NOTES AND RECORDS

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LECTURE

ADDRESS OF THE PRESIDENT, SIR PAUL NURSE, GIVEN AT THE ANNIVERSARY MEETING ON 1 DECEMBER 2014

Trust in science

Trust is important for science in a number of ways. Why should we have trust in science; what is it about science that makes it such a trustworthy process to generate knowledge about the natural world? By having trust in science, what benefits have been brought to humankind over the ages? How can trust in science be maintained and built upon with the public? What does society need from scientists to ensure that they are trusted? And what are the threats to trust in science and what can be done about them? These are questions we need to address as Fellows of the Royal Society, both to consider what needs to be done and then to act on those considerations.

Why should we have trust in science and in the knowledge of the natural world and ourselves that science brings? It is because of the way in which science is done. It is based on a range of attributes and ways of working, not necessarily unique to science, but which are combined together in science in a very effective way. Science is built on reliable and reproducible observations, generating accurate descriptions of how the natural world behaves; such evidence forms the bedrock of the scientific endeavour. The impetus to make observations and to carry out experiments derives from curiosity, natural in children and often persisting at a high level later in the lives of many scientists. From study of observations and experiments, regularities and patterns can be recognized, which in turn lead to ideas and hypotheses to explain the workings of the world. This requires an attitude of mind that the natural world is in principle explicable and is not the consequence of capricious supernatural forces.

Imagination and intuition are used in science to generate scientific ideas and hypotheses that then can be tested with more observations and experiments. This way of working has been well described by the philosopher of science Karl Popper, who has emphasized the importance of trial and error in science. He argued that a scientist considers the data obtained by observations and experiments relevant to a natural phenomenon of interest, and then, through leaps of the imagination and intuition, develops a framework to consider the data, and generates a hypothesis to explain the phenomenon. This hypothesis is tested by making new predictions, which are then examined by further experiments and observations. If the data do not support the hypothesis, it is either rejected or modified and the new hypothesis is further tested by new observations and experiments. So science proceeds by trial and error, with unsatisfactory hypotheses being rejected through a process of falsification. Popper goes further to argue that falsifiability is the principal way of distinguishing science from non-science. An important implication of this view of how science works is that scientific knowledge evolves, and is often tentative especially at the beginning of an investigation. It is only after repeated testing that it becomes more secure.

Science is also influenced by the way in which scientists behave and interact with each other in a community. Scientists should be open, honest, rigorous in their thinking and sceptical, especially of their own ideas. An effective scientific community should be interactive and collaborative, and should encourage the constant challenge of data, ideas and hypotheses. It is the overall strength of the evidence and argument that matters in science, not the hierarchical authority of the scientists involved. The combination of these attributes and ways of working produces a methodology that underpins science and which is very effective at generating reliable knowledge of the natural world and ourselves. It is a process in which we can have great trust.

This trust in the scientific endeavour has brought about revolutionary improvements for humankind. I will illustrate some of these benefits with examples of what science has achieved over the ages. The beginnings of science can be detected in prehistory with the development of agriculture and metallurgy.

The agricultural revolution was based on the domestication of wild plants, the selection and cultivation of crop plants with desirable characteristics. It first came about around 10 000 years ago in the fertile crescent of the Middle East with the cultivation of cereals, both wheat and barley, and later in the East with rice, and in the New World with maize. The materials revolution started with advances in metallurgy 5000–8000 years ago. Perhaps it was burning the charcoal produced from the day before in a camp-fire made on ground containing copper ore that accidentally generated the temperature needed to produce copper. Then copper ore contaminated with tin generated the more versatile bronze.

The Greeks brought about a revolution in ideas that changed our world, introducing the concept that the world was comprehensible, liberating humanity from the yoke of mysticism and superstition. In England at the turn of the seventeenth century and the beginning of the Enlightenment, Francis Bacon, courtier, statesman and philosopher, laid out his approach to science. He famously argued for a sceptical approach in the pursuit of knowledge, saying: ‘If a man will begin with certainties he shall end in doubts, but if he will be content to begin with doubts, he shall end in certainties’, and he advocated that ‘knowledge is power’.

In other words, that science was useful. However, it would have perhaps been best if he had confined himself to thinking about science rather than doing science. Driving during winter in Highgate, London, he stopped his carriage, bought a hen and then stuffed it with snow to see if it would delay putrefaction of the bird. As a consequence of his outdoor experiment he caught a chill, developed bronchitis, and died several days later. Meanwhile in the warmer climes of Italy, Galileo was more successful with his experiments and observations providing the evidence that moved the Earth from being the centre of the Universe to a planet circling the Sun.

The birth of modern science coincides with the founding of the Royal Society in 1660. Our motto, ‘nullius in verba’, reflects an emphasis on the need to rely on demonstrated observation and experiment rather than established authority. The early pinnacle of success for modern science was the work of Isaac Newton, whose laws of motion led to the idea of universal gravitation. This provided a quantitative description of the motions of visible bodies, demonstrating that the motion of a small terrestrial object such as an apple falling from a tree was subject to the same laws that applied to the motion of large celestial objects like planets orbiting the Sun.

The Enlightenment and the Royal Society, together with other scientific academies of the day, set modern science on its way. The consequence of this was knowledge that formed the technological basis for the Industrial Revolution that developed in the eighteenth and nineteenth centuries, and continues today. The significance of the Industrial Revolution cannot be overestimated, as it literally underpins the making of the modern world. The technological advances have been legion: the development of new energy sources from steam, to nuclear power; the use of new materials; the invention of machines of manufacture from the power loom to the robotized modern factory; the development of new means of transport, from the rail locomotive, to the space ship; advances in communication and information management from the telegraph, to the World Wide Web. However, together with these advances for the good of humankind, there have also been the construction of increasingly effective and deadly weapons of war. It is difficult to imagine any aspect of our present lives that is not influenced by these developments. They have brought major changes to everyone on the globe.

The Industrial Revolution was based mostly on the physical sciences, but the life sciences contributed as well. Scientific approaches increased agricultural production such that crop yields are many times higher today. The biological advances of genetics brought about by Mendel, and of biochemistry by Pasteur, spawned discovery after discovery in biology and generated molecular biology, which underpins much of modern medicine. Materialistic explanations of the phenomena of life have led to improvements in human health and increases in the longevity of humankind. Only 100 years ago, even in developed countries, life expectancy was around 50 years, probably only an increase of 15 years since the agricultural revolution 10 000 years previously. Yet in the past 100 years, life expectancy has increased to around 80 years. This change has its basis in science and is truly revolutionary, both for the well-being of individual human beings and for the whole demographic structure of society. In fact, in my view science is the most revolutionary activity known to humankind.

These examples illustrate some of the ways in which trust in science has led to many improvements to human society and culture. Given the importance of these advances for our civilization, how can we ensure that science will continue to prosper and bring about improvements in the human condition? For science to prosper requires great science to be done, and that is driven by great scientists. We need to provide a scientific education and training that allows such scientists to develop, then we need to identify and support them with an environment and adequate resources so that they prosper. Most importantly, they need to be given the freedom to pursue what they judge to be interesting and they should be protected from counter-productive interference from often well-meaning but sometimes misguided scientific managers and leaders. If we keep a focus on quality and freedom, science will prosper.

But to ensure that science continues to bring improvements for humankind requires more than this. It needs public trust in science, which goes to the heart of what I am talking about today. What is required is a healthy relationship between science and society, a relationship built on trust. Making good decisions about the use of knowledge based on science depends on societies that embrace the right values underpinned by effective democracies. It requires a public at ease with science, and a democracy that can cope with the complex decisions involving science.

So how can we build trust in science? We have to start with the scientists themselves. Scientists need to be open and transparent in their dealings with each other and with the public. There have to be accurate descriptions in scientific papers of how the scientific data were gathered and of the methodologies that were used. This has to be clear enough that, if necessary, the experiments or observations can be repeated by others. Next the data have to be openly available to everyone. An example of good practice in data sharing has been the depositing of genome sequences in the public domain, which has had great positive effects on the molecular understanding of biomedicine. Had the data been locked away for private profit, as some had wished to do, progress for human benefit would have been much slower. There is a particularly pressing need to make clinical data available that has been gathered in trials testing the effectiveness of pharmaceuticals and other interventions on human disease. Ways have to be found that appropriately protect commercial interests, but that also make this data publicly available to scientists and doctors, to health care providers, and to the public at large. Society needs this evidence to evaluate treatments of disease. This obviously applies to the pharmaceutical industry but it also should apply to herbal medicines, which like pharmaceuticals contain active chemical principles but which tend not to be so rigorously regulated. It is important that their safety and effectiveness are also properly assessed and communicated to the public.

To earn trust, scientists must be open and transparent about who supports their work. Research supported by a commercial organization needs to be declared, but it is important to recognize that just because science has been funded commercially does not mean that it is not to be trusted, as some argue. It is also important to realize that non-governmental not-for-profit organizations (NGOs) can also have biases that may distort the science they discuss or support. Single-interest groups may not be entirely objective across a wider range of issues, and it needs to be borne in mind that NGOs for example may rely on the financial support of individuals or sectors of the public who have particular ideological opinions. As a consequence, the need to keep these supporters content may also influence the NGOs' views about science. Some environmental organizations oppose the use of gene modification technologies even when this is aimed at producing crops that could reduce blindness among the world's poorest children. Such NGOs need to ask themselves whether their scientific positions are being over-influenced by ideology or concerns about raising financial support. Universities supported by arm's-length governmental funding agencies of scientific research are crucial for the scientific research endeavour, because universities can carry out research that is generally freer from immediate commercial or ideological interests.

To build trust in science, scientists have to be rigorous and honest in what they do, and be sceptical, particularly about their own ideas and hypotheses. Such qualities are a useful corrective when scientists feel under pressure to generate particular results. This can occur when junior scientists are pressurized by a senior colleague or by the demands of their career development to produce certain outcomes. This is best countered by a good culture in the scientific workplace that abhors the falsification or distortion of data. Science is a high calling in the pursuit of truth, and that should always be kept in mind by research scientists. Similar pressures to generate specific outcomes can come from the media or public pressures; work on stem cells is a case in point. But it is also important to remember that science proceeds by trial and error. As a result, scientific knowledge evolves and may be rather tentative, especially at the cutting edge of research. Science advances by constant testing and eliminating unsatisfactory ideas and hypotheses, which means that sometimes a piece of research may come to an incorrect conclusion. However, as long as the research has been carried out honestly and in good faith, such mistakes should not be a matter of shame, as can be the case in some cultures. Coming up with clear bold ideas that can be tested and rejected if incorrect often leads to faster progress in science than simply listing the results of observations and experiments, and then retreating into safe vague generalities. It is also important to ensure that so-called 'negative results' are published. If such publication is combined with effective search engines, it will improve the overall efficiency of the research endeavour.

Ensuring trust in science is not just a question of how scientists behave, it is also a matter of how society views science, and that is shaped largely by how scientists interact with society. The first exposure to science that most people have is at school, so getting science education right is crucial. Science is a difficult subject and requires teachers of high quality who can inspire pupils with the wonder of what science has revealed about the natural world and ourselves. It is essential for science teaching to emphasize how science is done and why it is such a reliable way of generating knowledge. Understanding how science is done increases trust in science as it can be seen to be built on reliable data, rational argument and repeated testing. If science is taught as just an assemblage of facts without dealing with the process that gave rise to those facts, why should pupils trust science more than fables or pseudo-science? Everyone leaving school should know the difference between astronomy and astrology by knowing how science is carried out.

The main exposure of adults to science is through the mass media, newspapers, radio, television and digital sources. Often science journalists do a good job at explaining the science in their work, only to have a good report spoilt by a misleading headline. A misplaced sense of a balanced view can distort science when prominence is given to a minority opinion that is poorly evidenced and argued. Science media centres are now appearing that can put journalists in contact with media-friendly scientists who are expert in the area under consideration. This can greatly help getting the balance right in the reporting of science.

To develop trust in science, it is important that scientists become fully engaged with the public sphere. Scientists need to identify areas of interest or concern to society and engage with the public. They need to explain what is being done and why, ensuring that conflicts of interest are revealed, and that it is clear what knowledge is secure and what is not. Sometimes I suspect that scientists are seen like the witch-doctors of the tribe: their usefulness is recognized by the public but they are feared because what they do is not well understood. Only by public engagement, by listening to people's concerns, by explaining what the science means, by participating in two-way dialogue, can trust be earned. That trust must be earned by scientists because if it is not, trust in science will be lost and society will not reap the benefits that science can bring.

Unfortunately there are also threats to science that undermine public trust. One problem is those politicians, columnists, commentators who distort science. They mix up science, based on evidence and rationality, with politics, ideology or religion, where opinion, rhetoric and tradition hold more sway. Such individuals usually behave more like lobbyists who do not properly respect the science or the way in which science is done. They cherry-pick data, distort arguments, misquote and personally attack scientists whose work they do not like. Their political or ideological views lead them to predetermined positions, and they distort the science to support those positions. Sometimes they refuse to name who finances their activities. There are certain areas of science that are prone to such misrepresentation and distortion; examples include work on genetically modified crops, vaccination, and climate change. Similar problems arise when those with fundamentalist religious beliefs distort science to support their opinions, which are based on faith and revelation. Science is revolutionary and can lead to unsettling conclusions that attack traditional beliefs and so can be strenuously opposed. This occurred when Copernicus and Galileo moved the Earth from the centre of the Universe, and when Darwin proposed that humans were not specially created.

Those in the public realm who distort science to support their particular political, ideological or religious beliefs ultimately damage trust in science and deny the benefits that science can bring to society. Scientists need to engage constructively with such individuals, explaining the science and why it should be taken seriously. However, serial offenders who continue to distort science repeatedly in this way need to be countered robustly, because if they are not, they will undermine the whole scientific endeavour.

Another threat comes from scientific contrarians, from within and outside the scientific community, who take up extreme positions because they like the attention that such positions can attract. Sometimes they argue that their extreme minority views should be respected because they are taking a sceptical stance. Sceptical views are important in science as I have already discussed, but the case must be well argued and have support from evidence. Such people often miss an important point; a true sceptic should be especially sceptical about their own ideas and hypotheses. In my experience such contrarians often show little scepticism concerning their own arguments. It is also important to determine how expert a contrarian is in the area of research they are commenting on, when they take extreme positions that differ from the majority consensus view of expert scientists.

In the end, of course, science will prevail, but these threats to trust in science can slow down progress. Societies with respect for science and with strong democratic traditions deal better with these threats. People throughout the world need to recognize the value of science and recognize how it can contribute to our culture, to our civilization, to our wealth, to our quality of lives, to our health, to improving the lot of the poorest in the world. But for science to reach its full potential in bringing benefit to humankind, we must build trust in science and educate our citizens to be at ease with science, and properly train our scientists and encourage them to fully engage with the public.