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Event: Sir Paul Nurse presents Horizon: *Science Under Attack*

People:

- **Dr Bob Bindschadler**: Senior research Earth scientist at NASA
- **James Delingpole:** Sceptical writer and journalist
- **Professor Jonathan Jones**: Sainsbury Laboratory, Norwich
- **Dr Phil Jones**: University of East Anglia (CRU)
- **Tony Lance**: HIV/AIDS sceptic
- **Keith Moore**: Librarian, Royal Society
- **Sir Paul Nurse**: Geneticist and president of the Royal Society
- **Professor Fred Singer**: Emeritus professor of environmental science at University of Virginia

Paul Nurse: The Royal Society, Britain's academy of science. The wonderful archives here bear witness to over 350 years of scientific achievements... and battles. I find this an inspiring place for the challenges that science now faces. I think that today there is a new kind of battle. It's not just the clash of ideas but whether people actually trust science. One of the most vocal arguments currently raging is about climate science. Many people seem unconvinced that we're warming our planet through the emission of greenhouse gases. And trust in other scientific theories has also been eroded, such as the safety of vaccines, or that HIV causes AIDS. There have been angry protests against the use of genetically modified foods. Science created our modern world, so I want to understand why science appears to be under such attack, and whether we scientists are partly to blame.

For me, becoming President of the Royal Society has been the culmination of a lifetime's fascination with science, and my attempts to answer questions about the world around me. I've been interested in science really all my life; it started when I was at primary school. I had a long walk to school, and I used to look at all the plants and the birds and the insects, I got interested in natural history. I used to wonder about things. I always remember, like - why, when a plant is growing in the shade, are the leaves bigger? That's the sort of thing an eight or nine year old would ask.

Fifty years later, I'm still trying to answer questions about the

most basic processes of life. Probably what my lab is best known for is discovering the control which regulates cell division, which will lead hopefully to a better understanding of diseases like cancer and maybe to cures. Ten years ago I shared a Nobel Prize for this work. It's fantastic. I'm really privileged. I've been doing this for forty years. I sometimes wonder why people are paying me.

But away from my lab, I've witnessed hostilities towards some key areas of science. There is one issue that's of particular importance today, the question of man-made climate change. It's a subject that polarises opinion, not surprisingly since climate science affects so many elements of our lives, from politics to economics to how we live. With so much at stake, scientists are rightly held to account. But some of my colleagues feel not under scrutiny but under attack.

I was pretty disturbed by a letter I read a few months ago in the magazine *Science*. It's one of the most prestigious journals in science. It was from 255, if I remember rightly, members of the National Academy of Sciences, that's the academy of science in the United States, very prestigious organisation. And these 255 members had written a letter really expressing concern about how climate scientists were being treated. The letter was about climate change and the integrity of science. Two sentences really stood out. The first sentence: "We are deeply disturbed by the recent escalation of political assaults on scientists in general, and on climate scientists in particular." That's pretty strong stuff. And then a sentence towards the end: "We also call for an end to McCarthy-like threats of criminal prosecution against our colleagues based on innuendo and guilt by association, [the harrassment of scientists by politicians seeking distractions to avoid taking action,] and the outright lies being spread about them." This is as tough as anything I've read in a magazine like *Science*.

What worries me is not just that scientists feel under attack but that many people think these attacks may be intellectually justified. Recent polls suggest that nearly half of Americans and more than a third of the British believe climate change is being exaggerated. It's this gap between scientists and the public that I want to understand. Are the public right not to trust science? Or is there something else that's not working? As always, the best place to start is with the scientific evidence.

I've come to Washington to visit one of the most respected scientific organisations in the world, NASA. I'm really rather excited about coming to NASA. I've always been interested in astronomy and space. The strange thing about NASA is that not only is it looking out into outer space like with the Hubble telescope, but it spends a lot of its time looking down at the Earth, because satellites are very very good at monitoring changes in the Earth, such as climate. I think we sort of really don't quite fully recognise that. Most of what NASA's doing is looking down rather than looking up.

NASA is a major centre for climate research. It spends more than two billion dollars a year studying the climate. I've come

to meet Dr Bob Bindschadler, to see where and how they get their information.

Bob Bindschadler: So here we can really visualise a lot of datasets, and this is the one I really like, because it shows us how scientists are getting their data. I mean NASA does a lot of stuff in the cosmos but we have half the satellites just looking at the Earth, just looking down at the Earth. Every 90 minutes, every one of these satellites orbits the Earth and collects data, sometimes in a wide swath, sometimes in a narrow swath. This is our bread and butter, this is where all the information comes from.

Paul Nurse: So how many of these satellites are there up there?

Bob Bindschadler: There's about sixteen, seventeen, eighteen satellites right now, just that NASA operates. There's at least as many from all the other space agencies, the European Space Agency, India operates satellites, Japan does, Canada does. So if you put that full constellation on here [referring to 3D display], it would be so busy it would just look like New York streets...

Paul Nurse: That's a gigantic amount of information being collected.

Bob Bindschadler: It's huge, it's terabytes, it's petabytes of data every day coming down.

Paul Nurse: NASA is just one of many organisations collecting global climate evidence. This information has helped create a view of how our planet's temperature has changed in the recent past.

Bob Bindschadler: Paul, I want to show you this science on a sphere [referring to 3D display], this fantastic way of looking at looking at data...

Paul Nurse: Look at that!

Bob Bindschadler: Recognise that world? And you can just walk around here, see the clouds moving around, and it's an absolutely fantastic way of looking at data.

Paul Nurse: So I guess, what we all want to know is: is this planet warming up?

Bob Bindschadler: This planet is warming up, the climate is changing. Just over the last 50 years, it's been about three quarters of a degree Centigrade. Which doesn't sound like a whole lot. And we've been able to calculate that over the next 50 years it's going to warm at least another three quarters of a degree if we do nothing else, if we don't even to continue to modify the climate.

Paul Nurse: So temperatures are rising. But what is really in dispute is the cause of that change, whether it's simply a natural temperature fluctuation.

Bob Bindschadler: There have been times when the Earth has been warmer than it is today, less ice, higher sea levels. And colder than today, with much more ice and lowe sea levels. But the important thing to remember is that back in those times climate changed very gradually. And now it's changing really fast. And that's a very important characteristic of climate change that we're living through right now, the pace of that change.

Paul Nurse: NASA's data is not the only evidence that our climate is warming rapidly, and that we are causing the change. There's also several decades of research from scientists across the globe. The extent of the data suggests we should have a lot of confidence in this idea. Yet this evidence is clearly not convincing a substantial part of the wider public. And those who are sceptical turn to other scientists. Professor Fred Singer has a reputation as one of the world's most prominent and prolific climate sceptics. He's an atmospheric physicist, who's been studying climate science for nearly 50 years and has been battling against the consensus view for over 20. Professor Singer's views influence sceptics all over the world.

[Paul Nurse and Fred Singer meet in a New York cafe.]

Paul Nurse (voice over): The first thing I wanted to ask Professor Singer was his view on global temperatures.

Paul Nurse: You're happy or agree that there has been warming in the last century...

Fred Singer: Some warming...

Paul Nurse: ... a bit under one degree, 0.7 degrees, I think, something of that sort.

Fred Singer: Something of that sort. It's been warming and its been cooling, and it's been warming again. It's not a clear record.

Paul Nurse (voice over): But where he differs from the vast majority of climate scientists is the cause of this warming. He doesn't believe that humans are responsible. He attributes it to natural forces.

Fred Singer: I'm of the opinion that the major natural effect comes from the Sun, and specifically from variations in what is called the solar activity. That is not the total radiation from the Sun, but it is the emission from the Sun that we call coronal ejections, which produce the solar wind. And the solar wind is a particle stream from the Sun that pervades the planetary space and can affect the situation near the Earth.

Paul Nurse (voice over): A record of this solar activity can be read from deposits in caves by measuring the level of a type of carbon atom formed by the Sun's rays.

Fred Singer: The good evidence we have comes from stalagmites in caves, but it's published in Nature...

Paul Nurse: But there's a correlation, so if you look at these estimates of solar activity and the temperature of the globe, they're well correlated.

Fred Singer: You cannot say "the globe". This is firstly local measurements in a cave on the Arabian peninsula...

Paul Nurse (voice over): In our conversation, Professor Singer drew on this stalagmite evidence to support his conclusions about solar activity. But it's important to consider how this specific finding fits into the wider body of evidence.

An important aspect of science is: it makes sense as a whole. Just imagine this field of grasses and plants that we see here. Imagine it as a scientific field. Imagine that we're looking at a lot of ideas or a lot of facts or observations. You have to look at every each one of them and make sure they make sense together. It's no good cherry-picking one part of it and just basing your argument on that. Look at this tree here. That attracts your attention, but if you just concentrate on that and ignore everything else, then you're not going to make progress, you're not going to make sense of what's going on.

In the climate debate, some have placed a lot of emphasis on the evidence of solar activity. But this data needs to be looked at in the context of all research. You cannot ignore the majority of available evidence in favour of something you would prefer to be true. Data that we are not warming our planet needs to be placed in the context of the greater body of evidence that we are, such as that gathered by NASA.

Bob Bindschadler: ... but you know, when you actually look at the data, the Sun doesn't turn out to be that important. On the historical scale, the paleoclimate scale, the Sun is important, we know the Sun is driving these long cycles, but if you look at the small variations in the solar radiation and the variations in the climate data that we have now, with these datasets, they don't match up. So there's just no doubt that the Sun is not a primary factor driving the climate change that we're living through right now.

Paul Nurse: The scientific consensus is, of course, that the changes we are seeing are caused by emissions of carbon into the atmosphere. But given the complexity of the climate system, how can we be sure that humans are to blame for this?

Bob Bindschadler: We know how much fossil fuel we take out of the ground. We know how much we sell. We know how much we burn. And that is a huge amount of carbon dioxide. It's about seven gigatons per year right now.

Paul Nurse: And is that enough to explain...?

Bob Bindschadler: Natural causes only can produce - yes, there are volcanoes popping off and things like that, and coming out of the ocean, only about one gigaton per year. So there's just no question that human activity is producing a massively large proportion of the carbon dioxide.

Paul Nurse: So seven times more.

Bob Bindschadler: That's right.

Paul Nurse: I mean, why do some people say that isn't the case?

Bob Bindschadler: I don't know, I think they get worried about the details of the temperature record or the carbon dioxide record, but again you need to stand back and look at the big picture. And there really is no controversy then, if you do that.

Paul Nurse: In this marketplace of ideas, who do you believe? If you're not a scientist, then ultimately it's a question of trust. Despite the weight of evidence in its favour, the theory of man-made climate change is not bringing a large section of the public with it. I think some clues as to why may be found at the University of East Anglia, the scene of Climategate, a story that broke in November 2009. Thousands of e-mails were taken from the computer at the Climatic Research Unit, also known as CRU, at the University of East Anglia, and posted online. According to the headlines, the e-mails contained one of the worst scientific outrages of all time.

Just look here [shows newspaper], Christopher Booker in *The Sunday Telegraph*: "This is the worst scientific scandal of our generation". Here, *The Daily Express*: "Now there are lies, damned lies and global warming", implying that global warming is nothing but lies and a sham. Here from *The Spectator*, an article by James Delingpole: "Watching the Climategate scandal..." Here he says in the first sentence: "This is the greatest scientific scandal in the history of the world."

At the heart of the scandal was one e-mail in particular, correspondence from the head of CRU, Dr Phil Jones. He talked about using "Mike's Nature trick to hide the decline." This seemed proof that climate scientists were tricking the world into thinking our use of fossil fuels is warming the planet. The news immediately went international. The timing couldn't have been worse. It was just three weeks before the UN Climate Change Convention, what many saw as the world's best hope to reduce carbon emissions before it was too late. And at the centre of it all was one man, Dr Phil Jones, head of CRU.

The unit's headquarters are tiny, yet Dr Jones and his colleagues have had a truly global impact. CRU's library holds centuries' worth of temperature data collected from instruments in every corner of the globe. To look further back in history, climate researchers have to extrapolate information from the rings in ancient pieces of wood.

Phil Jones: This is a measurement from a tree from the Andes in Argentina. This is a bog oak from Germany, which...

Paul Nurse: A bog oak? You mean it's been preserved in the bogs? So how old is that, then?

Phil Jones: This is about three to four thousand years old.

Paul Nurse (voice over): Tree rings have been shown to be a good way of measuring ancient temperatures, and they've mostly matched instrumental measurements since the advent of thermometers. However, after about 1960, some tree ring data stopped fitting real temperatures so well. The cause of this isn't known. When Dr Jones was asked by the World Meteorological Organisation to prepare a graph of how temperatures had changed over the last 1000 years, he had to decide how to deal with this divergence between the datasets. He decided to use the direct measurements of temperature change from thermometers and instruments rather than indirect data from the tree rings, to cover the period from 1960. It was this data splicing, and his e-mail referring to it as a "trick" that formed the crux of Climategate.

Phil Jones: The Organisation wanted a relatively simple diagram for their particular audience. What we started off doing was the three series, with the instrumental temperatures on the end, clearly differentiated from the tree ring series. But they thought that was too complicated to explain to their audience. So what we did was just to add them on, and bring them up to the present. And as I say, this was a World Meteorological Organisation statement. It had hardly any coverage in the media at the time, and had virtually no coverage for the next ten years, until the release of the e-mails.

Paul Nurse: So why do you think so much fuss was made about the e-mails and this graph rather than the peer-reviewed science?

Phil Jones: I think it's that a number of the climate change sceptics or doubters, deniers, whatever you want to call them, just wanted to use these e-mails for their own purposes to cast doubt on the basic science. The basic science is in the peer-reviewed literature, and I wish more people would read that than read the e-mails.

Paul Nurse (voice over): As well as the e-mails, much criticism of Dr Jones centred on his reluctance to hand over data. The team at CRU had been receiving requests under the Freedom of Information Act, also known as FOI requests, for access to their scientific data.

Phil Jones: Well, we started getting some requests in, in about 2007, and we'd responded to those.

Paul Nurse: These are Freedom of Information requests...

Phil Jones: Yes. And they were specifically for basic station temperature data and also for the locatiions of the stations. The situation got a bit worse in July 2009 when we got 60 requests over a weekend.

Paul Nurse: Over one weekend?

Phil Jones: Over one weekend, when there was clearly some sort of co-ordination between...

Paul Nurse: Was that from different people?

Phil Jones: Different people. But there was clearly some co-ordination of the requests because they each asked for five countries in alphabetical order. I thought at the time it was just to waste our time, in order to deal with these requests and maybe to get the data together.

Paul Nurse: So this is an interesting dilemma that we have here really, because obviously science is based upon open access to data. But obviously you can also be disrupted by having, if you like, more legalistic attempts to get data or simply trying to waste people's time. How do you sort of balance that?

Phil Jones: Well sometimes we get requests and, sometimes not through FOI, just from other scientists, we point them in the right direction as to where they might get the data. But when it became more, sort of, through the FOI, it really then became clear that it was some sort of harrassment.

Paul Nurse (voice over): This event raises questions about the openness of scientific research. Dr Jones and his team clearly felt persecuted. However, scientists do have to be open with their data.

It might be useful to think about the Human Genome Project, where similar issues came up about a decade ago, and there was clear discussion about this, and in the public genome sequencing laboratories, a real commitment, dedication to getting that data out into the public as soon as possible. And I think maybe there's something to be learned from that, for climate science.

There were at least four independent reviews of the work of CRU. The reports found there was no evidence of dishonesty. They said splicing the temperature data wasn't misleading, but this technique should have been made plain. They said generally the unit should have been more open. But crucially, they found no evidence of deliberate scientific malpractice.

This seems to have been the "greatest scientific scandal" that never really took place. I mean, it doesn't make sense to me at all, why it got blown out of proportion. It makes me wonder whether as scientists, we're not perhaps well suited to dealing with situations like this, and perhaps let them run out of our control. I mean, the world is changing, the digital world with blogs, with tweets and so on, we're perhaps not used to dealing with that, not able to cope with the sort of maelstrom of media attention that fell upon UEA during this event. I think there's something to be learned here. We've got to think about how we defend our science, how we project ourselves to the public.

In the end, the integrity of climate science was not faulted. But somehow a leak of some ten-year-old e-mails did real damage to its reputation. In all the clamour, the science

seems to have been left behind. I've come to meet James Delingpole, one of those who led the campaign.

[Sir Paul Nurse visits James Delingpole.]

Paul Nurse (voice over): James Delingpole is an online journalist for The Telegraph newspaper. He picked up the leaked e-mails from the deniers' website, and ran with it on his Telegraph blog under the name "Climategate". That week, his page got an extraordinary 1.5 million hits.

James Delingpole: The suggestion of the scientists in the Climategate e-mails was that you hide the decline using "Mike's Nature trick", which I think is some sort of fudge. This very fact of splicing two different sorts of data together on a graph - apples and oranges. Scientists don't do that. They don't try to hide the decline by using "Mike's Nature trick". What they do is admit to the flaws in their data and don't try and disguise that fact.

Paul Nurse (voice over): James told me the independent inquiries into what happened at CRU were a whitewash. He also said scientists fall too easily into a consensus and fail to be critical enough of the data.

James Delingpole: I've been following this Climategate story very closely for the last year. And I think that what is being done in the name of "science", "the consensus", is essentially advancing a political agenda, and that political agenda has much more to do with control, with governments, you know, intruding further into our lives...

Paul Nurse: "Consensus" can be used like a dirty word. Consensus is actually the position of the experts at the time, and if it's working well - it doesn't always work well - but if it's working well, they evaluate the evidence. You make your reputation in science by actually overturning that, so there's a lot of pressure to do it. But if over the years the consensus doesn't move, you have to wonder: is the argument, is the evidence against the consensus good enough?

James Delingpole: Science has never been about consensus, and this is why I think one of the most despicable things about Al Gore's so-called consensus - consensus is not science.

Paul Nurse: I want to give an analogy, which is in a different situation. Say you had cancer.

James Delingpole: Yes.

Paul Nurse: And you went to be treated. There would be a consensual position on your treatment. And it is very likely that you would follow that consensual treatment, because you would trust the clinical scientists.

James Delingpole: Yes.

Paul Nurse: Now, the analogy is that you could say "Well I've done my research into it and I disagree with that consensual

position." But that would be a very unusual position for you to take. And I think sometimes the consensual position can be criticised when in fact it is most likely to be the correct position.

James Delingpole:Yes. Shall we talk about Climategate, because I don't accept your analogy, really. I think it's very easy to caricature the position of climate change sceptics as the sort of people who don't look left and right when crossing the road, or who think that the quack cure that they've invented for cancer is just as valid as the one chosen by the medical establishment. I think it is something altogether different, and I do slightly resent the way that you're bringing in that analogy.

Paul Nurse (voice over): For many, the Climategate debacle is the embodiment of the current relationship with science. The anger it generated reveals the tensions and the widely divergent views that exist on both sides of the debate. And through all this noise, people are left to try and make sense of it all.

I think the public have got every right to sometimes feel confused about the reporting of science in the media. Let me just show you some reports of different scientific issues, starting with Climategate. *The Daily Mail* reporting this issue, concludes in its headline: "Secretive and unhelpful. But scientist in Climategate storm still gets his job back". Completely different tone about this news item in *The Guardian*: "Climategate scientists cleared of manipulating data on global warming". It's difficult to imagine it's reporting the same thing. But it's not just reporting news events to do with science, but the science itself. Let's look at *The Daily Express* is saying here, for example, about the effect of the Sun on global warming. They have their provocative headline: "What a climate con!" but specifically they say here that the Sun is the major cause of temperature variation, and sunspots in particular. If we now look at *The Independent*, almost the same day, we have: "Sunspots do not cause climate change, say scientists". I mean, what is going on here, this is just reporting science, coming to completely different conclusions.

It's not surprising that the public are confused reading all of this different stuff. There's these lurid headlines and there's political opinions, I think, filtering through, which probably reflects editorial policy within the newspapers, and we get an unholy mix of the media and the politics, and it's distorting the proper reporting of science. And that's a real danger for us, if science is to have its proper impact on society.

Somehow science has got to get through all these competing agendas. I wonder if part of the problem lies with communicating the complexities of science. What it is we understand and what it is we don't understand.

We're mainly taught science in school as if it's made up of immutable facts, such as Einstein's theory of relativity or Newton's laws of motion. And it was seeing these theories being translated into the real world that first got me hooked as a child. One of the most exciting things was seeing Sputnik

II, in 1957, '58. It was going across the streets of London. I got so excited, I was in my pyjamas and I ran out and saw this satellite going across the sky. Everyone thought I was crazy, of course, but that was the beginning of the Space Age and I was there.

I want to enthuse a new generation with the optimistic belief that science is a force for progress. However, at the cutting edge of science, where I work, the truth is not always so obvious. We often have to deal with uncertainty in science, but I think it helps to think of uncertainty in two different sorts of ways. There's uncertainty that often happens at the beginning of a research project when we don't know what's going on, and by testing and doing experiments things get more and more certain, knowledge becomes less and less tentative.

And there's another sort of uncertainty which is more probabilistic. Like, for example, if we treat somebody for a certain disease, we don't know whether that individual will be cured or not, though we do know probabilistically, over a hundred individuals, that twenty will and eighty won't, for example. And that uncertainty never goes away.

Thanks to decades of research and experimentation, our knowledge about the fundamentals of climate science has become less tentative. But there are uncertainties that won't go away, especially in our ability to predict the future, where scientists can only talk in terms of probabilities. Does this uncertainty mean that the science is flawed? Some of the biological problems I study are complicated. And so is climate science. Clouds, ice, chemicals in the air, plants and the Sun all interact with one another to affect our climate. Clouds are one of the most significant of these, yet also one of the most complex. Depending on their height and their makeup, they can either warm or cool the planet. So it's difficult to represent them correctly in the climate models. But if the scientists don't get them right, then quantifying what the temperatures might be in the future is very hard.

However, through enormous amounts of data collection and research, climate scientists are reducing the uncertainties in our climate system all the time. Back at NASA, Bob Bindschadler showed me just how much progress has been made.

Bob Bindschadler: Just to emphasise how good these models are [pointing to dynamic wall display]. Side by side comparison, here's data, actual observations, and this is what the computer is generating, predicting what should be happening. And you look at one, you look at the other of these major systems - it's there. These cumulus clouds popping up in the tropics...

Paul Nurse: And this is all happening in the same time scales...

Bob Bindschadler: That's right.

Paul Nurse: ... but one is just built on observation, what we

actually see, and below that is data and the modelling that that produces...

Bob Bindschadler: Exactly. So we're just testing a model here. We've got data. We've got a model. How good do the model predictions match the data? In your eye, will just tell you the answer.

Paul Nurse: You see these great things swirling here, and then they swirl up there, and little puffs there, and little puffs there...

Bob Bindschadler: So even that kind of detail about clouds, models are getting it right, now, And visually, I think this is just so stunning, because seeing is believing.

Paul Nurse: Sort of climate science is moving from more tentative knowledge to more certain knowledge, it still has uncertainties but they're getting less as time goes on.

Bob Bindschadler: There will always be a little bit of uncertainty, because there are some processes that we don't fully understand. But we measure scientific progress in our ability to reduce the uncertainties. And by that measure, we're making extraordinary progress.

Paul Nurse (voice over): All the information we have today helps us to predict our future climate. But the more we learn, the more complex the climate system becomes. This doesn't mean the science is flawed or that we shouldn't act, but ther may be a problem in the way those uncertainties are communicated to the public. Scientists may not be willing enough to publicly discuss the uncertainties in their science, or to fully engage with those that disagree with them, and this has helped to polarise the debate.

Making this film has made me think about the place of science in the modern world, and whether we scientists are keeping pace. Free and open access to information means our voices are no longer the only ones people hear. What I think is changing, in the way that we're talking about science in the public sphere, is the fact that now almost anybody can say whatever they like on the blogosphere and this is getting read. And I'm really used, in my science, which I've done for thirty or forty years, for a much more cooler approach. When I read these blogs, I mean, they're full of righteousness, full of zealousness, and they're clearly trying to persuade you very very strongly of their point of view. They cherry-pick data, they don't seem to be always and completely consistent, and what I get the sense of, is that they don't actually try and put a reasoned argument here. There's a case here on the left, there's a case here on the right, it's always very strongly on one side.

Searches on the internet do not differentiate between thoroughly researched evidence and unsourced, uncorroborated assertion. Conspiracy theories compete on level terms with peer-reviewed science. In this new world of information overload, we look to people we trust to find those answers. And these days, it's not necessarily the scientists.

[Paul Nurse is talking to James Delingpole.]

Paul Nurse: One question I would ask as one who has done quite a lot of scientific publishing is: are you looking mainly at peer-reviewed material or non peer-reviewed material? Peer-reviewed being material that in principle, and flawed as it is - as I know it can be flawed - has been looked at by other scientists and the case said: yes, there is an argument here worth publishing.

James Delingpole: One of the main things to have emerged from the Climategate e-mails was that the peer review process has been perhaps irredeemably corrupted. What I believe in now, and I think we are seeing a shift in the way science is conducted and at least transmitted to the wider world, is a process called peer-to-peer review. The internet is changing everything. What it means is that ideas that were previously only able to be circulated in the seats of academe, in papers read by few people, can now be instantly read on the internet, and assessed by thousands and thousands of other scientists, people with scientific backgrounds and people like me, who haven't got scientific backgrounds but, you know, are interested.

Paul Nurse: Just back to the evidence again, though. So we get, obviously there's a source of evidence through the internet, books, primary publications is probably not your thing...

James Delingpole: It is not my job to sit down and read peer-reviewed papers, because I simply haven't got the time, I haven't got the scientific expertise. What I rely on is people who have got the time and the expertise to do it and write about it and interpret it, you know. I am an interpreter of interpretations.

Paul Nurse (voice over): As a working scientist, I've learnt that peer review is very important to make science credible. The authority science can claim comes from evidence and experiment, and an attitude of mind that seeks to test its theories to destruction. Scepticism is really important. We are often plagued by self-doubt. I often tell my students and post-doctoral workers: be the worst enemy of your own idea. Always challenge it, always test it. I think things are a little different when you have a denialist or an extreme sceptic. They're convinced that they know what's going on, and they only look for data that supports that position, and they're not really engaging in the scientific process.

There is a fine line between healthy scepticism, which is a fundamental part of the scientific process, and denial, which can stop the science moving on. But the difference is crucial. Denial is not just a feature of the debate over climate change. People deny the evidence in favour of many things, like certain vaccines or that HIV causes AIDS. I want to understand better how people reach this state of mind.

[Paul Nurse meets Tony Lance.]

Paul Nurse (voice over): Tony Lance does not believe a virus causes AIDS. And rather than take anti-retrovirals, he treats himself using probiotics, like yogurt. There is such an overwhelming body of evidence that HIV causes AIDS. I really want to understand how Tony has reached his opinion.

Tony Lance: I came to the conclusion that much of what is called AIDS, at least how it appears in gay men, is the result of severe disregulation of intestinal microflora, and the causes of that being...

Paul Nurse: That's all the microbes growing in the gut...

Tony Lance: Yes, exactly. I mean, we have in our guts a very complex and rich ecosystem. These microbes live in a symbiotic relationship with us. They directly affect our immune system. They directly affect our uptake of nutrients. And it occurred to me, after many many years of reading and self-analysis and observing the gay community that there are really some very good reasons why certain subsets of gay men would have intestinal microflora that are abnormal. If you get down to brass tacks, I think HIV is a marker for immune dysfunction, as opposed to being a cause. I think immune dysfunction actually precedes HIV-positivity and makes it possible.

Paul Nurse (voice over): Holding these views puts Tony in a very small minority.

Paul Nurse: So what is it like, psychologically, for you and for people who think like you, to be on the outside?

Tony Lance: It's isolating. One of the labels that gets tossed at me, and others like me, is a "denialist", and that's actually kind of hurtful, to tell you the truth.

Paul Nurse: You don't like - that you wouldn't see yourself as a denialist...

Tony Lance: No, not at all. I don't even know what it is that they would say that I'm in denial of. I mean, I've lost many scores of friends to AIDS, I'm certainly not in denial of the actual illness, I just view the cause and effect differently.

Paul Nurse (voice over): I found that discussion with Tony really interesting. I mean, I'm completely mainstream about HIV/AIDS. AIDS is caused by the HIV retrovirus, there's no question about that. He doubts that, and he's sceptical about whether it's causal. You could say that he denies that it's causal. But he's at the end of the spectrum where you can have a conversation with him.

As a scientist, I find Tony's views hard to understand. However, I think there may be a link between how he approaches the evidence for the causes of AIDS and how some climate sceptics may look at the causes of global warming. Problems arise when you study complex data and try to distinguish cause from effect. Understanding what causes what in complex systems, like biology that I study, or climate, can be really difficult. Let me sort of illustrate that here. [With

three metal poles linked by a length of rope.] Imagine that each of these poles are different events, events A, B and C, and we have time running up here on the floor. Event A causes event B. Event A also causes event C. But if you're a scientist, you don't know anything about event A and you're studying B and C, then what you will see is that after a certain period of time, you'll see B and always - or nearly always - you will see C a certain time afterwards. It would be a natural consequence to think that B might cause C, when that is absolutely not the case.

Think of a concrete example, for instance. For example, smoking and lung cancer: let's imagine that event A here is smoking. Let's imagine that event B is yellow teeth, that occurs after a certain amount of time, and let's imagine event C is lung cancer. You could perhaps imagine, as a scientist, that you observe yellow teeth and you observe lung cancer, and maybe yellow teeth causes lung cancer. Now that's obviously nonsense, but if you didn't know about smoking, then you could perhaps be led into that erroneous conclusion. So that's the problem with complexity, that's the problem with working out what causes what.

There's an overwhelming body of evidence that says we are warming our planet. But complexity allows for confusion, and for alternative theories to develop. The only solution is to look at all the evidence as a whole. I think some extreme sceptics decide what to think first and then cherry-pick the data to support their case. We scientists have to acknowledge we now operate in a world where point of view, not peer review, hold sway. I think part of the problem may be past controversies, where mainstream science has failed to win over the public.

There is one such subject where the research has to be carried out under strict security, because feelings are still running high. Isolated in a remote corner of the country, a highly contentious scientific trial is being conducted.

Jonathan Jones: We're not protecting the public from them [view of plants in an enclosure], we're protecting them from anti-GM activists, who have been very keen to disrupt GM trials.

Paul Nurse (voice over): This field is home to a large experiment in genetically modified food. Professor Jonathan Jones is working to create a new kind of potato that would be resistant to a mould called late blight. Alongside standard potatoes, he also planted GM varieties and waited to see what would happen.

Jonathan Jones: This is perfect blight weather, actually. This is just - if you are a late blight pathogen, you would be very happy today. Potato blight is a disease that caused the Irish Potato Famine. It causes three and a half billion pounds a year of losses in potatoes and tomatoes. It's a fungus-like organism but it makes spores that can blow around. We didn't innoculate this [view of blighted plants]. It blew in from somebody else's field, probably, twenty, thirty miles away, and it can rip through a crop in a week.

Paul Nurse (voice over): The trial is at an early stage, but the GM varieties seem to be standing up to the blight much better than the standard ones.

Jonathan Jones: Farmers actually spend about five hundred pounds a hectare controlling this disease, so if you had a hundred hectares of potatoes, that's fifty thousand pounds out the door, for spraying fifteen times a year to control the disease. So what we're trying to do here is get genes into these potatoes that would mitigate the need for all that spraying.

Paul Nurse (voice over): But it's this manipulation of genes that's the source of contention. Critics have objected on several grounds, from safety issues to environmental concerns.

Young activist: It's time for us to say no, we don't want it. We don't want that technology. It doesn't benefit us, it doesn't benefit the environment. In fact, it threatens us and the environment.

Paul Nurse (voice over): The GM debate once again raises the question of public trust in science. There's a gap between the fears of some sections of the public and the opinion of scientists, that what they are doing is both useful and safe.

Jonathan Jones: I think my primary emotion is bemusement. Where are they coming from? What is going on in their heads, that they feel so strongly that this must be campaigned against? They often assert that this is a failed technology. If it's failed, why do 14 million farmers plant 134 million hectares of it? You know, they do so because it works. Farmers are not stupid.

Paul Nurse (voice over): There seems to be a mutual misunderstanding from both the scientists and the public. The controversy surrounding GM was something I really wanted to understand. I went and talked to members of the public to find out why they were so against it, and one thing that came up very often was that they were against eating food with genes in it. And that's something that would never occur to a scientist, because a scientist obviously knows that all food has genes in it. But why should a member of the public know that? What had happened here was that we scientists hadn't gone out there and asked what bothered the public. We hadn't talked to them about the issue, we'd not had dialogue with them.

Scientists had forgotten that we don't operate in an isolated bubble. We cannot take the public for granted. We have to talk to them. We have to communicate the issues. We have to earn their trust, if science really is going to benefit society.

Over the next few years, every country on the globe faces tough decisions over what to do about climate change. I've been thinking how scientists can win back the confidence we're going to need if we're going to make those choices wisely. Before I started my presidency of the Royal Society, Keith Moore, the head librarian wanted to take me on a tour

of the archives, to give me a glimpse of some of the jewels they contain.

Keith Moore: So here we hold some of the genuinely rare materials from the book stock.

Paul Nurse (voice over): Being surrounded by the products of so many brilliant minds is quite a humbling experience.

Keith Moore: These are the minutes of meetings...

Paul Nurse: Is this all the notes of the Society?

Keith Moore: That's right, yes, this goes right back to the very very first meeting of the Royal Society, so this is...

Paul Nurse: What, really? What year is this?

Keith Moore: This is 1660. So here we have the memorandum of November 28th 1660. These persons following met at Gresham's College. So this is the first meeting of the organisation.

Paul Nurse: Look at that...

Keith Moore: It wasn't even called the Royal Society at that point. And here's what they thought they were doing, founding a college for the promoting of physico-mathematical experimental learning.

Paul Nurse: Is that Wren, is that Christopher Wren? [Pointing to signatures.]

Keith Moore: That's Christopher Wren. Robert Boyle here, they're all present.

Paul Nurse: You know, this is making me feel a bit starstruck here.

Paul Nurse: I'm here in the Royal Society, 350 years of an endeavour which is built on respect for observation, respect for data, respect for experiment. Trust no-one, trust only what the experiments and the data tell you. We have to continue to use that approach, if we are to solve problems such as climate change.

It's become clear to me that if we hold to these ideals of trust in evidence, then we have a responsibility to publicly argue our case. Because in this conflicted and volatile debate, scientists are not the only voices that are listened to.

When a scientific issue has important outcomes for society, then the politics becomes increasingly more important. So if we look at this issue of climate change, that is particularly significant. Because that has effects on how we manage our economy and manage our politics. And so this is become a crucially political matter, and we can see that by the way that the forces are being lined up on both sides. What really is required here is a focus on the science, keeping the politics and keeping the ideologies out of the way.

Keith Moore: One of the things you can't get away without seeing is Sir Isaac Newton, of course.

Paul Nurse: His *Principia*.

Keith Moore: Indeed this is the manuscript version of *Principia Mathematica*, this is Newton's great work on the laws of motion.

Paul Nurse: Of course this was the book that laid the foundation for gravity and...

Keith Moore: Yes, that's right. So this was a standard text for scientists for like, two hundred years. It was really not until Einstein came along, that people began to seriously re-evaulate how the universe worked.

Paul Nurse: I need to touch it.

Keith Moore: Yes, do.

Paul Nurse: Maybe just finally, this is the great book of course, *The Origin of Species*. So this is the one that Darwin presented to the Royal Society, always nice to have a presentation copy.

Paul Nurse: Did he sign...

Keith Moore: It just says "From the author". Rather overwhelmed by the rather nasty '80s biro.

Paul Nurse (voice over): Earning trust requires more than just focussing on the science. We have to communicate it effectively, too. Scientists have got to get out there. They have to be open about everything that they do. They do have to talk to the media, even if it does sometimes put their reputation at doubt. Because if we do not do that, it will be filled by others, who don't understand the science and who may be driven by politics or ideology. This is far too important to be left to the polemicists and the commentators in the media. Scientists have to be there, too.