THE JAMES MARTIN
21ST CENTURY SCHOOL
UNIVERSITY OF OXFORD

# LORD REES: THE WORLD IN 2050

## Distinguished Public Lecture 23 February 2009

*Lord Martin Rees is President of the Royal Society, Master of Trinity College, and Professor of Cosmology and Astrophysics at the University of Cambridge. He was appointed Astronomer Royal in 1995, and was nominated to the House of Lords in 2005 as a cross-bench peer. With world population predicted to reach 9.2 billion by 2050, Lord Rees' lecture addressed the dangers and opportunities facing humanity in the 21st century.*

---

It's a privilege to be hosted by the James Martin School -- but it's daunting too. As Ian Goldin has described, the School contains a phalanx of experts who have thought longer and harder about the 21st century than I have.

It's doubly daunting because the Chancellor, Chris Patten has himself just written a book called 'What Next? Surviving the 21st Century' which I can thoroughly recommend.

He has, incidentally, a rather surprising precursor in this kind of venture. Lord Birkenhead (F.E. Smith) , Tory Lord Chancellor in the 1920s and crony of Churchill, published a book in 1930, entitled 'The World in 2030'. He'd soaked up the futurology of Wells, Haldane, and Bernal; he described human embryos being reared in flasks, and suchlike. But he was entrenched in the social mindset of his class and his time -- especially regarding female emancipation:

'In 2030 women will still ...... by their wit and charms, direct the activities of the most able men towards heights which they could never themselves hope to achieve'

We didn't have to wait till 2030 for a Margaret Thatcher!

No-one in the 1930s, could have confidently predicted the geopolitical landscape of today. Nor the social changes (though some might have done better than Lord Birkenhead) . And in science, the most transformational advances, the qualitative leaps, are unpredictable. Francis Bacon realised this 400 years ago. He noted that tekniques like printing had been developed incrementally, but that the qualitative leaps -- gunpowder, silk and the mariners' compass, for instance -- couldn't have been planned for.

Our lives today are moulded by three technologies that gestated in the 1950s -- but whose pervasive impact certainly wasn't then forseen.

It was in 1958 that Kilby and Noyce built the first integrated circuit -- the precursor of today's ubiquitous silicon chips. This was perhaps the most transformative single invention of the past century.

It's led to everyday consumer items like mobile phones and Google that would have seemed magic back then. And these technologies advance apace -- contributing to human welfare, in both the developing and developed world, in ways that are less demanding of energy and resources than most contributions to economic growth.

In the same decade, Watson and Crick discovered the bedrock mechanism of heredity --the famous double helix. This launched the science of molecular biology, opening exciting prospects in genomics and synthetic biology whose main impact still lies ahead.

And there's a third technology --space -- that's closer to my own scientific interests. It's just over 50 years since the launch of Sputnik. This event led President Kennedy to inaugurate the programme to land men on the Moon. Kennedy's prime motive was of course superpower rivalry -- cynics could deride it as a stunt. But is was an extraordinary technical triumph -- especially as NASA's total computing power was far less than is in a single mobile phone today. And it had an inspirational aspect too. Distant images of Earth -- its delicate biosphere of clouds, land and oceans contrasting with the sterile moonscape where the astronauts left their footprints -- have, ever since the 1960s, been iconic for environmentalists.

There was no real follow-on after Apollo: there is no practical or scientific motive adequate to justify the huge expense of NASA-style manned spaceflight, and it has lost its glamour. But unmanned space technology has flourished, giving us GPS, global communications, environmental monitoring and other everyday benefits, as well as an immense scientific yield. In the coming decades, cheaper launch techniques and the development of robotic fabricators will greatly enhance the range of space activities.

But of course there has always been a 'dark side' to space technology. The initial motivation for rocketry was to provide missiles to carry nuclear weapons. And those weapons were themselves the outcome of a huge enterprise, the Manhattan project, that was even more intense and focused than the Apollo programme.

Soon after World War II, some physicists who had been involved in the Manhattan project founded the journal called the the Bulletin of Atomic Scientists, aimed at promoting arms control. The 'logo' on its cover is a clock, the closeness of whose hands to midnight indicates the Editorial Board's judgement on how precarious the world situation is. It was closest to midnight at the time of the Cuban Missile Crisis. When the Cold War ended, it was put back to 17 minutes to midnight. But the clock has already crept forward again, in response to increasing concerned about nuclear proliferation, and diverse other threats. There is surely an increasing risk of nuclear weapons being used in a regional context. And, although the risk of global nuclear annihilation is thankfully in abeyance -- we can't rule out, by 2050, a global political realignment leadding to a standoff between new superpowers, that could be handled less well or less luckily than the Cuba crisis was.

The nuclear age inaugurated a new era -- what some have called the 'anthropocene' -- the first in our planet's entire history when one species, ours, could determine -- for good or ill -- the entire Earth's future.

Information technology, biomedicine and advanced manufacturing are enhancing the life-chances in the developing and the developed countries. But in today's more highly populated and interconnected world, these advances brings new perils: maybe not of sudden catastrophe -- the doomsday clock is not such a good metaphor -- but of global deterioration or breakdown that could be as devastating.

High on this list are concerns about energy supply and energy security -- crucial for economic and political stability, and linked of course to the grave threat of climate change.

The essential scientific basis of climate change should be uncontroversial. CO2 was identified as a greenhouse gas by Sir John Tyndall 150 years ago. It's also uncontroversial that the measured CO2 concentration has been rising for the last 50 years. And that, if we pursue 'business as usual', the concentration will reach twice the pre-industrial level by 2050, and three times that level later in the century.

The higher its concentration, the greater the warming -- and, more important still, the greater the chance of triggering something grave and irreversible: rising sea levels due to the melting of Greenland's icecap; runaway release of methane in the tundra, and so forth.

The IPCC studies still quote substantial uncertainty in just how sensitive the temperature is to the CO2 level, and what regions will be affected most. It is the 'high-end tail' of the probability distribution that should worry us most -- the small probability of a really drastic climatic shift.

Global warming involves long time-lags -- it takes decades for the oceans to adjust to a new equilibrium, and centuries for ice-sheets to melt completely. So, even though global warming has seemingly already begun, its main downsides lie a century or more in the future.

Leet me digress into a bit of history -- the Thames Barrier. This was conceived in the 1960s and completed in the early 80s. It was designed to cope with the kind of event that might happen less than once per century. Its planners extrapolated on the basis of the best evidence. It was an early example of making a major investment -- over a billion pounds in today's money -- as an insurance policy against an unlikely event -- the flooding of London. that would, if it occurred, have a negative economic impact many times larger.

The debate that led to the barrier was a micro and localised version of the global issue that confronts us today.

The committee that deployed these arguments was chaired by Hermann Bondi -- it was the first of his many contributions to public service. He was specially proud of it especially as he seemed an odd choice for the task. He was an academic in my own field: a cosmologist. I draw comfort from this as an encoiruaging precedent for myself venturing into topics beyond my own expertise.}

The science of climate change is intricate. But it's a doddle compared to the economics and politics. In his influential 2006 report Nicholas Stern argued that we should commit substantial resources now, to pre-empt much greater costs in future decades -- and that equity to future generations renders a 'commercial' discount rate quite inappropriate. We're mindful of the heritage we owe to centuries past. History will judge us harshly if we discount too heavily what might happen when our grandchildren grow old.

Global warming poses a second challenge, apart from the long timesales. The effect is non-localised: the $CO_2$ emissions from this country have no more effect here than they do in Australia, and vice versa. And indeed the worst effects may be in Africa and Bangladesh, which have contributed least to the emission. That means that any credible regime whereby the 'polluter pays' has to be broadly international.

It's the consensus view that to ensure a better than evens chance of avoiding a potentially dangerous 'tipping point', global $CO_2$ emissions must, by 2050, be brought down to half the 1990 level. This is the target espoused by the G8 (and enshrined in the UK's Climate Change Act) . It corresponds to two tons of $CO_2$ per year from each person on the planet. For comparision, the current European figure is about 10, and the Chinese level is already more than 4.

To achieve this target without stifling economic growth in the developing world -- to turn around the now-fast-rising global $CO_2$ emissions well before 2050 -- is a huge challenge. There's no chance of reaching it, nor of achieving real energy security, without drastically new technologies.

Efforts to develop a whole raft of techniques for economising on energy, storing it and generating it by low-carbon methods deserve a priority and commitment from governments akin to that accorded to the Manhattan project or the Apollo moon landing. We could afford it. The world spends more than 5 trillion dollars per year on energy and its infrastructure. Current R and D is far less than the scale and urgency demands. In his recent book Tom Friedman notes that US energy utilities spend less on it than the US pet food industry does. There's a glaring contrast here with health and medicine -- where the worldwide R and D expenditures, both public and private, are disproportionately higher.

I can't think of anything that could do more to attract the brightest and best into science than a strongly proclaimed commitment -- led by the US and Europe -- to provide clean and sustainable energy for the developing and the developed world. The Obama administration may spearhead this as part of the stumulus package -- but Europe should surely match the US in R and D and in commitment to infrastructure projects. My favourite would be a pan-European DC grid, connected to massive solar-energy generation plants in the Sahara.

Even optimists about solar energy-- and advanced biofuels, fusion, and other renewables -- have to acknowledge that it will be 30 years or more before they can fully 'take over'. Coal, oil and gas seem set to dominate the world's every-growing energy needs for at least that long. Last year the Chinese built 100 coal-fired power stations.

I'm hopeful about a transition to a quite different 'energy economy' in the decades beyond 2050. But that's not soon enough. If the world remains depended on traditional burning of fossil fuels for the next 30 years, $CO_2$ concentrations will irrevocably reach a threatening level. To meet the target, the rising curve must be turned around within 10 years.

That's the reason for urgency -- and why the Copenhagen conference this December is so crucial.

One essential priority must be a coordinated international effort to develop carbon capture and storage -- CCS. Carbon from power stations must be captured before it escapes in the atmosphere; and then piped to some geological formation where it can be stored without leaking out.

To jump-start a programme of demonstration plants would need up to 10 billion dollars a year of public funding worldwide. But this is a small price to pay for bringing forward, by five years or more, the time when CCS might be widely adopted and the graph of $CO_2$ emissions turned around.

What is the role of nuclear power in all this? This is an issue where both expert and lay opinions are divided. I'm myself in favour of the UK and the US having at least a replacement generation of power stations -- and of boosted R and D into 'fourth generation' reactors. But the non-proliferation regime is fragile, and before being relaxed about a world-wide programme of nuclear power, one would surely require the kind of fuel bank and leasing arrangement that has been proposed by the IAEA.

Developed countries can progress some of the way towards the target cuts by measures that actually save money (energy-efficient buildings, for instance). But globally there will be costs, falling on the fast-developing nations -- which somehow have to be reimbursed by the more developed West. These are estimated as 1 or 2 percent of the GNP for the developed world.

That seems managable. But I admit to some worries. We're aware of the underfunding of overseas aid -- below the 0.7 percent target -- despite the clear humanitarian imperative. This augers badly for the implementation within the next decade of the measures needed if we are to meet the 2050 carbon emission targets

Some pessimists argue that the international community should, as a fallback, contemplate a 'plan B' -- being fatalistic about the rise in $CO_2$, but intervening to combat its warming effects by (for instance) putting reflecting aerosols in the upper atmosphere, or even vast sunshades in space. Such 'geoengineering' would not "solve" climate change --it would at best buy time, probably at inordinate cost. Indeed it's by no means clear that any such scheme is technically feasible. And the political problems may be overwhelminng. Any effective adaptation policy depends on being able to model the Earth's climate reliably enough to anticipate not just the mean global temperature rise, but the actual regional impacts. Even more confidence would be needed before venturing actively to change the climate. (An alternative approach that might be politically acceptable would be direct extraction of $CO_2$ from the atmosphere -- either by vast numbers of 'scrubbers', based on the same principle as those used on small scales in (for instance) submarines, or else by growing trees and 'fixing' the carbon they absorb as charcoal. But this would surely be more expensive than measures to limit actual $CO_2$ emissions.

The Royal Society has embarked on a study of geoengineering -- in hope of clarifying which options make sense and which do not. This exercise may well put a damper on some enthusiasms -- and reveal that there is no realistic alternative to mitigation efforts.

Climate change is the prime long-term anthropogenic hazard to life and environment. But there are others -- for instance the erosion of biological diversity caused by rapid changes in land use and deforestation. There have been 5 great extinctions in the geological past; human actions are causing a 6th. The extinction rate is 1000 times higher than normal, and increasing. To quote Bob May, we are destroying the book of life before we have read it.

Biodiversity -- manifested in forests, coral reefs, marine blue waters and all Earth's other ecosystems -- is a crucial component of human wellbeing. We're clearly harmed if fish stocks dwindle to extinction; there are plants whose gene pool might be useful to us; and massive destruction of the rain forests would accelerate global warming. But there are environmentalists for whom these 'instrumental' -- and anthropocentric -- arguments aren't the only compelling ones. For them, preserving the richness of our biosphere has value in its own right, over and above what it means to us humans.

Some comments now on population growth -- which aggravates all pressures on the Earth's resources. Fifty years ago, world population was below 3 billion. It's now 6.7 billion. Plainly it will be in Asia, not in Europe and the US, that the world's intellectual and physical capital gets increasingly concentrated.

The percentage annual growth-rate has slowed, but the world population is projected to reach at least 8 and probably 9 billion by 2050.

However, there could thereafter be a turnaround. There are now more than 60 countries in which fertility is below replacement level -- it's far below in, for instance, Italy and Singapore. More remarkably, in Iran the fertility rate has fallen from 6.5 in 1980 to 2.1 today. We all know the social trends that lead to this demographic transition -- declining infant mortality, availability of contraceptive advice, women's education, and so forth.

If the transition quickly extended to all countries, then the global population could start a gradual decline after 2050 -- a development that would surely be benign.

There is, incidentally, one 'wild card' in all these long-term forecasts -- that the average lifespan in advanced countries may be extended drastically by some biomedical breakthrough.

James Martin's own book on the 21st century, incidentally, discusses (as one of his more optimistic scenarios) a transition to what he calls eco-affluence -- a high-tech lifestyle that isn't over-profligate in its need for resources. He says, and this is surely inarguable, that such a lifestyle couldn't be universal unless world population fell.

If world population continues to rise beyond 2050, one can't be other than gloomy. The prognosis is specially bleak in Africa, where there could be a billion more people in 2050 than there are today. In 1950, Europe had 3 times the population of Africa. In 2050, Africa will have 3 times Europe's.

Meeting the UN's Millennium Goals seems a precondition for achieving in Africa the demographic tradition that has occurred elsewhere: lifting Paul Collier's 'bottom billion' out of the poverty trap by providing clean water, primary education and other basics. Obama's reversal of Bush's policy on US support of family planning initiatives in developing countries is plainly a positive step.

Just as today's population couldn't be fed by yesterday's agriculture, a second green revolution may be needed to feed tomorrow's population -- especially as climate change and aggraveted water shortages must be contended with. Failure to achieve this would be a tragedy of continental proportions. It would also, as Crispin Tickell highlighted many years ago, trigger massive migratory pressures.

On positive development, incidentally, is the boost in medical research on diseases prevalent in Africa. -- hitherto understudied compared to 'diseases of the rich'. The initiative of the Gates Foundation in identifying 'grand challenges' for tropical medicine has triggered a welcome rebalancing.

But infectious diseases are a growing hazard worldwide. The spread of epidemics is aggravated by rapid air travel, and the impact would be maximal in the developing world where huge (and fast growing) concentrations of people live in megacities with fragile infrastructures.

A global pandemic could kill tens of millions and cost many trillions of dollars. Whether or not an epidemic gets global grip may hinge on the efficiency of worldwide monitoring -- on how quickly, for instance, a Vietnamese poultry farmer can diagnose or report any strange sickness.

If we apply to pandemics the same prudent analysis whereby we calculate an insurance premium -- multiplying probability by consequences -- we'd surely conclude that measures to alleviate this kind of extreme event need scaling up.

In everyday life, we have a confused attitude to risk. We fret about traces of carcinogens in food, a one-in-a-million chance of being killed in train crashes, and so forth. But we're in denial about others -- pandemics emphatically being one -- that should loom much larger.

This thought leads me to mention vulnerabilities of a different kind that may increase between now and 2050: vulnerabilities stemming from the misuse of powerful technologies -- either through error or by design. Biotechnology, for instance, holds huge promise for health care, for enhanced food production, even for energy. But there is a downside.

Here's a prediction from the American National Academy of Sciences: "Just a few individuals with specialised skills .. could inexpensively and easily produce a panoply of lethal biological weapons . ..... The deciphering of the human genome sequence and the complete elucidation of numerous pathogen genomes .... allow science to be misused to create new agents of mass destruction."

Not even an organised network would be required: just a fanatic, or a weirdo with the mindset of those who now design computer viruses -- the mindset of an arsonist. The techniques and expertise for bio attacks will become accessible to millions. There is debate about how effectively or readily a pathogen could be spread -- but, as in the anthrax episode in the US, scary amplification by the media can cause even a 'fizzle' to have national impact. The same is true for cyber-attacks, to which our networked and interconnected world will become more vulnerable.

We're kidding ourselves if we think that technical expertise is always allied with balanced rationality: it can be combined with fanaticism --not just the traditional fundamentalism that we're so mindful of today, but new age irrationalities. I'm thinking of the Raelians, extreme eco-freaks, violent animal rights campaigners and the like. The global village will have its village idiots.

In a future era of vast individual empowerment by bio-, cyber-, or nano-technology, where even one malign act woud be too many, how can our open society be safeguarded? Will there be pressures to shift the balance between privacy and intrusion? These are stark questions, but I think they are deeply serious ones.

We can't reap the benefits of science without accepting some risks -- the best we can do is minimise them. Most surgical procedures, even if now routine, were risky when pioneered.

In the early days of steam, many died when poorly designed boilers exploded.

Overall, our world may now be safer. But something has changed. The 'old' risks were localised. If a boiler explodes, it's horrible but there's an 'upper bound' to just how horrible. In our ever more interconnected world, there are new risks whose consequences could be so widespread that even a tiny probability is disquieting.

We're all precariously dependent on elaborate networks -- electricity grids, air traffic control, the internet, just-in-time delivery and so forth. It's crucial to optimise the resilience of all such system.

We can with some confidence predict continuing advances in computer power, in information technology, in techniques for sequencing and interpreting and modifying the genome -- all tracable back to the pioneering work in the 1950s that I mentioned at the start of this lecture.

But there could, by 2050, be qualitatively new kinds of change. For instance, one thing that's been unaltered for millennia is human nature and human character. But in this century, novel mind-enhancing drugs, genetics, and 'cyberg' techniques may start to alter human beings themselves.

And we should keep our minds open, or at least ajar, to concepts on the fringe of science fiction. Flaky Californian futurologists aren't always wrong.

Some of these 'prophets' claim that computers will by 2050 achieve human capabilities. It's hard to assess the odds. Calculators bought for a few pounds can hugely surpass us at arithmetic; IBM's 'Deep Blue' beat Kasparov, the world chess champion. But not even the most advanced robot can recognise and move the pieces on a real chessboard as adeptly as a five year old child – there's a long way to go before real 'robotic intelligence' is achieved.

But computers have hugely boosted sciences like meteorology and astronomy where you can't do real experiments but can in a simulated 'virtual world'. And I would confidently predict that computer modelling will play an ever-growing role in modelling complex systems. But what about creative leaps and "eureka moments"? 'Deep Blue' didn't work out its strategy like a human player: it exploited its computational speed to explore millions of alternative responses before deciding an optimum move. Likewise, machines may make scientific discoveries that have eluded unaided human brains. --- but by testing out millions of possibilities rather than via a deep insight. (But the programmer will get the acclaim -- just as, in Olympic equestrian events, the medal goes to the rider, not the horse. )

We can't predict the future course of science, but we can make one firm forecast that's important for the scientific community. There will surely be a widening gulf between what science enables us to do, and what applications it's prudent or ethical actually to pursue -- more doors that science could open but which are best kept closed

Opinion polls show that people are generally positive about science's role, but are concerned that it may 'run away' faster than we can properly cope with it. -- that discoveries can be applied dangerously or unethically. The best-known fictional scientists -- Drs Frankenstein, Moreau, Strangelove and their successors -- exemplify and fuel this perception.

More and more key issues have a scientific dimension -- whether about energy, GM technology, mind-enhancing drugs or whatever. And a global dimension as well – indeed regulatory regimes often need global reach to be effective. There may be a need for other international bodies, perhaps modelled on the WHO, or on consortia like the IPCC.

It's a duty of advisors to government, and of scientific academies, to ensure that policy decisions are based on the best science, even when that science is still uncertain and provisional. When President Obama announced the names of the scientists who would join his administration-- a real 'dream team', incidentally -- he said that their advice should be heeded "even when it is inconvenient -- indeed especially when it is inconvenient" .

But polititions seldom confront substantial issues that are solely 'scientific': strategic, economic, social, and ethical ramifications enter as well. And with regard to these other elements, scientists have no special credentials. Choices on how science is applied shouldn't be made just by scientists. That's why everyone needs a 'feel' for science and a realistic attitude to risk -- otherwise public debate won't get beyond tabloid slogans.

But (if I may speak for a few moments as a scientist, rather than as a worried member of the human race) there is another less utilitarian reason why the public needs a feel for science. It's part of our culture -- indeed it's the only global culture -- protons, proteins and Pythagoras are the same from China to Peru.

Scientists in my own field have, in recent decades, deliniated the chain of events that led from some mysterious beginning 13 billion years ago, to the emergence of atoms, stars galaxies and planets. And biologists have learnt how on at least one planet, a biosphere emerged and Darwinian selection led to creatures with brains able to ponder their origins. It's a cultural deprivation to be unaware of this fast-developing story.

This year we're celebrating Darwin's 200th anniversary; it's also the 400th anniversary of Galileo's telescopes.

I'd like to mention a scientific hope that I'd have for 2050 which links Darwin and Galileo. It's to discover whether life exists beyond our Earth.

Nowhere else in our Solar System offers an environment even as clement as the Antarctic or the top of Everest. (This is why, incidentally – especially in view of advances in robotics -- there is little reason for manned spaceflight except as an adventure or spectator sport). There may be simple life on Mars, or on

Jupiter's moon Europa (and its detection would be of crucial importance). But suppose we widen our gaze beyond our Solar System -- to other stars.

Since the 1990s we've learnt that many stars are orbited by retinues of planets, just like the Sun is. The evidence up till now pertains to 'giant' planets -- objects the size of Saturn or Jupiter. An astronomical highlight of 2009 has been the successful launch of NASA's Kepler spacecraft, which should reveal planets no bigger than our Earth by detecting the slight dimming of a star when such a planet transits in front of it.

It will be a decade or two before we can actually image Earth-like planets rather than just recording their shadows. It's a task like seeing a firefly next to a searchlight -- requiring giant arrays in space or the new generation of ground-based telescopes.

Would there be life on any of them? We know too little about how life started here. The outcome of the quest for alien life will influence our concept of our place in nature as profoundly as Darwinism has over the last 150 years. We may have learnt, by 2050, whether biological evolution is unique to the 'pale blue dot' in the cosmos that is our home, or whether Darwin's writ runs in the wider universe.

It's sometimes wrongly imagined that cosmologists must be serenly unconcerned about next year, next week and tomorrow. I'd like to conclude with a 'cosmic perspective' which actually strengthens my own concerns about the here and now.

Ever since Darwin, we've been familiar with the stupendous timespans of the evolutionary past that led to the emergence of humans. Many people envisage we humans as somekind of culmination of the evolutionary tree. But this seems specially implausible to an astronomer. Our Sun formed 4.5 billion years ago, but it's got 6 billion more before the fuel runs out. And the expanding universe will continue -- perhaps for ever -- becoming ever colder, ever emptier As Woody Allen said "eternity is very long, especially towards the end".

It won't be humans who witness the Sun's demise: it will be entities as different from us as we are from a bug.

But, even in this 'concertinered' timeline -- extending millions of centuries into the future, as well as into the past -- this century is special. It's the first in our planet's history where one species --ours -- could jeopardise not only itself, but life's immense potential.

Suppose there were some aliens out there, and they'd been watching our planet for its entire history, what would they have seen? Over nearly all that immense time, 4.5 billion years, Earth's appearance would have altered very gradually. The continents drifted; the ice cover waxed and waned; successive species emerged, evolved and became extinct.

But in just a tiny sliver of the Earth's history -- the last one millionth part, a few thousand years -- the patterns of vegetation altered much faster than before. This signalled the start of agriculture. The pace of change accelerated as human populations rose.

Then there were other changes, even more abrupt. Within fifty years -- little more than one hundredth of a millionth of the Earth's age, the carbon dioxide in the atmosphere began to rise anomalously fast. And something else unprecedented happened: small projectiles launched from the planet's surface and escaped the biosphere completely. Some were propelled into orbits around the Earth; some journeyed to the Moon and planets.

If they understood astrophysics, the aliens could confidently predict that the biosphere would face doom in a few billion years when the Sun flares up and dies. But could they have predicted this sudden 'fever' half way through the Earth's life -- these human-induced alterations occupying, overall, less than a millionth of the Earth's elapsed lifetime and seemingly occurring with runaway speed?

If they continued to keep watch, what might these hypothetical aliens witness in the next hundred years? Will a final spasm be followed by silence? Or will the planet itself stabilise? And will some of the objects launched from the Earth spawn new oases of life elsewhere?

The choice depends on us. Wise choices will require the idealistic and effective efforts of natural scientists, environmentalists, social scientists and humanists ---all guided by the knowledge that 21st century science can offer. And that the James Martin School can help to distil.

**CONTACT INFORMATION**

**James Martin 21st Century School**

**www.21school.ox.ac.uk**

**info@21school.ox.ac.uk**

**+44 (0) 1865 287430**