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New Scientist and Greenpeace Science Debates

Science, technology and our future: the big questions

Can Science be directed?

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Chair: Perhaps I can invite the member of the panel to occupy their places at the table. Now, when you raise your hand to speak, someone with a microphone will come and stand in front of you. Don't start your oratory without it because we want to record this and it's rather difficult to do. Even if you've got a voice, which carried, throughout the theatre, it's still important that you should wait for the microphone to come. Keep it short and I want, first of all, to call on Doug Parr who is the Chief Scientist at Greenpeace, to make the first observation.

Doug Parr: Thanks to our speakers for that. Vandana mentioned the speech by Mr Blair. It was during that speech or in the comments before that he said there was a problem with Britain, that the public were rather anti-science. Was he right?

Chair: Would one of you like to respond to that?

Steve Fuller: I don't think the public is anti-science. I think the public is a bit bewildered about how exactly decisions about science and science policy are made and, in fact, this is why I brought up the business about the consensus conferences, that there is no clear medium, no clear way, and so the public then starts to get very suspicious that something's afoot, especially when they learn through journalists and others about the various financial and political interests that scientists have, which seem to be influential with the government. But I don't see the public as being particularly anti-science. They just want to be more involved.

Chair: Right, does anyone else want to comment on that? Bill?

Bill Stewart: Consensus conferences are the easy way of dodging issues. You get together a bunch of people at Imperial College or wherever and you can make some

conclusions. What relevance has that got to the people of Scotland? I can tell you, if there was a consensus conference in Edinburgh, they would come out with very different conclusions so the great problem about consensus conferences is that you're only tapping a very small proportion of the population and I would say that they are useful but don't expect them to do everything.

Steve Fuller: Do you want a discussion about the technicalities at consensus conferences or not?

Steve Fuller: Well, first of all, in the context where they're made part of policy, Denmark has the longest history. Several of them are convened throughout the country simultaneously within a period prior to when parliament is going to be taking a decision on a scientific technology-related matter so it isn't just one, local area. The problem in this country is that, so far, these things have just functioned as experiments so they've been fairly local, like in Imperial College, usually in academic settings. So, not surprisingly, they just represent the constituency of the people they can gather for those experimental purposes.

Chair: Let me now ask Jeremy Webb who is the editor of the New Scientist to say something.

Jeremy Webb: Thank you very much everybody for their contributions. My interest is more with the independent scientists that used to exist. We now have academics getting money from companies. We have university departments getting money from companies. We have a government minister who earns millions from investments in biotech and it seems to me that we're getting this blurring of lines between academia, government and industry and there are two things that I really want to ask: one is, do you think this is causing a loss of public trust, and the second one is really, shouldn't we be stopping industry from buying up our best talent?

Vandana Shiva: I was trying to answer that question before it was asked and the last point I made about the new arrangements, the new partnerships that are emerging, are very efficient at harvesting publicly generated knowledge but they are useless in maintaining the generation of future knowledge, because they are not either nurturing the social base within the scientific community or the political base beyond the scientific community and it's that larger crisis which is causing a rupture, where people recognise that science is a public enterprise; it cannot but be a public enterprise. It is a social endeavour but if companies were that efficient in generating knowledge, they would have generated the knowledge that

universities did. After all, they've had the money, they've had the stocks and Wall Street can get good rapid quarterly returns but Wall Street is a bad director of good science.

Steve Fuller: I agree with what Vandana Shiva has said but I would also add that it would be good if science journalists, as a rule, looked into the financial and political scientists who seem to be outspoken on various sorts of public issues and make that a kind of a routine part of reporting. I mean, it does happen sort of episodically but, if this was made part of what in fact the journalist was doing, then it seems to me that this would, you know… Once the scientists realise exactly the kind of impact that knowing, let's say, that you're in the pocket of a certain company or you're working for a certain think tank, maybe they would think twice about whether they want to get involved in that way. In a way, has science journalism become more like investigative, political journalism. I think that, in a way, will start to address the question in a very grass roots level.

Chair: I think there's a widespread suspicion in Britain at the moment that an awful lot of science is being financed for commercial reasons and that universities themselves are in some danger of being heavily tainted by this. So the more you ask for private partnerships, the more people feel, well, what's going on? So that's a very important point you make. I would like to ask Satish Kumar here.

Satish Kumar: My concern is whether science is value-free or science should have some values. At the moment, it is assumed that science is totally objective and it has no concern with any kind of values and, when you have no values of any kind and you become totally objective, then you are, or science becomes misdirected. So, I would like to ask some of those on the panel to say, what is the relationship between science and values, whether they are psychological values or spiritual values or social values, human values, any kind of values? Science should be a tool to serve something, which is valuable rather than just blind research.

Chair: Right, thank you and I think I might turn to Martin Rees to be the first to respond to that because you touched on the issue yourself.

Martin Rees: In fact I agree with what underlies the question. All I would add is the gloss that I think that, for many of us, actually trying to understand the world and wondering whether the world is worthwhile in itself. So we would say there is a value in trying to understand the world but when you come to apply our knowledge, then clearly we need some values to guide us and the concern is that we may not have values or may not find appropriate ones. So in all the applications, we do have to have a system of underlying

values and I'd just like to say that I agree with what the earlier speaker said about the trends towards commercialisation. I think the only respect in which I differ from Vandana is that I don't think things have yet got quite as bad as she says but there is a dangerous trend and I think we should be concerned to preserve the independence of the university scientists.

I did note in an opinion poll about whether people were trusted, for some strange reason, professors were trusted more than scientists. So if you're pronouncing on something scientific, then you must call yourself professor but I think the underlying thing is that there is a greater respect for the independence of the universities than for a government or industrial scientists and it would be a tragedy if that were eroded by the trends that have been referred to.

Steve Fuller: Just an historical point about the role of values in the teaching of science. In the 1950s, in the wake of CP Snow's famous speech on the two cultures, there were several programs that instituted that in this country, at Edinburgh, at Manchester, in the subjects that were designed actually to instil larger cultural and social awareness in what was perceived, at that time even, as an increasingly technocratic society, so that scientists had a much rounder view of the world in which they were operating and unfortunately, what happened was that, by 1970, these teaching fields ended up becoming professionalised themselves and that's how we got academic research in the sociology of science in this country.

William Stewart: I just wanted to make a point about what was said earlier, about science and industry. I think there's something wrong with the view in which you say the best scientists go into industry and basically, as soon as they're in industry, you say they're not doing good science anymore. I think you're getting confused about science on the one hand and who sponsors them on the other.

Paul Rowland: Does the panel think it would be a good or bad thing to perhaps forcibly separate pure science and, like, commercially-driven science, perhaps even to the point of every paper having to be headed "curiosity-driven" or "commercially-driven"?

William Stewart: Certainly not because it's a continuum. I remember being at the Royal Society once and there was a Japanese speaker and he says, the difference between you in the UK and us in Japan is that we find applied problems and we get basic science to try and solve them, whereas you in the UK do basic science and then you find a use for it. I think that there is a continuum and you can't have a sort of divergence that you're suggesting.

Martin Rees: Two Points. First, I think that it's good that journals like Nature do require the authors of papers to state their sponsorship at the end. That's a step in the right direction. As

regards the opposition between pure and applied, I think it is indeed blurred and, as I mentioned in my contribution, it's not that pure science leads to applications. It's equally that new technology allows further advance in pure science by allowing more delicate instruments etcetera. So it is hard to separate the two. The motive may be different between the academic scientists, industrial scientists, but the enterprise isn't all that different.

Jackie McGlade: Jackie McGlade, a professor from the UCL in mathematics so whether that means you trust me or not, I don't know. Two points really, to Bill and to Martin. The geography of science has changed dramatically in the last 10 years. We do much more problem solving with our science than perhaps we have done before and what seems to be lacking is that the institutions haven't really caught up. We still have institutions that are doing very disciplinary-based approached and the lifeblood of science, which is peer review, actually seems to dip considerably when you're into these inter-disciplinary areas. So, do either of you have ideas about how you could address that, from the Royal Society or more generically and secondly, I still fundamentally believe that, without more women involved in science, you genuinely do not have the kind of participatory science that Steve was talking about, because I've seen it for myself. Laboratories where you have more women as opposed to laboratories filled with men are completely different animals, addressing completely different problems and I wonder whether some of you might have a comment on that, thank you.

Martin Rees: Well I certainly agree with you that the low proportion of women is deplorable and I think there are trends that it is increasing if you compare the cohort now in their late 20s and 30s in science with those in their 40s and 50s, and so I hope that does continue.

What I'm going to say is somewhat heretical in that I think I don't go along with you in saying that peer review is, to such an extent, the bedrock. I think, even journal publication, which is the tradition of science, is something which may be on the way out because, if we think of how we publish papers now, how I publish my papers, they immediately appear on the Internet and this is marvellous democratisation because it means that it's not just a few people on a mailing list who get your papers before publication, it's possible for students in Eastern Europe and India to be able to respond to you the next day, having seen your paper, and you can respond to their papers and vice versa. This is a great democratisation and the exchanges, which occur in response to a posted paper on the Internet, can lead to an improvement, which is at least as effective as peer review. So, I frankly would not shed any tears if tradition of peer review and traditional journals were to disappear.

Vandana Shiva: When I left academic science, I remember saying I will never, ever participate in the rat race of publication. I write a lot but it's for different purposes. It's not just for mine, as a member of a scientific community. But the point is there is so much discussion right now in the intellectual property community that you don't really need publications anymore. Let students go to patent offices and re-patent applications and, having read many, many patent applications myself, I can tell you, we will create generations of scientifically illiterate people because patent applications are not about communicating science; they're about something else.

So I think what we do need to address is, how will science be communicated in the new context and how will an authenticity of the content of that communication be judged? To me, the big worry is that fraudulent science and fabrication of data used to be fringe activity. Today it has become the dominant way in which facts, as Mr Blair talked, are being generated, especially in the biotech field, not the tools that I use. I don't think you can fudge too much on that but in claims about the yields, about the resistance impact on beneficial species, all those basic issues of public debate and environmental debate. I think that is the worry, that there is no check today, no public check, no scientific check about the difference between fraud and fact.

William Stewart: That statement worries me quite a lot because basically I get the impression sometimes that the less somebody knows about in any particular subject area, the easier they find a solution to it and basically, I think it's absolutely wrong to believe that science has got fraudsters all over the place. You're absolutely wrong about it. I would like to see what peer review there is from various other commentators who made comments about the right or the wrong science so what you say worries me quite a lot. Maybe I could just make a comment about the inter-disciplinary nature. I agree that it's much more difficult to get grants in inter disciplinary subjects, just as it's more difficult to get a double first.

Steve Fuller: I want to address the issue of women in science that you raised. The first point is that it's an issue that hasn't arisen yet in the debate and it has to do with the fact that women, typically, do at least as well or better than boys when they're in primary or secondary school but gradually drop out of the system so there's a great deal of discouragement of women early on in the educational system, with regard to the teaching of science and that needs to be addressed.

The second point is, and this is a general sort of problem that we have with fields where women are very dominant, the more women get into a field, typically, the lower the status of the field. So in fact fields in fact lower their status as more women get into them and this is

not just true in science but it's across the board and so there's a sense in which, while of course it would be good for more women to be in physics and mathematics and fields where women aren't so represented at the moment. The point is that the kinds of fields that women do happen to go into at the moment, it seems to me those could perhaps be valued more and that, in a way, there's a sort of deep problem here about how fields are valued that I think needs to be addressed.

Martin Rees: Could I tell you why I think it's a special problem with women getting promotion in the academic world. It's that academic careers are unusual in that, traditionally, promotions are based on your past, cumulative record and obviously anyone with an unorthodox career who hasn't followed the straight line is handicapped and that's in contrast to most careers like a journalist or an actor, where no one cares very much about your past career. They want to know what you're going to do in the next year and you could make a reputation very quickly and lose it very quickly and I think it's because of this inertia and cumulative nature of the evidence used in making appointments that is it's very hard for a woman, say of forty, to get the senior position that she deserves.

Anthony Ferguson: I'd like to ask the panel, with the emphasis on science rather than technology, do they think science can be directed with any precision?

Vandana Shiva: I think it's partly related to the presentation Professor Stewart was making, that the individual scientist is obviously not directed. It's the context of science that is directed and that context is done with clear precision. You will either promote organic or you will promote GM. Those are very clear directions, given to the scientific enterprise. If you look at tremendous data generated now on ecological agriculture, it has happened outside the official direction. It has happened by independent, small-scale initiatives and I think it is really micro-tuned in that sense and the continuum that you mentioned about, Bill, there is not separation and the point is there are some very fundamental scientific issues of how nature works are involved in the basic debates around commercialisation of science and that's why the debates are so intense.

Martin Rees: I think it can be directed in the sense that funds can be thrown at a particular problem area and that will increase the volume of work and it can be directed in the sense that certain styles of work can be prohibited if they're ethically unacceptable etcetera but I think perhaps the other issue underlying your question is whether it's a good thing to direct science and I think it's clearly a mistake to attempt to direct science narrowly, whatever your criteria for judging success are, because you will obviously not have been following up certain pure knowledge and you'll also be missing out on the benefits that arise serendipitously. I mean, I gave the example of x-rays as a classic one but many 20th century

scientific discovery having arisen from entirely undirected research, which would not have been programmed or planned for.

Steve Fuller: When I hear the question: Can science be directed? I don't actually think of it in the terms that you seem to be presupposing. I think of it more in terms of whether one can live with the consequences, whether we have institutions in place that, let's say, can spark whether something's working or not. If we do decide to go along a certain line of science and then we find out that some problems have arisen, are we in a position to be able to reverse that? Will we be able to discover this in time? And, if we do come up with something that's beneficial, will it be distributed equitably across the society?

It seems to me those are the questions in terms of the consequences of the research and those are being monitored, that the issue of the direction of science would arise from me. I mean, I don't think of it in terms of being able to predict precisely that we'll be able to do this within a certain period of time but rather to handle whatever consequences come about as a result of supporting the research.

Chair: Thank you very much.

Michael Hopkins: Hello. Vandana, just coming back to your earlier claim that biotech research is not peer reviewed, you mentioned earlier on work by Pusztai and, more recently, work by Ignacio Chapela. Surely, those are two issues where peer community has been involved most vigorously probably in the history of biotech research and the peer community played a part in discrediting the scientific content of that work?

Vandana Shiva: Well, in the case of Chapela, there have been articles written since then that showed very clearly that there was a pretence of scientific response and there was a bombarding of the journal to get that paper retracted. Now, given that this area of impact, ecological impact is a whole new field, obviously it doesn't have the kind of standardisation that sees where something has been done for 20 years. There will be a little validation but it was not fraudulent research. You can always find ways in which the particular tests could have been done using slightly different parameters but it was an assault by a special interest community and that, to me, is the worry, that there were only two or three papers that have been published in this area and that's the kind of assault that came.

Most of the entry of products of biotech into our lives are coming through totally, secretly held data and I'm saying this on the basis of the debate in India, the Supreme Court litigation in India, the clearances by committees. Two hundred scientists, including the founder of molecular biology, Dr Pushbum Halgath, Dr Yashpan [phonetic] who used to be a Secretary of Science and Technology, Dr Truplar who's the Head of Agricultural Research, two hundred scientists of that calibre had to write a letter of protest and try and get the courts to

stop the clearance on grounds that the data was not public and therefore could not be judged.

The point is the commercial clearances are coming on the basis of totally non-transparent data generation and we have the case in one product, BGH, the bovine growth hormone, where the research data that had been used in the US was then visited, revisited by the Canadian experts who found, again, that there was fraud. I'm carrying this book, The Global Sting, the Dioxin Story. Even the numbers of how many people died in an accident get changed. That's the level. All this work on the basis of commercialisation is happening, claims on yields, claims on the evolution of resistance. How much of that has been scrutinised by either the public or the scientific community?

Chair: It seems to me that it's a very important point and we shouldn't leave it too quickly.

William Stewart: I don't actually accept the generalisation. I'm prepared to accept that there are occasions when that happens but as a generalisation, I don't accept it.

Vandana Shiva: Dr Stewart, I wasn't being general. I was talking concretely about data in India, BT Cotton, a company called Monsanto. Yields of the BT Cotton versus the conventional variety, claims of no impact on beneficial species, we dig up the data, it turns out there's no impact because there are zero populations of beneficial species in the test plots. We are not making generalisations. These are very concrete, very concrete cases, particular fields, particular crops, particular access.

Martin Rees: If peer review goes out of the window, then openness is even more essential than it would be otherwise. Let me give you an example from a quite different field of science – cold fusion. The cold fusion advocates, they were berated for bypassing peer review. In fact it didn't matter very much because they were open. People could quickly attempt to replicate their experiments and they couldn't, so no great harm was done except to their reputations but, had they been working, say, in the Livermore Laboratory and had they had the ear of Edward Teller or someone like that, you would well imagine that a billion dollar programme could have been started on cold fusion, in secrecy. So, if you have neither peer review nor openness, then there is a risk of some tremendous bandwagon with no scientific justification getting us there. You've got to have one or the other.

Chair: Right, well thank you.

Trilby: I'm an impactee of science and technology. I want just to get the panel's reaction to the fact… I think it's a leaked document. The government wants to push through legislation to stop the public being able to intervene and have hearings on items to go on the seed list and they want to do it quickly enough so that the second hearing of Chardon LL will get

through before… rather, the legislation will get through before the second hearing comes up. That's a pesticide-resistant maize; cattle feed that has been challenged by members of the public. They're not to go on the seed list. The seed list, no seed can be sold in this country unless it's on the seed list and there's a process whereby the members of the public can challenge it. They can do it by writing or they can actually go before parliament if they pay a fee to do it and the legislation… well, it is leaked, I mean, there are not many people here but if you're a member of Friends of the Earth, you'll have had a mailing about it and perhaps Greenpeace has sent one out as well. But in the light of open discussion on what happens…

Chair: Well, unless you want to respond I think all we can say on that is the panel takes note.

Toby Andrew: My name's Toby Andrew and I'm a genetic statistician. I just wanted to make a contribution about whistle blowing because it strikes me, what we've heard this evening from Steve Fuller and Vandana Shiva and also, at the last session with Robin Grove-White is, very often, hand-in-hand with the democratisation of science is raising the issue of how important whistle blowing is. It seems to me that the problem is not so much secrets, commercial or otherwise, particularly if you're talking about public confidence in policy-making or scientific research. The key problem, I think, is actually the premature release of undigested research, exactly like Pusztai potato and so on and that's what's been encouraged with whistle blowing, that you're actually putting out into the public domain something that hasn't been established in any way. Now that doesn't mean that you have to keep it secret but that's where peer review is so incredibly important and I'm all for openness but you do need Peer review. Expertise is very, very important to actually have a process itself before you can actually have a democratic process of how to use that knowledge in policy making and otherwise. Otherwise, it just feeds into general panics because nobody knows what the state of play is, if by definition the research is on-going.

William Stewart: Basically, I agree with that because the way science is organised at the present time, speed is of the essence and guys who come second are not usually… don't get the same accolades as the guys who come first. I could tell you a story in 1967, I was at the University of Wisconsin and we found out that the competitor lab was working on the same subject and not only the competitor's labs. The guy who did it was also editor of a journal which produced the papers in five months. So we worked all night for a week. We produced a paper that the professor went down to Washington and proceeded to the National Academy of Science. One paper per year they could get out in four weeks. So that paper came out on the 28th December 1967 and the other paper came out on the 2nd

January 1968 and that was an important thing at that time but I agree that too much attention is given to speed rather than quality.

Steve Fuller: I would agree but I would just point out that one of the reasons why peer review very often turns out to be slow is because it's very hard to get peer reviewers to actually review the thing. While it's true that peer review is very often the kind of old boys' network, there's also a kind of default problem, mainly, there's only certain people who'd be willing to review this stuff and it takes forever to find them and that's why you're always relying on the same people. And it seems to me if the scientific community, was a little more responsible individually about the importance of this kind of process, then some of these problems about time delays would be eliminated.

Ronald Wellow: My name is Ronald Wellow, Millennium Trust, and I'm a layman. I want to ask a question about values because I think it is in the area of values that we laymen interact with you scientists. There is a very ancient concept, which has guided the affairs of mankind over the millennium. The concept in the Sanskrit word is Ahinsa [phonetic]. It means, harmlessness, roughly translated. Acting without doing harm. Now, as a layman in this age, I am very concerned about science and the way that it may be leading towards doing harm but, as a father of a son who died of cancer, I'm also very concerned about the people who appear to try to stop the progress of science, just in case they may alight on something, which would have saved a young man's life.

My question is really, how do you as scientists, and how do I as a layman, and how do those who have a consuming desire to direct us all, how do we act without causing harm?

Martin Rees: Well I think we all share the dilemma that you posed so eloquently. If you want to achieve benefit, we do have to take risks and that is something where we'd need advice, not just from specialists but the wide community and lay people in particular, in particular choices. I remember though reading a very good essay by Jim Dyson, which was called, The Hidden Cost of Saying No, and the theme of that was that if we are over-cautious in, for instance, making the development testing of a drug too long and too expensive, then we will forgo potential benefits and so there's always a trade off between the risks and the benefits but it's very important that advice on that trade off should come from people who are not actually actively involved in the experiments, that it comes from lay people and outsiders.

Chair: I may just mention that this is basically at the heart of the argument about the use of the precautionary principle and it causes a great deal of difficulty in the use of the precautionary principle and I'm sure you're all aware the dilemmas it invariably creates.

Steve Fuller: First of all, I agree with what Martin has said but I would add that this raises again the issue of being able to monitor the consequences of scientific research once it's

already been allowed to go forward and I think, sometimes, we seem to operate with a kind of all or nothing strategy. We're either allowed to go on and then it just goes on indefinitely or we don't allow it at all. I think that it's really important that we think about science policy in the context of something that's reversible, just like any other kind of public policy is and we need institutional safe-guards to allow us to say, no, we've gone too far here; we've got to turn back. Because, at the end of the day, I actually would like to see us take a few chances and a few risks and I think we're simply not going to be making any progress unless we do so but we have to be able to reverse the consequences and be able to identify them, once they happen.

John Fox: I'm a computer scientist. I work for Cancer Research UK, the old imperial Cancer Research Fund and my colleagues and I for many years have been interested in trying to find ways of getting the work we do, which is extensively published in peer review journals and so on, out for the benefit of patients. This is actually surprisingly difficult. Certainly, it's more difficult the more your work is perhaps a little unorthodox. I work in artificial intelligence, which is a surprising subject to find in medical science but because of that, because of that difficulty and simply getting the work taken up, we started a company, with the support of Cancer Research UK, and the reason for that was very honourable and I really would be unhappy if one was left with the feeling for much of this discussion that commercialisation is, of necessity, dishonourable, which often seems to me to be the sort of subtext of some of the comments.

Vandana Shiva: I think that the context of the discussion and the commercialisation of science is, again, not general; it's very particular. It's about scales of economic paths that have become so big. Five companies controlling the biotech field in agriculture. The capacity to corrupt science and corrupt decision-making. It's partly an issue of power at a scale that human institutions have not been evolved yet to manage. Commercialisation in terms of application, as you are talking about, doesn't throw those kinds of debate up at all. After all, that is the nature in which any scientific product enters the public domain, through commercialisation. The difference is one of scale, in part, and the second is what I call Wall Street science. You do work on artificial intelligence. Eventually, you want to form a company to get your information out to cancer patients. There's a way in which you can have it all reversed. When Wall Street start to dictate what should be counted as science and that corruption of the very foundation of what the scientific enterprise is, and given the influence of a particular size of commercial interest, I think those are where the debates are coming out. So I think commercialisation per se is not the issue and commercialisation after research is done is definitely not problematic.

Steve Fuller: I think you've raised a very important point that needs to be dealt with. I think the first thing to say is commercial interest needs to be declared. I think, in a sense, that's kind of the first point, especially because these are for profit things primarily that we're talking about here and I think that it is important that the public knows if, in fact, a certain group of people are going to be benefiting from this disproportionably. So, I think that there's a confidentiality issue, basically. That's the main problem but I suppose there's a larger issue about commercialisation in the sense that, at the moment, commercialisation operates in a very kind of covert way with regard to the way our universities are going for example, and so forth. One area that I happen to do some work in is in knowledge management and one of the sort of nostrums of knowledge management is, you always want to have a kind of lean R&D division in your company and, as it were, draw as much as possible from universities and other places so you don't have to do the research yourself.

You sort of exploit what's already out there and you don't train your own people, you exploit what universities are already training and so there's a sense in which I think if commercial interest were declared more openly and the kind of commercial interest in doing science was declared more openly, that perhaps maybe the corporate sector might fund more openly, rather than just sort of exploiting what universities are already doing and so, in a sense, I would like to see, as it were, the corporate sector to be more obvious, more out there and rather than just sort of operating behind the scenes.

Chair: A particular case arose recently, if your chairman can intervene for a moment, in which some research was done by a company into a new technique and they found the new technique was immensely cheaper for the customer than the one that they were selling earlier. So they tried to suppress the results of the research that had taken place because it would have meant lower profits for the company. When the person who'd done the technique leaked it, they were prosecuted for doing so. It's quite interesting the sorts of moral dilemmas that arise throughout, which I believe, as you've been saying, that transparency perhaps is the only possible answer.

Oliver Morton: I'm a writer and I wanted to ask about the question of choices. We've talked a lot about external constraints on the optimum distribution of what scientists do. I'm interested in the internal problem of scientists directing themselves towards what is more broadly relevant rather than what is their own particular interest and, actually, an example from the wide-ranging career of our chairman is what immediately comes to mind and I think it's something that Martin definitely could speak to and maybe, in more general terms, the others could too. Astronomy is widely accepted and, indeed, admired for being of very little practical use.

There is, however, one particular area of astronomy, which though not a pressing problem, is actually on the public policy agenda albeit in a small way and that's the possibility of the impact of an asteroid or comet on the earth. Now, one of the problems that people have in actually addressing this problem is that astronomers, taken en masse, have almost no interest in it. It's anecdotal from talking to astronomers but also, if you look at where astronomers urge the funding bodies to spend their money, they are more or less inversely correlated to how nearby the object is, thereby stars are largely out of favour, galaxies are okay as long as they're old galaxies, not any of the nearby riffraff. Quasars are great, remnants of the big bang even better but to actually get a few million pounds to spend on things that might hit you, is not possible because it's not actually very interesting. It's not sexy science, even though it's broadly relevant.

Chair: Well you realise that, as you say, I have a vested interest.

Martin Reece: Your analysis, Oliver, is perfect. But just to defend my community, I think that the general consensus is that something should be done in order to survey the asteroids that might be a risk to us in the foreseeable future. Nonetheless, that should be done as a routine problem. It's not of academic interest, at the research frontier. There's no doubt about that. I can think of many other examples of something, which is actually important, which is not of research interest so I think we can afford them both; there's no conflict between the two.

Since we're talking about asteroids, I'd just like to mention that they're interesting in that it's a risk, which is small but quantifiable. It is the difference between risk and uncertainty in this game. It's a small risk but we know what that risk is to within a factor of 2 or 3, whereas in most other risks that we worry about, the risk is uncertain by many powers of 10 and that's why experts can't give us much confidence. But in the case of asteroids, the number of asteroids is known within a factor of 2 or 3 of the relevant masses and we know what they will do if they hit us and so we know what the risk is fairly accurately: it's a small one but that's the problem in most of science, we have an uncertainty so we can't quantify the risk.

Chair: I hate to say this to the Astronomer Royal, but the trouble is we don't know where all those asteroids are, we haven't identified an awful lot of them. I spent months trying to assess the risks, I know the difficulties.

Anna-Maria Taroscz: I think we all agree here that applications of science needs to be debated with the wider public if our aim is true democracy. However, one of the important questions in this issue might be how we enable the public to be equal partners in this so-

important debate, how we provide the crucial information so they can make informed decisions. I wondered what is your opinion? What would be the most effective way?

Vandana Shiva: I think the brief that is being made at this point, both in the way science is shifting as well as the way in which social and environmental impacts are going to be very different, very new, I think we need nothing less than public referendums on the future of science and what are the directions the public would like it to go in. I think we need far more than consensus conferences. Consensus conferences basically assume that you will get the consensus. I think we are in a, you know, we have to correct, you know, without sounding too harsh, let me say, we have to correct two hundred years of past errors and the new risks of today. The past errors are exclusions of major actors - women, as Jacqueline mentioned, other cultures and their knowledge systems. A tremendous loss to humanity. I think we need a whole new stock taking about how much more rich the science enterprise would be if Ayurveda was treated as equal to Allopathy, if organic was treated as more sophisticated than chemical agriculture. That those are reassessments of a societal level, of a large democratic kind, and anyway you need so many hundreds of disciplines in any of them that there is no one community that can stand there and say trust us, we are experts.

Steve Fuller: Well I mentioned in the speeches the consensus conferences and I do think when we do talk about the democratisation of science we should always be thinking in terms of concrete institutions. It seems to me at the moment the way the government is going, which is that the government is very keen in the rhetoric of democratisation, is to actually invite lots of different ways for people to express their viewpoints and in particular one I've read sort of closely has been the public consultation paper on nuclear waste disposal where there is no less than fifteen different ways for the public to get involved including consensus conferences and internet polls and everything under the sun, but of course what will happen, and one can easily predict this, is you're going to get fifteen different kinds of responses and then the government will do whatever is politically expedient on the day in which the vote needs to be taken. And so the whole point of democratisation then gets defeated because there isn't any really clear institutionalisation of the process. Instead, what you have is a kind of grab bag of multiple opportunities for people to blow of steam and of course the government can use any of those it needs to use in order to ratify whatever decision it wants to make. And this is a problem that arises again and again in the history of democratic politics, that unless you have secure institutions, right, that you can trust and that you can use on a regular basis even if that ends up constraining the way in which people have to voice their opinions that's the only way you're actually going to get anything that we would normally recognise as democratisation.

Sarah Fletcher: I'm a government scientist. First point I'd like to raise is very brief in terms of public education of science. That I was working for a government institution part of which was responsible for looking at the risk associated with mobile phones and I heard one of our senior scientists in a conversation with a member of the public, and I heard him trying to explain to somebody who was obviously very upset about this issue what was going on in scientific terms, to then hear him say 'no, it's not exactly the same as BSE and I wasn't involved'. So I think in that sense there is a big problem with the level of science education, particularly the public understanding of science in the UK.

I would also like to point out I'm still working for an agency that is predominantly government funded. When you are referring to issues or you say 'whatever the government is considering, whatever is politically expedient at the time' is continuing to emphasise that there is, that the government cannot be trusted to make scientific decisions. I wonder how a forum can be set up and who can create a forum if it's not the government, if it's not people within commercial interest. Most universities now do have an element of commercial interest; who can create an independent forum that is able to inform the public and to direct science?

Steve Fuller: Well, this is a very big issue, but the first point I would make is that I don't see, you know, if consensus conferences were institutionalised in the way I would have in mind, it wouldn't be oppositional to the government, in fact, I would see the government as, in a sense, commissioning these things, as they do in Denmark, prior to the time in which a vote is going to be taken relating to science and technology. So the government would commission them. Who would actually organise them and how the people would be selected, now it seems that would have to be an independent body and one of the things that we need to develop, I think, as part of, you know, you might say as part of the general public understanding of science movement is a kind of expertise in being able to organise consensus conferences. I mean there is already people who are capable of doing this, many of them associated with fields that I interact with, but it needs to be kind of something that is regularised, something that one can actually, you know, have an expertise in doing, and the sort of people who would be involved as the so-called citizens' jurors, right, would be specifically selected in the way in which one selects juries, you know, where you want to make sure people don't already have a pre-conceived notion or they already have a vested interest, so they are not a stakeholder in anything that's involved, so they are relatively neutral to the issue being decided. Of course not neutral for everything, but relatively neutral to the issue being decided. And so that would be in a way sort of the general background sort of thing, but the government would in a sense delegate, right, it would commission these

things on a regular basis and then basically abide by the decisions they come up with as guidelines within which legislation is made. They wouldn't set the law, they wouldn't displace parliament, but they would provide guidelines.

Chair: Right, Bill, I think this is a subject which must have worried you a great deal in your long and distinguished past, would you like to say a word about that?

William Stewart: Basically in relation to consensus conferences, I was just going to make the point that what you are proposing is a scientific experiment. Now who is going to peer review that to know that the experiment you so choose to do will give you valuable and useful results?

Steve Fuller: Well actually, this thing has been done in 25 different countries; over and over again the results have generally been regarded as pleasantly surprising by experts. So I think the experiment is already validated, it's just the political will that's needed to implement it.

Chair: Anything else you wanted to say?

William Stewart: No, I wanted to say something about mobile phones. I chaired a committee on mobile phones and health, and basically what we did then is we came up with a precautionary approach because the information was not there to allow us to take an absolute decision. And then if you are going to have a precautionary approach you don't say well the precautionary approach is to stop people using mobile phones. What you do is that you analyse each stage of the twelve sort of components, each associated with the use of mobile phones and seeking to analyse these, none of these on their own might necessarily make a big difference, but collectively, by using a precautionary approach about twelve of these, then you come out with something which I think is helpful and better until more definitive data become available.

Chair: Thank you. If I could just add a personal word myself as an ex-Permanent Secretary at one stage I found this is a very serious dilemma because you haven't really mentioned in this discussion accountability. That is to say, that you take a decision that a particular line of research should be pursued and another one should not be pursued, but you are accountable to the tax payers and for that reason you do feel that although indeed you can accept the guidelines that you mentioned and make sure they are taken into account, you still have a responsibility to say is this in the public interest and should I therefore authorise something to take place? And I remember this dilemma does actually arise in real terms relatively more often than you might think.

Michael Le Page: New Scientist. I think a lot of the discussion so far has been sort of quite abstract and when it comes to the direction of science, what you might call the mis-direction of science, one of the most striking examples is the fact that, and this is just one example, we spend a hundred billion on developing that great white elephant in space called the International Space Station and yet very little money is spent on diseases that kill millions and millions of people, like malaria, HIV, leishmaniasis, the list goes on. And what's more, you could argue that under the current system for companies that are, for example, selling anti-retrovirals for 10,000 dollars a year to patients, it doesn't actually make sense for them to develop a vaccine which you sell once for a hundred dollars. So there are two questions, first of all, do the members of the panel think this situation is acceptable, and secondly, if it isn't what on earth can we do about it?

Vandana Shiva: I definitely don't think the situation is acceptable and as I mentioned, the issue is not just that the past priorities have left a huge burden on society and deprived people of access to other users of that public money, other directions of scientific innovation, but that we are facing a whole new challenge: the combination of the emergence of new technology and the emergence of new property rights on knowledge including the $20,000 cost for retrovirals that in India, without the patent coverage in generic terms, can be produced for $200; and the $200 is now treated as crime, $20,000 is the legitimate development. And the whole science system, including the item in the news, world role in science needs elite universities, well, that partnership will end up pushing science much more in the kind of direction of the absurd situation. And I think these are such fundamental shifts added to the past perversions, I would say, that deny people the right to water, the right to health care and put up space stations, or my country arms itself with more and more nuclear devices while fewer and fewer people get the food and water that that money would be able to provide. That's why I was talking about a very, very fundamental basic international level referendum in every society about the future of science, the future of technology, the future of priorities, where should public money go, for what?

Steve Fuller: Well, just very briefly, I would say that one thing that's never… again this goes back to the transparency issue. I think sometimes we make a mistake in thinking that when one has to make decisions about science it's like one science project versus another science project when in fact it's often not clear what the decision making environment is often, you know, the alternatives are often things that to us might seem very strange in terms of let's say if parliament has to make a decision, there's a limited amount of funds and it just so happens the interest groups mobilise in a certain way, it might be, you know, funding a space station, you know, or funding, you know, something that has nothing to do with

science. Maybe that's sometimes the way in which the decision in fact gets framed and I think if you look at, for example, what happened to the super collider in the United States, it's very clear that's a great example of something like that, where it wasn't that, you know, the money didn't go to the super collider so therefore it, you know, that nine, ten billion dollars was freed up for other science. No, right, it went somewhere else non-science. And I think there's a sense in which we need more transparency about the context in which decisions involving science are made because it isn't just a matter of one science project versus another science project.

Martin Rees: First, I agree with what Steven has said about the US situation, but as I mentioned in my remarks at the beginning, I think it is entirely unacceptable that there is disparity between the resources of the developing and the developed world and globalisation's benefits are going to the developed world and many of these things that we've mentioned like the lack of research into tropical diseases, etc, the lack of market for drugs in developing countries, they are really a symptom of this overall inequality which affects the world in so many different ways far beyond science.

Chair: Thank you very much. Now we have our last question, which comes from Miss Hoskins.

Liz Hoskins: Thank you. I'd like to pose two questions. One is related to the proposal of perhaps what scientists need is a code of ethics to really look at what the scientific enterprise, its role in society, what it is trying to achieve, and to have a very clear orientation, but perhaps scientists like we've heard this evening could start looking at setting up some kind of code of ethics and perhaps, a Vandana was saying, we can look to other cultures. I had the privilege last night of being with an indigenous leader who talked about the seventh generation that I think many of us have heard about, that decisions are made within that larger context, what is the effect on other human beings, on the planet as a whole and on the seventh generation.

That leads me to my second question which is that I think that probably most of us would agree that the human species is in crisis with itself and with its home, the planet, and my question would be what is the role of scientists in this predicament? Again, the indigenous leader last night was saying that they see what is going on and they seek scientists to help to explain from a scientific perspective and then somehow to get this out to the human population and to decision makers as to what sort of decisions need to be made and I think we have a crisis in governance as we see in the international forum that decisions are not being made and I'm not sure if scientists are really helping those decisions to be made that

are difficult to make. And so my plea would be for a wider kind of science and a scientist that really looks to serving the greater whole and not serving to his academic or her academic agenda. And I think there is also this crisis of ego and personal gain that is affecting human society and is affecting scientists as well. So perhaps we could search for scientists that can help to put us back in the larger perspective and really try to be the intelligent species we are supposed to be.

Vandana Shiva: It's related to the theme of the discussion about science being directed, it's getting directed so heavily away from self-awareness or what we as humans are doing to the planet and other species and to ourselves. There was this amazing analysis that even though Charles Darwin had said that the earthworm was the most significant species for the planet, no earthworm ecologists are being trained. There is no money for that. There is no money for the ecological impact of GMOs. There is no impact research being financed and the speech that the Prime Minister gave keeps talking about the explosion of knowledge, but doesn't talk about the explosion of ignorance because each time we are releasing a new GMO there are a hundred new things we need to know which we didn't need to know in its absence.

I would just say that the code of ethics really comes from taking full responsibility and working on the principle of the precautionary principle without the arrogance that somehow the world will only be fed and cured with your next brilliant move tomorrow. It's fed itself and cured itself in many ways for a long time.

Steve Fuller: The first point about the code of ethics: it's a great idea, I'm all for it, but we have to think about how it would be enforceable. In other words, what if somebody violates this code if we adopt it? What are we going to do, strike them off the scientific record, not peer review their articles any more? I mean, it seems to me that one has to think in this context before this thing becomes a realisable possibility. I'm all for it, but it really requires a lot of hard work, especially given the sort of rather independent nature of scientists, ok, it's not like the Hippocratic Oath where you can be struck of the medical register.

The second point about the scientists trying to do good for the world and all this, again, a great idea, scientists ought to be getting some professional recognition for this, right, in terms of the way the incentive structure is set up in science at the moment, right, it doesn't work for research assessment exercise, for example, if you are saving the world, because it might not lead to a peer review publication. So it seems to me we need incentive structures so that scientists are professionally rewarded for doing these admittedly very good things for humanity because at the moment they're not.

Martin Rees: Well, again as I said in my talk, I think it is crucial that all scientists should feel responsible for the consequences of their work, good or ill, and also feel an obligation to participate in wide discussions, consensus conferences or other political fora where their work is discussed. I think those are two important things.

William Stewart: Basically, very briefly, I agree with what you say in its entirety. The issue has got to be addressed, but I can't tell you tonight how to precisely address it.

Chair: Well on that modest conclusion, I wanted just to say that I think we've had a very good discussion and I know how, you know, we've had four admirable speakers and we've had some very good questions. Anyone who is concerned with the kind of messiness of daily life and the need for compromises and all the difficulties that go with making policy will understand that in many ways the stark choices are often perhaps a little less stark than they appear because there is sometimes a way through and sometimes, as we've heard, there isn't. I don't know whether you've seen Fukuyama's latest book called 'A Posthuman Future' which rather brings out the point about the human species being in something of a crisis at the moment.

As it happens there is going to be a world summit on sustainable development at Johannesburg at the end of August, beginning of September. This is the kind of discussion that should be taking place really in a great many countries and a lot of people in government should be listening because it's very important that the science element should be heard there, that the real problems should be addressed and not the kind of old clichés which can come out on these occasions so very easily and frequently. So I would simply appeal to this intelligent and interesting audience that you make your voices heard, not just to government but also within non-governmental organisations, by all the means available to you including the use of such organisations as the New Scientist and, of course, Greenpeace, to make your views known on these questions and make sure that when that great opportunity comes at the end of August something actually is done, the right subjects are discussed and we can begin to look at some of these very, very tricky issues that we've all been discussing tonight.

So first of all, thanks very much to the four speakers, thanks very much to the New Scientist, thanks very much to Greenpeace, and I hope you all go peacefully home, sleep well, and feel a bit disturbed when you wake up in the morning.