DURING DISCUSSION THE FOLLOWING POINTS WERE RAISED:

Any Member of Parliament will tell you instantly that their constitutents do not want any security cameras applied to them, but to every other constituent! The growth in scale of mobility and the freedom to travel results in a desire for more information about the activities of the much larger, but much less well known, groups of people that we now interact with. The legal situation concerning photography in the street is not well understood. With regard to Government databases how can individuals find out what information is already on the database about themselves? Much of the technology and information used is obtained from third parties. In the case of the G20 demonstration in the City, office workers were requested to dress down so as to become indistinguishable from protesters and therefore able to go about their work undisturbed. Could this lead to subsequent misidentification of City employees as protesters by association? What protection, if any, do we have from misuse or misinterpretation of such data by potential employers or others? The order of magnitude of surveillance and analytical ability to interpret data have both increased, resulting in greater awareness and concern. The upcoming Olympic Games in London will pose a wide range of security issues, yet the public will expect this to be conducted in a non-intrusive manner. This increases personal freedom to move around, knowing that surveillance is providing protection but at the cost of privacy.

How do the police know about us? They don't, suspicion is categorical, if you are in a certain place at a certain time alongside people who are suspects, you are also a suspect. You are on a categorical database. This may affect you later in your life. There will be increasing concern in future at the growth and use of databases. You cannot be sure you are not on a database. Their power is greatly extended as the number and variety of databases increases. There are already a very large number of databases in existence providing information about individuals that cannot be deleted by those affected. There is already a hierarchy of quality of information so who do you trust? The chances of controlling personal data in the public domain are essentially zero. The National Institute of Standards and Technology (NIST) in the US have concluded that regulation is a waste of time as it is impossible to keep up with the growth in technology. It is better to establish benchmarks and legal expectations and obligations on those who hold the data, as there is no technical fix available. "City air makes you free" due to the anonymity which exists in cities which we are now losing. We never fully adjusted to the new freedoms and we have not adjusted yet to the new restrictions. These are big issues.

TAKING SCIENCE TO THE STREET

Meeting of the Parliamentary and Scientific Committee on Tuesday 19th May 2009

TAKING SCIENCE TO THE STREET

Professor Anthony J Ryan OBE
Pro Vice Chancellor,
Faculty of Science,
The University of Sheffield

In December 2008 BBC Radio 4 ran a week of programmes called 'Street Science'. The basic premise was that most scientists are passionate about what they do and believe that it's in a good cause. But the programmes asked the question "What happens when scientists are taken out of their comfort zone, to church or to the school gates, to try to explain what they do and why, to members of the public?"

I was one of those scientists and spent a couple of afternoons in Sheffield's Winter Gardens talking to the public, quite literally accosting people as they walked down the street, asking them their hopes and fears about nanotechnology. The technical level of the debate was somewhat variable but discussing the applications of carbon nanotubes with retired miners and giant magneto resistance with school kids obsessed with their iPods was, I hope, as entertaining for them as it was for me.

The potential dangers of nanotechnology have been in the media and fear of the world being overrun with "grey goo" was even highlighted by HRH Prince Charles. This fear comes from an unfortunate extrapolation of a reasonable argument. The idea that atom-by-atom construction could build fantastic devices that could reproduce themselves and take over the world has its proper place in the world of fiction, as exemplified by Michael Crichton's book '*Prey*'. But all the potential problems of nanotechnology, both real and imagined, have to be balanced against all the potential benefits it could bring to medicine and the environment, with nanomachines saving lives and cleaning up pollution. If one asks the question "What will a nanobot look like?" the answer won't be the shrunken submarine envisaged by Hollywood. Physics at the nanoscale mean that shrunken submarines won't work and nanobots will actually look more like bacteria or sperm and that soft nanotechnology, based on self-assembly and Brownian motion, is the way to go.

. . . What happens when scientists are taken out of their comfort zone. . .

The substance of my 'Street Science' programme surrounded the economic and ethical

implications of nanotechnology, how it might affect people's lives in unanticipated ways and what kinds of research are needed to ensure that we don't create new environmental problems. I was challenged repeatedly about how nanotechnology could be used for malevolent purposes and, as a researcher, what was I going to do about it. It was this part of the debate that I found most illuminating because, as a citizen, I am just as concerned that the fruits of human ingenuity are not put to nefarious uses for political or economic reasons and that technology results in a more equitable distribution of the world's resources amongst its vast population.

But why should a scientist go out into the street? One reason might be to ensure democratic approval for the public funds that have been spent on expensive research. Another could be to secure appreciation for all the minor miracles that we take for granted, the seemingly trivial things that scientific progress brings us, like 2-in-1 shampoo and conditioner, or the ubiquitous mobile phone that has more computing power than the Apollo mission which put man on the moon. But it is essential that people also realise that science and technology are responsible for the earth's population growing to be more than six billion people, and that this population explosion was based on the exploitation of fossil fuels and the fertilisation of the earth to grow enough food. We existentially depend on oil for much of our nutrition and need to find new sources of clean energy if we are to continue feeding the population and at the same time combat global warming.

Communicating science has gone through many transformations since the Royal Society's work in the 1980s. We have moved through public understanding to public engagement and now we are in the era of dialogue and the people's jury. The standard reasons given for engaging are: to ensure a good supply of young people to train as the next generation of scientists and engineers; to enable the individual and society to make informed choices; and to enrich our cultural life. All three are important and drive my work in this area. Science can be both beautiful and inspirational, appealing to the natural inquisitiveness of children. Ensuring that we (you!) set policy wisely, based on evidence and logic rather than emotion and prejudice, requires appropriate dialogue. Had we engaged with the public in a different way, and the economic model of exploiting progress not been so divisive, we might now be taking advantage of genetic modification in the production of more nutritious food with fewer "chemicals" and more efficient use of scarce water resources.

. . . Science can be both beautiful and inspirational, appealing to the natural inquisitiveness of children. . .

Science as part of culture is something I am most passionate about. It never ceases to amaze me that in polite society it is perfectly acceptable to be scientifically illiterate, in fact people are often proud of it, and this in one of the most technically advanced countries in the world.

Wonderland is a collaboration between an artist (Helen Storey from The London School of Fashion) and a scientist (me). We took science to the streets via an exhibition of disappearing dresses that was seen by two million people in Sheffield's Meadowhall shopping mall. Wonderland's ambition was to challenge people's attitude to consumption and waste. It uses the dress as a metaphor for waste in the world. It took a visually striking and quite beautiful creation and destroyed it, in an interesting and engaging way, over a period of a month as shoppers went about their business. The dresses were made of a specially-developed, water-soluble plastic and had neat little chemical tricks embedded in them so that the material danced as it entered the water and the garments shot out little underwater fireworks from buttons and buckles. We wanted to provoke the question "Why are you destroying these dresses?" so we could turn the question around. The ambassadors who worked on the exhibition wore T-shirts emblazoned with the slogan "Plastic is Precious" because plastic is buried sunshine. Plastic is made from oil, which we all know is geologically derived from plants grown millions of years ago using energy from the sun. People were shocked to hear that we are burning through this fossilised energy at the rate of millions of years of history per year. Apart from the dresses, the majority of the materials of the exhibition were made from reused or recycled materials. A comment/drawing book and message-board were used to record the public's response and many children took the opportunity to sketch their own inventions to save the planet or make drawings of their own disappearing dresses.

Whilst we were always pleased to see that people found the exhibition beautiful and interesting the most satisfying responses were those from people who had not previously considered the environmental impact of their visit to a shopping mall and who would alter their patterns of consumption as a result. Using fashion as a lure we had managed to engage people who would have walked past something that was obviously scientific or environmental. Once people were intrigued, we could both introduce the science and have some dialogue about environmental responsibility.

There is a collateral benefit to scientists in engaging with the public. The public will often ask questions that you wouldn't ask yourself, and these can lead to new research ideas and applications of science. We have started research into water purification technology because a non-scientist realised that we had all the technology to make such a device when we were explaining how we are constructed of wholly synthetic muscles based on block copolymers. In another example our research on tissue engineering has adapted some of the technology used in the production of textiles for haute couture to fabricate scaffolds for the culture of cells in

replacement organs. Devoré is a process for making delicately patterned fabrics by weaving and printing a dense cloth with a variety of materials and then removing some by dissolution in acid. When making nanofibres by electrospinning we faced difficulties in controlling the pore size and fibre diameter independently. If the pores were big enough for the cells to come through the fibres were the wrong size for them to attach to, and the scaffold did not work. Without the interaction with artists we would have never thought of applying the devoré technique to the production of nanotechnology devices for regenerative medicine.

Now we are really taking science into the street, in a new project that uses the clothes that people wear to clean the environment. Catalytic clothing has the potential to be a significant intervention, only made possible through the collaboration of the arts and creative sector and those working in science and technology. There are already a number of self-cleaning applications of nano-titania, for example the self-cleaning glass on the walls of tall buildings, and the technology has the potential to be widely applied. There is a self-whitening church in Spain and self-cleaning roads in Japan but these applications have a limited effect on the wider environment because they have a relatively small surface area. But taken from a chemist's viewpoint, the fibres that constitute clothing provide a very large surface area for catalyst support. For each person carrying two kilos of fabric in the clothes they wear, there is, at nano-scale, a 'passive'surface area the size of a football field. So the population of London, say 10 million people, has a useful surface area for chemistry collectively covering more than the total area of the UK. Currently, despite many advances in smart materials and 'smart clothes', this surface area has not been used to catalyse a reaction for environmental benefit. We are working on the development of a system in which the surface of a fibre can be given a secondary function such that it can actively remove airborne pollutants whilst the wearer goes about their daily life. One manifestation is that the treated fibres would be able to collect volatile organic compounds and an embedded catalyst could render them harmless through washing. A second is that the fibres could absorb nitric oxides (which cause smog) that would then be neutralised on washing.

Art-science collaborations, and collaborative research in general, allow researchers to break out of their traditional restrictive boundaries, and it is these cross cutting interdisciplinary areas that will be the key to tackling the 'big' issues and translating research into real life solutions. The process of engagement has fundamentally affected my scientific development. Whilst maintaining my presence at the forefront of hypothesis-driven, fundamental research, I have become involved in science-art collaborations that have a definite social and economic outcome through the innovative application of established science and technology in new areas. So the next time I take science to the street it will be to ask the people if they want to be a part of a great big clean-up process by *them* taking science into the street!

TAKING SCIENCE TO THE STREET

PUBLIC TRUST IN SCIENCE OR SCIENTISTS TRUSTING THE PUBLIC?

Dr Daniel Glaser
Head of Special Projects,
Public Engagement,
The Wellcome Trust

I will suggest that 'street science', properly understood, is a true implementation of public engagement, seeking the democratic empowerment of a scientifically literate citizenship by taking science into territory and language which they own and control.

Public engagement with science is the preferred UK term to describe organised relations between scientists and the public. It is not a term used for example in the US where the 'deficit model' still pertains, where science communication is supposed to fill a deficit in the public understanding of science, allowing citizens to attain their full potential through more complete knowledge of scientific facts in particular. As John Durant has pointed out, scientific facts are only one aspect of what the public needs to know about science. The other two are 'how science works', for example scientific methods such as hypothesis testing or statistical analysis, and 'how science *really* works' which deals with the political and social underpinnings that determine how science is conducted as a professional endeavour. Arguably the UK move towards engagement speaks as much to the last two elements. It was promulgated in response to the well-known crises in public trust

in science of the late 1990s. At the time a concern about the public trust in all kinds of authority was frequently expressed. This was perhaps best summarised in the House of Lords Science and Technology Select Committee Report on Science and Society 2000. While the commitment was sincerely entertained it is arguable that many scientists today regard public engagement as merely the new term for science communication. Actual public participation in scientific decision making is still extremely restricted.

But is it defensible that the public are not directly engaged? Is professional scientific training a proper preparation for making practical determinations? Perhaps it is civil servants, lawyers or even politicians who should be responsible for drawing up consensus views on scientific questions. Clearly top-level funding decisions about state-sponsored science do fall within more general political spending considerations. Here, scientists lobby like any other special interest group, selling the importance of the scientific sector and of their own area within it. Of course, increased scientific literacy among politicians and civil servants would enhance the likelihood of reasonable decisions, but equally, public understanding of all aspects of science must increase if there is to be a meaningful democratic engagement at the level of funding priorities and ethical frameworks.

Unfortunately, in public discourse scientific questions tend to be put under an ethical spotlight in a small set of 'issues' which evolve from year to year and from country to country. In the UK obvious recent examples include the MMR vaccine and its possible link with autism, the siting of mobile phone masts, GM crops and foods, and questions surrounding human fertility, reproduction and cloning. The focus on polarised issues generates specific problems. Firstly, since they are newsworthy, they are generally covered in the press and media by news and features journalists rather than the skilled and generally very professional science correspondents. This often results in the effective but emotive communication of restricted aspects of a question, and can rapidly generate intuitively compelling imagery that is impossible to modify (Frankenstein foods; the dangers of railway travel). These issues can spawn activist groups some of which promote a frankly, anti-scientific agenda, which in turn can generate a symmetrically closed response from elements of the scientific community. The escalating cycle of mistrust which sometimes results is extremely difficult to combat.

With particularly entrenched arguments, such as those which triggered the crisis in trust in the first place, public consultation is often too late. For example, work to promote informed public debate about genetically modified food in the UK had a worrying outcome. It has been a theoretical commonplace in science communication that public understanding of science is not the same as public acceptance of science, but in the GM case it was found that the more exposure people had to scientific information, the more opposed they became. This may confirm suspicions that efforts to direct new scientific research and public engagement activity towards issues where public alarm has been generated are often doomed, since many will automatically disbelieve a conclusion that does not support their entrenched position. Interestingly, efforts to bring together different sides to discuss these questions succeed best when role playing is employed to generate discussion of fictitious or unrelated scientific scenarios.

How can public ignorance especially about 'How science really works', be combated? Of course the media, education – both general and scientific, the structure of scientific discourse, including peer review and the politics behind science and science funding, can all be improved. But I would like to emphasise a particular approach that harnesses a bottom-up process, not one restricted to a small number of popularisers, or lay members of ethics committees. What is required is an extensive social interpenetration, allowing scientific practice to escape from the laboratory and the library and engage a broad and curious public.

A most effective example of this is Café Scientifique, a model which has now spread across the UK and into many other countries. This is one particular practical attempt to promote local, regular interactions between scientists and non-scientists, which is derived from the French Café Philosophique, and was developed by a television producer from Leeds named Duncan Dallas. It is a non-hierarchical and democratic formula for involving non-scientists in a scientific discussion, and is held in a café or other informally seated setting, ideally outside an academic institution, often with an experienced facilitator. A speaker talks for 20 minutes or so and gives an outline of his or her field and a couple of relevant questions, generally without slides or visual aids. There is then a ten-minute break for informal discussion and refilling of drinks. This pause

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combats the 'thinking of a question on the bus on the way home' phenomenon, allowing individuals and small groups to formulate and mutually validate their responses. There is then a discussion, typically just under an hour, involving – but not led by – the speaker. It is not a question and answer session, and the expert's voice does not dominate. Paradoxically, it is often the silent presence of a professional that legitimates and promotes an empowered discussion.

The idea is to generate community-based structures in a non-professional context, where the public can discuss scientific issues with experts. These are not lectures or demonstrations. Since they are not primarily about contentious issues, they escape from many of the problems outlined earlier. By weakening the conventional power relationships and specialist language that conversations in a scientific institution involve, they encourage individual non-scientists to develop their own scientific questions and opinions. An appreciation of the practice of science weakens common misconceptions, such as the assumption that a dissenting scientific voice necessarily means that a field is fatally split. These insights are not conveyed didactically, but arise naturally from a new familiarity with the everyday life of science.

Café Scientifique offers a practical tool to address many of the issues of empowerment and alienation that have been identified in all sorts of spheres. The undeniable fascination that scientific stories generate among non-experts of all ages makes these kinds of scientific engagement an attractive model for more general grass-roots, non-hierarchical democratic activity. But, the structure has the power to undermine hierarchical knowledge tyrannies of all sorts. As more scientists gain the courage and experience that enables them to engage directly in this kind of publicly validated ethical practice, the scientific domain may come to be seen as a leading example of this kind of transformation, and other areas of expertise, other concentrations of power, remote from engaged public scrutiny, will come to seem more and more anomalous.

. . . Café Scientifique offers a practical tool to address many of the issues. . .

TAKING SCIENCE TO THE STREET

SCIENCE IN A NEW KEY

Dr Mae-Wan Ho
Director, Institute of Science in Society (ISIS)

ISIS was co-founded by my husband, Peter Saunders, and myself in1999; our motto is "Science in action, in and for society." We don't take science to the street just for the sake of popularising science. Our mission is to provide accessible and reliable science information to society, which is very important as corporations are taking over science. We promote critical understanding and appreciation of science, or science literacy, which is vital for democracy. And we want social accountability and sustainability in science and science policies. Science in the most general sense is reliable knowledge of nature that enables us to live sustainably, regardless of how that knowledge is acquired, either in the laboratory or in life, and includes the use of indigenous, local knowledge.

CP SNOW AND BEYOND

This year is the 50th anniversary of CP Snow's lecture "The Two Cultures" about the failure of science and the humanities to intercommunicate, and the lack of scientists in positions of power, thus obstructing solutions to serious problems such as poverty. We share those concerns. We also encourage appreciation of both art and science through our trend-setting magazine and website with an e-mail list of thousands. Art historian Martin Kemp and others lament the general decline in the appreciation of culture and overspecialisation in education. ISIS is well placed to tackle

. . . Our mission is to provide accessible and reliable science information to society . . .

those problems; our scientists are all polymaths, and very keen on the humanities and art. Where we part company with CP Snow is that he belonged to the establishment that recognises only one science. Science is inherently anti-establishment; it can't help but challenge the status quo as it advances. ISIS keeps abreast, and often ahead, of mainstream science; especially concerning the new opportunities that cutting-edge science can offer for a world, which after 50 years of development is now facing a crisis in food, fuel, and finance, while attempting to respond to climate change.

The good news is we have all the knowledge and technologies to exit the crisis and save the climate. The bad news is the lack of political will and vision as our leaders are stuck in the mindset of the obsolete scientific paradigm that created the problems. Einstein's saying, "We can't solve problems by using the same kind of thinking we used when we created them", is now a cliché. Nevertheless, it's a good launch pad for the new science and new thinking we need. Let me set the scene with the briefest history of science starting from the Enlightenment.

FROM MECHANISM TO ORGANISM

The European Enlightenment brought many good things. It was the age of reason over received wisdom; it transferred creation from God to nature, which we can begin to understand through science. The Enlightenment also reinforced a powerful view of the world as a machine that ushered in the industrial revolution; and with that, the enclosure of the commons, capitalism, imperialism, colonialism, world wars, and the industrial,

. . . Biogas provides a smokeless fuel for cooking, for co-generating electricity and heat, and is the most environmentally friendly transport fuel. . .

mechanised, chemical 'agriculture without farmers' we have today. It has been 200 years since Darwin's birth, 150 years since his *Origin of Species*. Darwin and Victorian England elevated 'competition for survival of the fittest' to the way of progress. Add Darwinism to Adam Smith's *The Wealth of Nations*, and we get the neo-liberal economy that has dominated the world since, fuelling the accelerating over-exploitation of planet and people that has brought the world to its knees. The mechanistic model was becoming obsolete at the beginning of the past century with the emergence of the organic model. The three books that influenced me the most were all inspired by the new physics, especially quantum theory. Whitehead's eloquent critique of the static, flat, and colourless Newtonian universe in *Science and the Modern World* is all of a piece with Bergson's insistence in *Time and Freewill* that time is multidimensional and heterogeneous, giving unique qualities to our innermost experiences. Whitehead argued we can only understand nature as an organism embedded within the super-organism of nature. Schrödinger's *What is Life?* predicted the genetic material DNA. But that's only the half of it. The other half predicted the molecular coherence of organisms discovered in my laboratory in 1992. Living organisms have such a high degree of molecular coherence that they appear as dynamic liquid crystal displays under the polarising microscope geologists use for identifying crystals. Some of these images grace the cover of the 3rd edition of my book *The Rainbow and the Worm, the Physics of Organisms.*

CIRCULAR ECONOMY OF THE ORGANISM

One main reason organisms are so coherent is because they use energy and resources in a circular way, a circular economy that minimises waste. In the ideal, the organism accumulates no entropy (representing waste energy and disorganisation), and even the waste exported is minimum. The key to a sustainable circular economy is to maximise co-operation and reciprocity, instead of competition. The organism has structured activities spanning all space-time scales, those yielding energy are directly coupled to those requiring it, and the giving and taking can be reversed so both material and energy are recycled. In contrast, the dominant neo-liberal model of infinite unsustainable growth based on competition has no closed cycle and no structures within; it thrives on profligacy and waste, and tends to spiral out of control. Boom and bust are inherent to the model.

SUSTAINABLE SYSTEMS AS ORGANISMS

It soon occurred to me that all sustainable systems are like organisms. And this applies especially to sustainable farming, as documented in ISIS' report *Food Future Now* launched in April 2008 in this Parliament. It shows how farming, according to nature's circular economy, can potentially compensate creatively for all greenhouse emissions, and free us from fossil fuels. Circular economy is very productive. For example, Takeo Furano in Japan releases ducklings in the rice paddies. Weeds and pests become food for the ducklings, while the ducklings provide mechanical stimulation and aeration for the rice plants to grow big and strong, resulting in a bumper harvest from the two hectare farm that supports his family of nine, and vegetables for another

. . . Geneticists are now documenting how exposure to toxic substances affects several generations. . .

100. The dyke-pond systems, perfected by the peasants of Pearl River Delta in China, supported on average 17 people per hectare in their heyday. One involved growing mulberry, elephant grass and vegetables, and raising pigs and silkworms on the dykes, the wastes going to fertilise the plankton and macrophytes in the ponds, thus feeding five species of Carp. Professor George Chan, who trained as an environment engineer at Imperial College, spent five years near retirement in the Pearl River Delta and developed an Integrated Food and Waste Management System, which I have schematised as Dream Farm 1. It is an incredibly productive mixed farm with diverse crops, livestock, fish, and fowl, organised around a biogas digester to recycle livestock manure and waste water into nutrients and energy.

DREAM FARM 2 TO FEED AND FUEL THE WORLD AND MITIGATE CLIMATE CHANGE

By incorporating other renewable energies such as wind, solar and hydroelectric, food and energy are thereby integrated in Dream Farm 2. The ideal would be to set this up as a model for education and research, serving as an incubator and showcase for new technologies, information exchange and a resource centre for Dream Farms around the world, all using local resources and biodiversity. Biogas provides a smokeless fuel for cooking, for co-generating electricity and heat, and is the most environmentally friendly transport fuel, as Sweden discovered. If Dream Farms were adopted the world over, it would mitigate an estimated 56.6 per cent of greenhouse emissions and 50.5 per cent of energy use on biogas alone. Fossil energies could well be eliminated altogether in combination with the other renewable energies. There is a lot of interest in Dream Farm 2; versions are implemented everywhere. The closest to home is an urban Dream Farm for London proposed by Alex Smith who owns an organic food factory near the Eurostar terminal.

BAN GM CROPS

There's no need for GM crops. They have failed on every count: less yield and income for farmers, bad for biodiversity, more pesticides and water use, more dependence for farmers and more suicides, more vulnerability to pests, disease and climate extremes, and outstanding safety concerns. GM crops belong in the old mechanistic paradigm superseded by the fluid genome, as the first GM plants were created in the 1980s. The fluid genome belongs in the new science of the organism. Geneticists are now documenting how exposure to toxic substances affects several generations by changing the heritable expression of genes. Decades of sequencing and dissecting the human genome have only confirmed that the overwhelming causes of ill health are environmental and social; early nutrition and parental care are crucial for physical and mental health. Consequently, organic, localised and biodiverse agriculture is the most effective way to deliver health, wealth, and happiness to the world's nations; and that's the message we should be taking to the street.

For a fuller version of this paper and all issues raised go to www.i-sis.org.uk.

IN DISCUSSION THE FOLLOWING POINTS WERE MADE:

Public understanding of science is important but is not equivalent to the public acceptance of science. Appreciation of what scientists are intending to do is also important since the debate which follows will be more informed with the evidential processes better understood. Unfortunately in the House of Commons too few members want to know about science. The differences between how science works and how science really works requires explanation. For example, how does a scientist get funded? What happens when students fall out with their PhD supervisors? Why is research on some diseases much better funded than on others? Whereas artists reflect, scientists are remarkably unreflective and do not spend much time considering such questions. Taking science to the street enables scientists to become more reflective but this raises other issues.

Does this imply therefore that Peer Review should not be done by one's Peers? Is a little knowledge a dangerous thing? How does one convey as a scientist the importance of energy and overpopulation and the need for change? For example, the claims advanced for a global sustainable human lifestyle based on organic food (unsupported by ammonia generated by the Haber/Bosch process from limited supplies of natural gas) would however only suffice to feed 2 million people worldwide, which is the estimated extent of the naturally sustainable population base.

The public expect certainty from scientists rather than the answers received, which are often based on risk and probability. However, scientists are also members of a society where conflicts between scientists and politicians, on the one hand, and also between scientists on the other, arise and often confuse people in the street, probably due to the mathematical basis underlying much science which is not generally understood. A wider recognition of the mathematical core to science is therefore likely to be one of the keys to a better understanding of science. Outreaching to non scientists in the street can encounter even more fundamental problems of trust and engagement.

The media, however, may not help by focusing on issues which may be considered marginal to the main issues challenging science, such as the Brent Spar and Climate Change Deniers, for example, where they are often given equal prominence to viewpoints supported by the majority of scientists. You don't get ahead in science by agreeing, as successful scientific publications have an innovative component. Disagreement is fundamental to the progress of science.

The evidence of a perceived need for an increased supply of scientists is usually generally lacking, as indicated by the struggle to survive and obtain tenure in a permanent job in science. And if there is a shortage of scientists there should be no difficulty obtaining a job as a scientist, which is clearly not the case. Scientific jobs have to be fought for and it is an arduous process.

Science in the street is important because it brings society into the scientific process and enables science and society to interact constructively. Scientific answers can then be provided to societal questions from the street. Other ways forward are to make all laboratories open to the general public and to give the public a greater say in what science is undertaken and a better understanding of risk versus certainty.