plausible and that our modern lifestyle might, at least in principle, be making us more vulnerable, there could still be intellectually valid and ethically respectable reasons (aside from individual feelings of impotence) for retreating into what we might call defensive solipsism. By which I mean concern only for one's own family (bearers, of course, no matter how individually altruistic you may all be, of the Selfish Gene). Crudely, such arguments can be characterised as either optimism or fatalism: either the belief that things must turn out better than we fear, or else that they will turn out as they must, regardless of our efforts. Expanding those two labels into logical propositions, there are at least three ideas that offer varying degrees of comfort to many people.

By far the most widely embraced of these is religion, which has several aspects. First, if any beneficent deity exists, cares about us and is of an interventionist bent, they can

presumably be relied on to protect us from destruction (whether caused by outside agencies or by our own folly). Alternatively, if such a deity exists and has a definitive plan for the universe, He has presumably already shaped our ends, leaving us powerless to influence our eventual fate. And, if you further believe that this same deity has arranged our earthly lives only as a prelude to a distinct eternal and incorporeal existence, then nothing that might happen to mankind in the distant future is relevant to the all-important fate of your own soul. Far and away the most popular solace, this alarmingly entails gambling absolutely everything and every future generation on one particular unprovable world view. Furthermore, religions tend actively to discourage adherents from facing questions much wider than their own morality or required observance, so the world's faiths collectively constitute a powerful force for rejecting apocalyptic forecasts made by anyone other than themselves. And of course many fundamentalist flavours of religion explicitly reject almost all of science, thus disbarring their congregations from taking any new threat to the species seriously; fatalism on a truly cosmic scale.

The second reason dispenses with God, but assumes with buoyant optimism that humanity's seemingly limitless resourcefulness, inventiveness and sheer tenacity will continue to triumph over adversity as they always have in the past. Civilisation has evidently survived the Mongols and the Plague, the Cuban Missile Crisis and AIDS. Change and decay may be inevitable but the species has recovered from many past catastrophes and perhaps even once returned from the brink of extinction, only to triumph and enjoy its present unchallengeable pre-eminence. Are there any compelling reasons why we can't pull off the same trick again? (Sadly, I think there are).

The third (a dramatically contrasting train of reasoning) could provide only a very cold comfort for most of us, but is worth including as another variant of fatalism. It recognises that intelligent life on Earth may be gone in a fleeting instant in the history of the cosmos but clearly if it can appear here, the laws of physics are unlikely to prohibit it elsewhere. The sheer, mind-bogglingly vast number of potential habitats suggests other intelligent beings may (some would say *must*) exist in sufficient numbers for a few to have surmounted similar threats and even to have progressed much further in understanding how the universe works. Even if we fail, some being somewhere, must surely have succeeded?

All three of these are, I think, mere whistling in the dark, but let's leave them until later (Chapters 9, 10 and 11 respectively) and just look a little more closely at a few worst cases. We can quantify many of the challenges listed above; we can do something practical about a few. But, even where we can, do we have the will? They are disparate and in some cases complex, so it would be naive to expect one overall solution, but we do have both one uniform starting point and one tested technique. First, we need to face them, ensure that each is recognised and (as the international community did with climate change when setting up the IPCC) allocate them to a suitably qualified study group whose advice is openly available for discussion. In most cases, we've not even got that far yet. To invert the optimists' position, being physically fairly feeble, the only weapons we have ever had to ensure our survival are human intelligence, human adaptability and human altruism. We will discover that many of the countervailing forces that could undermine any effective response are similarly to be found within ourselves.

Before dissecting the various threats on our original list though, I'm going to address another quite fundamental reason why anyone might conclude that none of it matters. This concerns the ultimate fate of the Earth, the Sun, our Galaxy and the entire Universe. Most people are perhaps vaguely aware that our Sun is now a middle-aged star and not destined to die peacefully, or perhaps that we face collision with the Andromeda Nebula within a similar timescale. If the Earth itself is in fact doomed, surely there's nothing we can do that will avert eventual catastrophe and the distant future offers only a choice between different routes, all converging on an unavoidable extinction? It's really just a further version of fatalism but disposing of this small matter first should also neatly prepare the ground for examining in

more detail the more immediate astronomical threats listed above. So let's look a really long way ahead and review the current, very incomplete understanding of our likely eventual fate, using that unassuming word 'our' in its widest possible sense, to include everything from the proton, through people, to the universe as we know it. Fasten your seatbelt.

Notes

Chapter 1

7 *A fuller quotation is:*

> *We are … bringing about the end of the world we were born into. Not out of evil or malice, or not mainly, but because of a lopsided mixture of extraordinary cleverness, extraordinary greed, extraordinary proliferation of our own kind and a biologically built-in short-sightedness. Every day I read of a new extinction, of the bleaching of the coral and the disappearance of the codfish … I read of human projects that destroy the world they are in, ingeniously, ambitiously engineered oil wells in deep water, a road across the migration paths of the beasts in the Serengeti park, farming of asparagus in Peru, helium balloons to transport the crops more cheaply, emitting less carbon while the farms themselves are dangerously depleting the water that the vegetables, and the humans and other creatures, depend on …*
>
> *Almost all the scientists I know think we are bringing about our own extinction, more and more rapidly.*

8 *At about £1,000,000, as of 2009, this is the largest single annual financial prize award given to an individual by a philanthropic organisation, its value being adjusted so that it exceeds that of the Nobel Prizes, as Templeton felt 'spirituality was ignored' in the Nobel Prizes. It is awarded ostensibly to someone who 'has made an exceptional contribution to affirming life's spiritual dimension, whether through insight, discovery, or practical works' but, until 2001, the name of the prize was Templeton Prize for Progress in Religion. Martinus J. G. Veltman, the 1999 Nobel laureate in physics, suggested the prize 'bridges the gap between sense and nonsense.' Aside from Rees, Paul Davies and Freeman Dyson (both of whom have written source material used elsewhere in this book) are amongst those other scientists who have – shamefully to my mind – accepted a Templeton. There's more on scientists and religion in Chapter 9.*

9 *It's worth pointing out that scientists have not always foretold doom: quite the reverse. From 1833, when the term 'scientist' was first coined by William Whewell, until well into the twentieth century, they were reassuringly positive, often even gung-ho about humanity's rosy future. How that has changed! Our nineteenth-century image of a static world, spinning predictably through the unchanging heavens, has been displaced by that of a vulnerable, interdependent and possibly unstable ecosystem, bombarded by cosmic WMDs and sudden outbursts of lethal radiation. But if scientists are now throwing up their hands in despair, it's not because of the newly-discovered threats themselves, but because of our unwillingness as a society to face any uncomfortable truths or really complex problems.*

10 *Though no match for another Nobel winner, Richard Feynman, Bohr was reckoned a wit among physicists. In one memorable line, he once chided 'Einstein, stop telling God what to do.' Asked why he had nailed a horseshoe over his door he replied 'Of course I don't believe in it, but I understand it brings you luck, whether you believe in it or not.' Other remarks include 'We're all agreed that your theory is crazy. The question which divides us is whether it's crazy enough to be true'; 'A physicist is just an atom's way of looking at itself' and 'An expert is a man* [sic] *who has made all the mistakes which can be made, in a narrow field'*

11 *At the risk of being accused of political correctness (Happy Winterval, anyone?) I'm adopting the forms of CE and BCE (Common Era and Before CE) in place of the AD and BC familiar to Christians; the values of course are the same. For earlier and less precisely datable events, YBP (Years Before the Present) is useful. For even longer time intervals, these units are cumbersome and the last 2000 years can for all practical purposes be ignored. Indeed, not to do so might repeat the common solecism of conveying precision without accuracy, as in 'about 30 yards (27.432 metres)'. For anything much before the appearance of the genus* Homo, *we'll use Ma for million years ago. We shouldn't need numbers greater than about 13,700 Ma too often since this is the estimated age of the Universe (derived by projecting the current expansion backwards)! Oddly, modelling allows us to make statements about events that must have taken place a fraction of a millisecond after the initial Big Bang, but we can't be precise about the elapsed time since, any closer than the nearest half billion years or so.*
>
> *Incidentally (or should I say 'even more incidentally'?), there is in fact a fundamental atomic unit of time – atomic in the sense of being indivisible – and it's known as the Planck time, after Max*

Planck. To convert years to seconds, just multiply by around 31 million: to convert seconds to Planck units, by another 10^{47} (that is, '1' followed by forty-seven zeros)!

12 *The discoveries of plate tectonics and the existence of supervolcanoes will be more fully discussed in Chapter 4.*

13 *First, what is bunk, in this context? It seems to be slang for nonsense, related to 'bunkum' and 'debunk'. This particular quotation from Henry Ford is only one of many showing his contempt for history. It occurred in an interview with Henry A. Wise Wood about defence issues (Ford was a prominent pacifist in World War I), as reported in the* New York Times *of 15 May 1916.*

14 *Engineers like to present themselves as offering solutions, not as generating new problems, but that's wholly disingenuous. It's worth stressing that, whereas science is ethically neutral, seeking only understanding, technology (as the application of scientific discoveries to human ends) is deeply imbued with the ethical flavour of those ends and hence is almost never neutral. Sometimes the ethical component is manifest even at the design stage or, if you prefer, the requirement specification: irrigation canals and immunization, electric light and antiseptics have remained fundamentally beneficent from conception through employment but nobody ever envisaged altruistic uses for thumbscrews or trebuchets, the Gatling gun, phosgene or the V2 rocket.*

Very commonly, the ethical status can change with circumstances. Antibiotics saved millions of lives but their abuse has driven the emergence of resistant superbugs and left us defenceless against them. Nuclear research began benignly as pure science 'of not the slightest use' and then delivered (largely from laudable motives mixed with naivety) the atom bomb. It then seemed to offer the dream of limitless energy which spun off the nightmare of Chernobyl and a waste disposal problem so intractable that we are simply bequeathing it unsolved to unborn generations. Refrigeration too was at first unambiguously beneficial, wonderfully preserving food and medical supplies from thermal spoilage, but the incidental release of refrigerant gases led to depletion of the planet's protective ozone layer and introduced a new vulnerability: to the harmful effects – including some particularly aggressive cancers – of unshielded ultraviolet radiation.

Sadly, the millenarian view of technology that we inherited (in Britain's case from the Victorians) is very slow to relax its hold. We have become so attached to our packaged holidays by air, our mobile phones and our freedom to drive anywhere, that we wilfully blind ourselves to the associated disadvantages and blithely expect technology to provide solutions to the most intractable problems. The logical circularity of that hope, requiring more and more technology to solve both pre-existing problems and those it creates afresh, will be obvious. As will the hopelessness of expecting quick results from directed research: if trying were all that was required for success, would people still be dying of cancer?

15 *Since the Watergate conspiracy of 1972, the suffix '–gate' has entered the language, serving as an instantly recognisable tag to identify any scandal involving those in high places.*

16 *Strictly, on all pollinators, but most economically important food crops rely on some type of bee. And of course ironically, at the time of writing, bee populations do seem to be threatened by colony collapse disorder and perhaps separately by* Varroa *mite infestations. Some plants do get by with wind pollination but it's a riskier strategy and most commercially important food crops require the help of insects (usually bees).*

17 *This jargon is seldom explained and, when scientists are opaque, they do everyone a disservice. Influenza type A viruses are divided into subtypes on the basis of two proteins on their surfaces: hemagglutinin (HA) and neuraminidase (NA) and together these define the strain. For example, an "H7N2 virus" designates an influenza A virus subtype that carries an HA7 protein and an NA2 protein.*

18 *I might mischievously interject that raw statistics don't always help in risk assessment: I believe it's a fact that, in the UK at least, you are more likely to be killed by a falling piano than by an adder bite, but that doesn't mean you can safely cavort naked and barefoot through the heather in the remoter parts of Scotland, looking up regularly to check that there are no pianos visible in the sky above! And moving pianos is of course so dangerous that* The Goon Show *once devoted an entire episode to it. There's a delightful Laurel and Hardy short too (*The Music Box?*), though I recall it as having rather minimised the perils.*

Potentially lethal risk can be quantified in micromorts (each a one-in-a-million probability of death), a measure devised by Ronald A Howard. Any day of an average life theoretically exposes us to

a risk of about 40 micromorts simply because of the passage of time but only about one micromort risk of premature death; that premature risk is doubled if you ride a horse (once) or fly about 900 miles in that day.

19 *The first Millennium seems by some accounts to have been even more dramatic. It is alleged that some authorities even released prisoners from their gaols, so certain were they than God used the same calendar, counted in the decimal system and had a tidy mind. Evidently they were wrong on at least one of these counts and were so vexed by their very public miscalculation that the prisoners were quickly rounded up again.*

Probably that too was celebrated a year early. Though the ghastly Pol Pot declared a Year Zero, the Christian Era began in 1 A.D. (the West hadn't then discovered the usefulness of the number zero) so strictly its millennia fell at the ends *of 1000 and 2000. Also, not all societies then counted their years from 1st January to 31st December: Scotland made that switch before England, which persisted in starting new years on 25 March until 1752.*

In fact, since King Herod died in 4 BCE, we could already have been sure this time that God hadn't decided to mark His Son's 2000th birthday by ending His misconceived experiment of creation for good. More generally, the universal insistence that the new millennium began on 1st January 2000 is a useful reminder that near-unanimity is no guarantee of the truth of an opinion.

It had briefly seemed as though 1 January 2000 might be made memorable anyway as computers all over the world were predicted to malfunction, possibly causing planes to fall out of the sky, bank accounts to freeze and lighting and heating systems to fail. They didn't, which left the UK government and its scientific advisors looking just a little over-cautious. Were the huge sums spent on apparently unnecessary measures against the Millennium Bug simply an expression of Anglo-Saxon anal retentiveness, since the Japanese (and more locally the Italians, with their 'che sera, sera' *approach) escaped the dire consequences that we might feel their casualness deserved? Though the Bug turned out to be mostly harmless, it's another useful reminder, this time of the way our inventive capacities outstrip our introspective ones, so that we raced ahead to put everything under computer control, with nobody considering the effect of one elementary short-cut (among thousands which must have been made). And, as a further numerological curiosity, its trendy abbreviation of Y2K was inaccurate; strictly 2K was 2 x 2^{10} or 2048 ('was', because the industry has bowed to the inevitable and made K an abbreviation for a round thousand as in kilobyte). Still time, then, for Armageddon if God should happen to use binary instead of decimal! However, I should be 102 in 2048, so I'm afraid you may have to manage that party without me.*

The Mayan calendar reset regularly, by the way, and ending in 2012 no more betokens any kind of cataclysm that does the resetting of a five-digit odometer from 99999 to 00000 means your car ceases to work. I believe the Mayans, like many farming communities and most transhumant nomads, regarded time as endlessly repetitive, with neither beginning nor end.

It remains true that the most self-important people in any age love to predict imminent apocalypse. It soothes their egos to imagine their own lifetime is cosmically significant and that no normality can survive so uniquely gifted a generation as their own. This egotism is most potent when allied to profound credulousness, with many of the doom-mongers dismissing real risks as a conspiracy and cherishing the certainty of arcane revelation while remaining utterly unable, say, to grasp the mechanics of eclipses.

20 *This was actually tried recently in Cuba. The fall of the Soviet Union in 1989 deprived the island of its high-tech supplies but didn't immediately lead to a relaxation of US sanctions, so the Cubans had to rebuild a low-tech agriculture. Even with central direction and coordination, it took them a full decade to breed sufficient heavy horses. The other telling consideration is that horses are inefficient; to keep them available for when they're needed, you need to reserve a considerable acreage of land under grass, something an overpopulated Earth may begrudge.*

21 *Low earth orbit is up to 1250 miles above sea level and is where, for example, the Hubble Space Telescope and International Space Station can be found. Geostationary orbits lie much further out. Since orbital velocity decreases with distance, an object orbiting about 22,000 miles above the equator will exactly keep pace with the rotation of the Earth beneath it and thus remain fixed with respect to the ground, making it ideally suitable for communications and global positioning satellites, which don't need tracking antennas because they always appear to be in the same place.*

22 *The geomagnetic solar storm of August-September 1859, also known as the Carrington Event, occurred when a solar flare and/or CRE observed and recorded independently by Richard Carrington and Richard Hodgson hit the Earth's magnetosphere. On September 1–2, aurorae were seen around the world, even as far south as Cuba and Hawaii; those over the Rocky Mountains were so bright that*

their glow awoke gold miners, who reportedly began preparing breakfast. People who happened to be awake in the north-eastern USA could read a newspaper by the aurora's light. Telegraph systems all over Europe and North America failed, in some cases giving operators electric shocks. Some systems continued to send and receive messages despite having been disconnected from their power supplies.

More remote events, from before reliable records began, can be discovered from analyses of nitrate-rich layers in ice core. Data from Greenland show evidence that events of this magnitude – as measured by high-energy proton radiation, not geomagnetic effect – occur approximately once per 500 years, though the data may be skewed by more extreme cosmic ray events outside the solar system. Less severe storms in 1921 and 1960 did cause widespread radio disruption.

It is interesting that the Sun gives us few identifiable indicators of brewing storms (currently only about two days' warning, representing sensing down to 60,000 miles below the surface photosphere) or of their severity. Optimists hope to extend this to perhaps a week, possibly allowing time for suitably equipped satellites to be boosted to higher orbits. There's really not much else we can do at present and the prospects of influencing our parent star seem remote: the radiation Earth receives from the Sun still represents some 2000 times the entire world's energy use but of course we're a tiny target; most of it radiates uselessly in other directions and the Sun's total output actually dwarfs our consumption by a factor of over ten trillion!

23 *GM seed manufacturers claim that terminator technology was originally used only for self-fertilizing plants (thus making it impossible to 'spread sterility'), and was in any case abandoned in the late 1990s and replaced by legal contracts. So that's all right then…*