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REITH LECTURES 2010: SCIENTIFIC HORIZONS

Presenter: Martin Rees

Lecture 1: The Scientific Citizen

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SUE LAWLEY: Hello and welcome to the Radio Theatre in Broadcasting House for the first in this year's series of Reith Lectures. They're being given by a man who's been called "a scientific magician; a man who leaves you wondering where he got his ideas from." Magic, however, is not his business. He's rooted in the pursuit of rigorous scientific inquiry, and his work has taken him to the pinnacle of his profession as President of the Royal Society, Astronomer Royal, and Master of Trinity College Cambridge.

He's called his four lectures 'Scientific Horizons'. His subject is the challenges and threats man faces as he starts his journey through the rest of the 21st century. He believes we're in danger, as he puts it, of "destroying the book of life before we've read it." Man may be at the top of the evolutionary tree, but there are still many things he doesn't understand - and possibly never will. Indeed the form of life of which he's a part may not be the only one in the universe.

So in 'Scientific Horizons' our lecturer will look at the threats to the whole existence of man and explore some of their solutions. Ladies and gentlemen, please welcome the BBC's Reith Lecturer 2010: Martin Rees.

(APPLAUSE)

SUE LAWLEY: Welcome, Martin. You've been Astronomer Royal for the past fifteen years, I think. I gather it's a deeply arduous task?

MARTIN REES: It was fifty years ago arduous, but I'd like to say the duties are so exiguous I could do them posthumously. I need never retire.
(LAUGHTER)

SUE LAWLEY: But you must get letters or emails from lots of people who think that they've cracked it; you know that they've learned the darkest secrets of the universe. What do you do with all of them?

MARTIN REES: Oh I get those. You do best to tell them to write to each other. (LAUGHTER) Sometimes they hit it off. Sometimes you get a letter from each saying: 'Why did you tell me to write to that nut?' (LAUGHTER)

SUE LAWLEY: But seriously, you do like interaction, don't you? You are not the kind of scientist who sits poring over his papers in his ivory tower for ages. Debating, travelling, talking, lecturing is what you do?

MARTIN REES: Well that's right. The science I do is fairly interactive - I have lots of collaborators; I'm interested in data obtained in different ways. But also I'd derive less satisfaction, I think, if I could only talk to fellow specialists. I get more satisfaction from the fact that my subject is of gratifying interest to a much wider public than professionals.

SUE LAWLEY: But puzzles and conundrums are what you do, and they're whirling away, one likes to imagine, in your head the whole time. Is that how you do your science: you think of a brilliant solution and then set about trying to prove that it's the correct one?

MARTIN REES: Well sometimes I sit and think. Sometimes I just sit. But one hopes that ideas eventually generate. But they generate more actually when they're stimulated by some new observation or by some remark made by someone else. It's a very interactive subject. But I'm very fortunate actually. The subject I work in - astronomy - has been developing very fast. It was developing fast when I started, but the pace of change has not slackened at all.

SUE LAWLEY: Wonderful. Well we hope also the debate here is going to inspire you, just as we hope you're going to inspire us - which I'm sure you are. Can I invite you to take to the podium and deliver your first lecture. It's called 'The Scientific Citizen'. Thank you.

(APPLAUSE)

MARTIN REES: I'll start with a flashback to the 1660s - to the earliest days of the Royal Society. Christopher Wren, Robert Hooke, Samuel Pepys, and other 'ingenious and curious gentlemen' (as they described themselves) they met regularly. Their motto was to accept nothing on authority. They did experiments; they peered through newly-invented telescopes and microscopes; they dissected weird animals. But, as well as indulging their curiosity, they were immersed in the practical agenda of their era - improving navigation, exploring the New World, and rebuilding London after the Great Fire.

Today, science has transformed our lives. Our horizons have hugely expanded; no new continents remain to be discovered. Our Earth no longer offers an open frontier, but seems constricted and crowded - a 'pale blue dot' in the immense cosmos.

My theme in these lectures is that the Royal Society's old values should endure. Today's scientists, like their forbears, probe nature and nature's laws by observation and experiment. But they should also engage broadly with society and with public affairs.

Indeed, their engagement is needed now more than ever. Science isn't just for scientists. All should have a voice in ensuring that it's applied optimally - and to the benefit of both the developing and developed world. We must confront widely-held anxieties that genetics, brain science and artificial intelligence may 'run away' too fast. As citizens, we all need a feel for how much confidence can be placed in science's claims. And these are themes I'll explore in all four lectures.

And, as I'll discuss, this is a crucial century. The Earth has existed for 45 million centuries. But this is the first when one species, ours, can determine - for good or ill - the future of the entire biosphere.

But first, a comment on how science itself has changed our perspective on nature.

Last year, we celebrated Charles Darwin's anniversary. Darwin's impact on Victorian thought was profound - and he resonates even more today. His concept of natural selection has been described, with only slight hyperbole, as 'the best idea anyone ever had'. His insights are pivotal to our understanding of all life on Earth, and the vulnerability of our environment to human actions. Other sciences have disclosed the nature of atoms, of DNA, and of stars. Spectacular images from space have enlarged our cosmic horizons.

It's a cultural deprivation not to appreciate the panorama offered by modern cosmology and Darwinian evolution - the chain of emergent complexity

leading from some still-mysterious beginning to atoms, stars, and planets. And how on our planet, life emerged, and evolved into a biosphere containing creatures with brains able to ponder the wonder of it all. This common understanding should transcend all national differences - and all faiths too.

Science is indeed a global culture, and its universality is specially compelling in my own subject of astronomy. The dark night sky is an inheritance we've shared with all humanity, throughout history. All have gazed up in wonder at the same 'vault of heaven', but interpreted it in diverse ways.

Today, I'm not going to speak further about the findings of science, nor will I extol it as the greatest collective achievement of humanity - though it surely is. I'll instead focus on how it impinges on our lives - and how it will in future.

Some changes happen with staggering speed. Everyday life has been transformed in less than two decades by mobile phones and the internet. Computers double their power every two years. Spin-offs from genetics could soon be as pervasive as those from the microchip have already been. Ten years ago, the first draft of the human genome was decoded. Now, genome sequencing - the 'read out' of our genetic inheritance - is a million times cheaper than 10 years ago.

These rapid advances - and others across the whole of science - raise profound questions.

For instance:
Who should access the 'readout' of our personal genetic code?

How will our lengthening life-spans affect society?
Should we build nuclear power stations - or windmills - if we want to keep the lights on?
Should we use more insecticides or plant GM crops?
How much should computers invade our privacy?

Such questions didn't feature much in the recent election campaign here in the UK. That's partly because they transcend party politics. But it's more because they are long-term - and tend to be trumped by more urgent items on political agendas.

But often science does have an urgent impact on our lives. Governments and businesses, as well as individuals, then need advice - advice that fairly presents the level of confidence, and the degree of uncertainty.

Issues come up unexpectedly. For instance, back in April, the eruption in Iceland raised urgent questions about vulcanology; about wind patterns, and about how volcanic dust affects jet engines. In that instance, the knowledge was basically there: what was lacking was coordination, and an agreement on the acceptable level of risk.

Sometimes, though, the key science isn't known. An example was the outbreak of 'mad cow disease' in the 1980s. At first, experts conjectured that this disease posed no threat to humans because it resembled scrapie in sheep, which had been endemic for 200 years without crossing the species barrier. That was a reasonable conjecture, and comforting to politicians and public. But it proved wrong. The pendulum then swung the other way. Banning 'beef on the bone', for instance, was in retrospect an over-reaction, but at the time seemed a prudent precaution against a potential tragedy that could have been far more widespread than it actually turned out to be.

Likewise, the government could have been right to stock up vaccine against swine flu - even though, fortunately, this particular epidemic proved milder than feared.

Indeed, 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 actually need scaling up.

Incidentally, there's a mismatch between public perception of very different risks and their actual seriousness. We fret unduly about carcinogens in food and low level radiation. But we are in denial about 'low-probability high-consequence' events which should concern us more. The recent financial crash was one such; but others that haven't yet happened - lethal pandemics are one example - should loom higher on the agenda.

The varied topics I've just mentioned show how pervasive science is, in our lives and in public policy.

President Obama certainly recognised this. He filled some key posts in his administration with a real 'dream team' of top-rate scientists. And he opined that their advice should be heeded, I quote, "even when it is inconvenient - indeed especially when it is inconvenient."

The UK has 'chief science advisors' in most government departments. Not yet, however, in the Treasury (LAUGHTER) - though I can't help thinking this would be worthwhile, even at the sacrifice of one economist. (LAUGHTER)

Winston Churchill once said that scientists should be "on tap, not on top." And it is indeed the elected politicians who should make decisions. But the role of scientific advice is not just to provide facts to support policies. Experts

should be prepared to challenge decision-makers, and help them navigate the uncertainties of science. But there's one thing they mustn't forget. Whether the context be nuclear power, drug classification, or health risks, political decisions are seldom purely scientific. They involve ethics, economics and social policies as well. And in domains beyond their special expertise, scientists speak just as citizens.

There's no denying where science has recently had the most contentious policy impact, and where the stakes are highest: climate change.

It will feature, along with other global threats, in my second lecture, but I'll venture some comments today too. As regards the science, there is, in my inexpert view, one decisive measurement: the amount of carbon dioxide in the atmosphere is higher than it's been for a million years, and is rising, mainly because of the burning of fossil fuels. This finding isn't controversial. And straightforward chemistry tells us that carbon dioxide is a so-called 'greenhouse gas': it acts like a blanket, preventing some of the heat radiated by the Earth from escaping freely into space. So the measured carbon dioxide build-up in the atmosphere will trigger a long-term warming, superimposed on all the other complicated effects that make climate fluctuate.

The predicted rate of warming, however, is uncertain - depending on the poorly-understood 'feedback ' from water vapour and clouds, which themselves affect the blanketing. Nevertheless, even the existing uncertain science convinces me that the threat of disruptive climate change is serious enough to justify its priority on the agenda of this country and others.

This confidence may surprise anyone who has dipped into all that's been written on the subject. Any trawl of the internet reveals diverse and contradictory claims. So how do you make up your mind? I'd suggest the following analogy.

Suppose you seek medical guidance. Googling any ailment reveals a bewildering range of purported remedies. But if your own health were at stake, you wouldn't attach equal weight to everything in the blogosphere: you'd entrust your diagnosis to someone with manifest medical credentials. Likewise, we get a clearer 'steer' on climate by attaching more weight to those with a serious record in the subject.

But - as I said earlier about science advice in general - it's crucial to keep 'clear water' between the science on the one hand, and the policy response on the other. Risk assessment should be separate from risk management.

Climate projections still span a wide range, but even if there were minimal uncertainties in how the world's weather might change, there would still be divergent views on what governments should do about it.

For instance, what balance should be struck between mitigating climate change and adapting to it. How much should we sacrifice now to ensure that the world is no worse when our grandchildren grow old? How much should be incentivise clean energy?

On all these choices, there's as yet minimal consensus, still less effective action. But policies, and investment priorities, are being influenced by climate change projections. So it's inevitable, and right, that climate science is under specially close scrutiny.

We are today far more questioning of authorities on every topic. We can all access far more information and want to weigh up evidence for ourselves. Such scrutiny should be welcome: just as there are instances of shoddy work, error or even malpractice in the medical and legal profession, so there

occasionally are in science.

But science is generally 'self-correcting'. Scientists are their own severest critics. They have more incentive than anyone else to uncover errors. That's because the greatest esteem goes to those who contribute something unexpected and original - like refuting a consensus. That's how in science initially-tentative ideas firm up - not only on climate change, but - to take earlier examples - regarding the link between smoking and lung cancer, and between HIV and AIDS. But that's also how seductive theories get destroyed by harsh facts. Science is 'organised scepticism'.

Our scientific knowledge and capability is actually surprisingly patchy. Odd though it may seem, some of the best-understood phenomena are far away in the cosmos. Right back in the 17th century, Isaac Newton could describe the 'clockwork of the heavens' and predict eclipses. But few other things are so predictable. For instance, it's still hard to forecast, even a day before, whether those who go to view an eclipse will encounter clouds or clear skies. And guidance on some everyday matters - aspects of diet and child care for instance - still changes from year to year.
If you ask scientists what they are working on, you will seldom get an inspirational reply like 'seeking to cure cancer' or 'understanding the universe'. They focus on a tiny piece of the puzzle; they tackle something that seems tractable. They're not ducking the 'grand challenges' - but they're judging that an oblique approach can pay off best.

A frontal attack may be premature. For instance, forty years ago President Richard Nixon declared a "war on cancer". He envisaged this as a national goal, modelled on the then-recent Apollo moon-landing programme. But there was a crucial difference. The science underpinning Apollo was already understood. So, when funds gushed at NASA, it became reality. But in the case of cancer, the scientists knew too little to be able to target their efforts

effectively.

By the way, I'm using the word 'science' throughout, in a broad sense, to encompass technology and engineering - this is not just to save words, but because they're symbiotically linked. 'Problem solving' motivates us all - whether one is an astronomer probing the remote cosmos, or an engineer facing a down-to-earth design conundrum. There is at least as much challenge in the latter - a point neatly made by an old cartoon showing two beavers looking up at a hydroelectric dam. One beaver says 'I didn't actually build it, but it's based on my idea'. (LAUGHTER)

Nixon's cancer programme, incidentally, facilitated a lot of good research into genetics and the structure of cells. Indeed, the overall investment in scientific research in the 20th century paid off abundantly. But the pay-off happens unpredictably, and after a time-lag that can be decades long. And that of course is why much of science has to be funded as a 'public good'.

A fine 'case study' is the laser, invented in 1960. It applied basic ideas that Einstein had developed more than 40 years earlier. And its inventors in turn didn't foresee that lasers would be used in eye surgery and in DVD players.

Traditionally, discoveries reach public attention only after surviving peer review. But this 'copybook' procedure is under increasing strain, due to competitive or commercial pressures, 24-hour media - and the greater scale and diversity of a scientific enterprise that's now widely international.

A conspicuous departure from traditional norms happened back in 1989 when Stanley Pons and Martin Fleischmann, then at the University of Utah, claimed at a press conference to have generated nuclear power using a table-top apparatus. If credible, it would have ranked as one of the most momentous breakthroughs since the discovery of fire.

But doubts set in. Extraordinary claims demand extraordinary evidence, and in this case the evidence proved far from robust. Others failed to reproduce what Pons and Fleischmann claimed they'd done. Within a year, there was a consensus that the results were misinterpreted, though even today a few believers remain.

'Cold fusion' bypassed the normal quality controls of the scientific profession, but it did no great harm in the long run. Indeed in any similar episode today, exchanges via the internet would have led to a consensus verdict even more quickly.

But this fiasco holds an important lesson: what's crucial in sifting error and validating scientific claims is open discussion. Suppose that Pons and Fleischmann had worked not in a university but in a lab whose mission was military, or commercially-confidential. What would have happened then? If those in charge were convinced that they had stumbled on something stupendous, a massive programme might have got under way, shielded from open scrutiny and wasting huge resources.

The imperative for open-ness and debate is a common thread through all the examples I've discussed. It ensures that any scientific consensus that emerges is robust and firmly grounded.
Even wider discussion is needed when what's in contention is not the science itself, but how new findings should be applied. Such discussions should engage all of us, as citizens - and of course our elected representations, not just the scientists.

Sometimes this has happened, and constructively too. In the UK, ongoing dialogue with parliamentarians led to a generally-admired legal framework on embryos and stem cells - a contrast to what happened in the US. But we've

had failures too: the GM crop debate was left too late - to a time when opinion was already polarised between eco-campaigners on the one side and commercial interests on the other.

But what about ideas 'beyond the fringe' - the illusory comfort and assurance of the pseudosciences? Here there is less scope for debate - both sides don't share the same methods or play by the same evidence-based rules. I've not found it fruitful to have much dialogue with astrologers or with creationists.

A word now about communicating science. I mentioned Darwin earlier. Back in 1860, his book 'The Origin of Species' was a best seller: readily accessible - even fine literature - as well as an epochal contribution to science. But what scientists today call ‘the literature’ isn’t accessible in this way at all. But its essence can generally be conveyed, free of jargon and mathematics, by skilled communicators.

Misperceptions about Darwin or dinosaurs are an intellectual loss, but no more. In the medical arena, however, they could be a matter of life and death. Hope can be cruelly raised by claims of miracle cures; exaggerated scares can distort healthcare choices, as happened over the MMR vaccine.

When reporting a particular viewpoint, journalists should clarify whether it is widely supported, or whether it is contested by 99 percent of specialists. Noisy controversy need not signify evenly-balanced arguments. Of course the establishment is sometimes routed and a maverick vindicated. We all enjoy seeing this happen - but such instances are rarer than is commonly supposed.

Scientists should expect media scrutiny. Their expertise is crucial in areas that fascinate us, and matter to us all. And they shouldn't be bashful in proclaiming the overall promise that science offers.

I'll end, as I began, with a flashback - this time to the atomic scientists who developed the first nuclear weapons during World War II. Fate had assigned them a pivotal role in history. Many of them returned with relief to peacetime academic pursuits. But the ivory tower wasn't, for them, a sanctuary. They continued not just as scientists but as engaged citizens - promoting efforts to control the power they had helped unleash.

These men - Joe Rotlat, Hans Bethe and the others - were an elite group. The alchemists of their time, possessors of secret knowledge. The dominant issues today, in contrast, span all the sciences. They are far more open, and often global. There 's less demarcation between experts and laypersons. Campaigners and bloggers enrich the debate. But professionals have special obligations to engage - the atomic scientists were fine exemplars. Scientists shouldn't be indifferent to the fruits of their ideas. They should try to foster benign spin-offs - commercial or otherwise. And they should resist, as far as they can, dubious or threatening applications.

Unprecedented pressures confront the world, but there are unprecedented prospects too. The benefits of globalisation must be fairly shared. There's a widening gap between what science allows us to do and what it's prudent or ethical actually to do - there are doors that science could open but which are best left closed. Everyone should engage with these choices but their efforts must be leveraged by 'scientific citizens' - scientists from all fields of expertise - engaging, from all political perspectives, with the media, and with a public attuned to the scope and limit of science. Thank you very much.

(APPLAUSE)

SUE LAWLEY: Martin Rees, thank you very much indeed. Now I want to open up the subject to the floor and invite some questions from the audience. I'm aware of some questions that we have, but we've also been collecting

some written ones during the course of the lecture. And if you have any more during the course of the debate, please feel free to hand them in. I'm going for a question first of all from Dr David Elliman who's a consultant in community child care at Great Ormond Street Children's Hospital.

DR DAVID ELLIMAN: I agreed with most of what you said, but you touched on the MMR debacle and this was one example where people didn't follow your logic, which was if they have a medical issue they will listen to a medical practitioner. In this instance, they listened to celebrities and newspaper people. How do you help people decide which information they value, they listen to, when they're confronted with all the information you mention on the internet?

MARTIN REES: Well, first, I didn't imply that people actually did view the internet in a discerning way. I said it would be better if they did. But of course it isn't easy, particularly in the case when you have people who have similar paper qualifications taking quite different views. And here again, I think there is a role for, in a sense, the leaders of the profession, but also for journalists and commentators who do have the chance to go round and get a fair sample of opinion. And I think what went wrong was that certain segments of the press did not present things in a balanced way. They presented equally what was a maverick viewpoint and what was a majority viewpoint. So I think although some parts of the press were responsible, others were highly irresponsible and I think they should take the blame.

SUE LAWLEY: Well we've got the Science Editor of The Times in the front row: Mark Henderson. I think you're on the spot, Mr Henderson.

MARK HENDERSON: Yes, I hope that 'The Times' was one of the media outlets that was responsible in this respect, and I think we did I think always take the view that we should behave as Martin said and evaluate claims. And

in fact it would be interesting to ask Martin to what extent he thinks the media has a role in fact often not to be directly objective or narrowly objective and balanced in discussion of issues like this, and to what extent it's actually incumbent on responsible journalists to evaluate competing claims and offer a view as to their relative merits?

MARTIN REES: Well I think you would accept that other newspapers were not as responsible as you were, and they in fact have a lot to answer for …

MARK HENDERSON: *(over)* Certainly, yes.

MARTIN REES: … in that they maintained this controversy.

AUDIENCE MEMBER: (actually Professor David Nutt) Why do you say that?

SUE LAWLEY: Hold on, hold on. I'll come back to you. *(to Martin Rees)* Go on.

MARTIN REES: Yes, okay. But I would have thought that it was appropriate that journalists should try and present what the balance of argument is on a particular issue.

SUE LAWLEY: But should they be evaluating it themselves really, Mr Henderson's asking?

MARTIN REES: Well I mean obviously they don't have the expertise if it's a technical matter. But journalists tend to have a wide network of contacts and they can, either through their contacts or by going indirectly to them, get a feel for what the consensus view is. Of course the consensus isn't always right, but I think what they should be doing is reporting a consensus if there is one.

SUE LAWLEY: Was that Dr Elliman who wanted to come back in there? There was a call from the back there. Is it on this subject, sir?

PROFESSOR DAVID NUTT: Well it's on the subject of the media. David Nutt here, one of those scientific advisers who tried to tread the line between policy and science and found that the line had disappeared and so went over the cliff.

SUE LAWLEY: Shall we just say for people listening, you were the former Chairman of the Advisory Council on the Misuse of Drugs?

PROFESSOR DAVID NUTT: That's right, yes.

SUE LAWLEY: Who resigned because …

PROFESSOR DAVID NUTT: No, no, I was sacked.

SUE LAWLEY: You were sacked. (LAUGHTER)

PROFESSOR DAVID NUTT: Let's be …

SUE LAWLEY: Alright, let's be clear. (LAUGHTER/APPLAUSE)

PROFESSOR DAVID NUTT: I <u>refused</u> to resign.

SUE LAWLEY: It was felt that you crossed the line between scientific advice and policy.

PROFESSOR DAVID NUTT: Yes. And I think there are many questions I could ask you, Martin, but I think the challenge we have at present is that we

have a relatively educated citizen, but in parliament we have very few MPs who seem to understand evidence or science. And I presume one of the main roles of the Royal Society is to try to balance out that inexperience with the experience of 350 years of scientific progress, and I just wonder how you're going to take on this challenge given that the Shadow Home Secretary said when I was sacked that it should have happened a lot sooner because I wrote a paper that tried to balance out the relative harms of ecstasy and horse-riding.

MARTIN REES: Well I won't comment on what's come to be called the Nutt Case (LAUGHTER), but I will address the question of the small number of scientifically informed people in parliament. Of course all learned societies should engage with politicians to try and interest them. It is sad that there are rather few who are expert in science among the new intake. But that in itself doesn't matter because if we look back on those who were active in scientific areas in the last parliament, they weren't all people with a scientific training - just as the best scientific journalists aren't always people with scientific training. So I think although we started off in the Royal Society by focusing on those who seem to have some sort of scientific background, it wouldn't surprise me if those in a new parliament who show the greatest interest in science and scientific matters will be people who didn't have a scientific background.

SUE LAWLEY: We've got Lord Drayson here, Paul Drayson, who's been Minister of Science. What do you say about all of this and the lack of scientists in politics?

LORD DRAYSON: I think Martin is right: it's to be regretted. We really do need more expertise in politics generally. With our modern political system, to establish an effective political career, it requires such a commitment of time and your life that it is very difficult to do that whilst at the same time being a

very active scientist. If you have a structure which, therefore, requires a scientist who has spent their life developing a career, building up their expertise - to ask them to then take a career break, which is going to require them to lose their currency, it's just not practical.

SUE LAWLEY: Martin …

MARTIN REES: There's two things. First I'd like to acclaim Paul Drayson for all he did through his commitment to science during his time in office. I think we were fortunate to have him there. But I'd also like to say that I think the concern that we are expressing is not peculiar to science. It's really that politics is becoming a career and very few of these people in parliament have had any real career other than being a political adviser, working in a think tank, or something of that kind.

SUE LAWLEY: Let me bring in someone who's Chairman of a body that I know you feel works very well, and that's the Human Fertilisation and Embryology Authority, the HFEA: Professor Lisa Jardine.

PROFESSOR LISA JARDINE: You ask for an engagement between the public in general, parliamentarians, those who are not experts with science. I try to do that, it's one of my responsibilities - to communicate difficult issues in IVF, stem cell research to that broader public. But there is a fundamental difficulty, which is that the public and decision-makers want the right answers, right now. Whereas science, as I think you elegantly said, trades in organised doubt. So how are we going to engage with a public that wants to know whether it's red wine that causes breast cancer or whether eating fewer chips will give you less prostate cancer?

SUE LAWLEY: And they want to know now.

PROFESSOR LISA JARDINE: They want to know now.

MARTIN REES: Yes. Well I think we have to make clear that science does have its limits and hope people will be encouraged to support further research in science. But I think people have to realise that the key questions I meant to sell in my lecture are not yet solved. One consequence of what you're saying is that people have an irrational way of comparing different risks. They fret too much about some minor risks. As to what we do about it, I would not have thought it's only scientists who confront this problem. There are other areas where clearly there are uncertainties and people have to accept that we have to make judgements on the basis of probabilities in many contexts, and I'd have thought not just in science.

SUE LAWLEY: Let me bring in somebody who knows something about the public perception of risk. He's David Spiegelhalter and he is the Winton Professor of the Public Understanding of Risk at Cambridge University, and he tried a few weeks ago to predict the football results and got them entirely wrong. (LAUGHTER)

SPIEGELHALTER: Exactly, exactly. That was deliberate. It was quite deliberate. (LAUGHTER) You appear to speak approvingly, for example, of the government response to swine flu; but I think many people, the popular opinion would be that that might have been an over-reaction. I mean the problem with low probability high consequence events is that they hardly ever happen, and we're deeply uncertain about what the probabilities and the consequences might be. You would like to take a more rational, perhaps insurance based approach, but how are you actually going to do that in the face of these really deep uncertainties without the public continually accusing the scientists of crying wolf about things that just don't happen?

MARTIN REES: Yes. Well of course many of the things we should worry

about have a less than 50 percent probability, and you could take the view we don't take any precautions if the chance is less than 50 percent. But that's not the attitude we take when getting fire insurance for our house; and many people are aware that you do insure against things which have a much less than 50 percent chance of probability, and therefore in those contexts people accept that they are likely to waste their money because what they're insuring against won't happen. And it seems to me that that was entirely analogous to what was done in stocking up the vaccine. The chance might have been less than 50 percent, but if you multiply the probability by the consequences it was not necessarily foolish. I don't have enough expert knowledge in that particular case, but there are surely many cases when there's much less than 50 percent chance of something happening but, nonetheless, it is worth a major investment to guard against it.

SUE LAWLEY: I've got a question here from Oliver Morton. Tell us what you do and who you are.

OLIVER MORTON: I'm Oliver Morton. I'm the Energy and Environment Editor of 'The Economist'. You said in your talk that scientists are their own fiercest critics, but when we actually come to media presentations of scientific controversy, you very, very rarely have a controversy where there are eminent scientists on both sides. It tends much more to be science on one side; critics on the other. So the question is: are the media just covering the wrong things and there are lots of great stories where scientists are pitted against each other that we're just missing, or are the sort of internecine criticisms within science not actually germane to the world outside?

MARTIN REES: There are certainly many debates within science. I mean, as you know, within my own field of astronomy - cosmology - there have been very longstanding debates and vendettas between those who believe different things about the universe, so there are lots of cases when there are internal

debates within science; and of course in the early stages of any investigation, there are a whole lot of views and contention. It may take some time before one emerges. And I think the question really is at what extent the public is likely to be interested and needs to be informed. Is it better to wait until a consensus has emerged among the specialists before this becomes something which is widely known, or should the debate be public at early stages? And I think if it's interesting, then there's no reason why the internal debate among experts should not be publicised. But the public is, as we said earlier, more concerned about what is certain or nearly certain than about things which are admitted to be very uncertain by the experts. And so the public may not be all that interested in these internal debates, although in things like cosmology - to my surprise - they were very interested.

SUE LAWLEY: I'm going to Sue Blackmore. Would you tell us, Sue Blackmore, what you do before you put your question?

SUE BLACKMORE: I'm a Visiting Professor in Psychology at the University of Plymouth. You started, Martin, by applauding the idea of the founders of science that we should accept nothing on authority. Great, but that was different in those days when an intelligent scientist could actually try out everything for themselves. Now science is so complex, requires so much money, so much equipment, so much knowledge - in effect I as a scientist in one field have to take on authority almost everything else in science. Should I?

MARTIN REES: I think it's inevitable that you have to. You can't repeat the experiments made by all your colleagues in different fields. But I think it's very important that there should be some cross-calibration. That's why people need to get out of their disciplinary ghettoes and that's why there is a role for scientific commentators and critics, such as the best scientific journalists, because they in fact have a network that spreads across different subjects and

they can calibrate the quality of work in different fields.

SUE LAWLEY: I have a question here from Alom Shaha who's a science teacher.

ALOM SHAHA: I don't know if you know, but in 2006 the National Curriculum For Science changed to introduce something called How Science Works, which I think was intended to improve scientific literacy. Do you think we need to go further in differentiating between the education we provide for so-called future scientists and scientifically literate citizens?

MARTIN REES: Well I think that's a very good point. I mean science is not just for those who are going to be professional scientists, and it is quite right that there should be different approaches. So I think we do need to try very hard to ensure that some feel for science is given to those who are not going to pursue it further because otherwise the debate on all these important questions we've been discussing won't get above the level of tabloid slogans.

SUE LAWLEY: Thank you to you all. Next week we'll be in Cardiff where Professor Rees will be revealing his optimism about scientists providing answers to our global problems, but some pessimism about the politicians and the sociologists who put them into practice. I hope you'll tune in then. For now, Martin Rees, Reith Lecturer 2010, thank you very much indeed.

(APPLAUSE)