Creating and communicating science: The experience of the Royal Institution*

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There is a general agreement that, more than at any previous period of history, the public need to be made aware of the implications of science and technology in their lives, and of the nature of the process that brings new scientific knowledge into being. It is also widely acknowledged that practising scientists are uniquely placed to contribute to this endeavour. These thoughts are far from new, however, having been at the heart of the ethos of the Royal Institution of Great Britain since its foundation almost two centuries ago. It is described how lectures on science for young people, as well as for the adult general audience, came to form a major part of the Royal Institution's work, combined with the prosecution of science in its own laboratories. This intimate conjunction between the creation of new science and the communication of science to the wider audience is a unique feature of the Royal Institution. The lecture describes the formative part it has played in British public life and draws conclusions about the relevance of its mode of operation to the contemporary world.

THE name of Patrick Blackett is one that has a special resonance in India, and, I would like to think, to the topic I have chosen to speak to you about. His contributions to science, of course, were many and lasting but, being myself a solid state chemist, I am not the person to speak to you about them with any great professional authority. In any case, it is not Blackett's science that is relevant to my topic today. He was, of course, a great friend of India and advocate of the way in which science and technology might be harnessed to the needs of a rapidly developing country. There is no question that his first visit to India in January 1947, when he had the opportunity of meeting Mr Nehru, was a formative influence on his life thereafter. He was a frequent visitor to India over the next twenty-two years, and wrote: 'I came to love the country and its people'[1], while in a Nehru Memorial Lecture, 1967 (ref. 2), he proclaimed 'an increasing commitment to attempt to help in however small a way, this great country to a state of prosperity and growing wealth.'

And yet he sensed an enigma. In a lecture entitled 'Aspects of India's Development'[3], he stated: 'It is curious to note that, though everyone accepts that the vast wealth today of the developed countries is somehow due to science, it is by no means fully agreed as to how in detail it happened.' Could it be that the gap perceived by Blackett may have its origin in the diffusion through the public at large of the essence of the scientific approach to nature?

If it is a truism that the fabric of modern society is founded on the fruits of science and technology, the consequence must be that it is more important than ever before for the broadest range of the public at large to have some appreciation how science works, and the kinds of conclusions it reaches. Such understanding has to proceed at two levels: the first is purely professional in the sense of providing a sufficient number of people with the training needed to operate an advanced technological society. That is the job of the educational system, and is not my theme today. The second level of understanding is more difficult to define, and hence to achieve. It is something more pervasive within society: that as many citizens as possible should comprehend the nature of scientific argument and enquire – what could be called the 'process' of science. That is not so much a matter of spreading knowledge of the scientific principles behind specific issues such as nuclear power generation or genetic engineering, as of inculcating a feeling (indeed empathy) for the way that new knowledge is uncovered, and hence of the status of scientifically backed statements.

I am delighted to say that I am not alone in these beliefs. Some of you may know that, in a very welcome development about one and a half years ago, the British Prime Minister appointed the first Minister for Science to have a seat in the Cabinet for twenty years. In advance of announcing his policy White Paper, the Minister William Waldegrave launched a wide consultation exercise, seeking the views of the scientific community, industry and the public at large on what the

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important issues might be. Among the many points made, it was widely urged on him (by myself among others) that high priority be given to enhancing public awareness of science, engineering and technology, as the makers and arbiters of our lives. For example, I wrote in a phrase that was quoted in the White Paper: 'Any National Policy for science and technology must contain, as a necessary foundation, the diffusion among the public at large of an appreciation of what science is'[4]. Such awareness would help the public to know what they could expect of science, and what they could not, and to form soundly argued judgments on matters that require democratically based debate.

One might approach the matter from a narrower point of view: any organization, be it commercial, industrial or governmental, that spends 1.2 billion pounds each year, should (and in most cases does) spend a small fraction of that turnover on explaining what it does and why and how it does it. This should be no less true of the government's research spending. How then is – if I can coin a phrase – the 'public relations of science' organized today? I refer to the British experience, though I have reason to believe that the Indian situation is broadly similar.

Roughly speaking, it is undertaken in two distinct ways. First, and most straightforwardly, the government agencies responsible for particular fields, such as the Medical Research Council, publicize their activities, and especially their successes, through press releases, brochures, laboratory open days, visiting speaker programmes, etc. Though desirable and valuable, this activity is purely sectorial, and to a certain degree self-justificatory. Therefore, above and beyond this first category of actions, there is a need for programmes that do not suffer from the latter defects, but aim to enhance appreciation of science itself, in a positive spirit but not as a lobby. In Britain three venerable bodies engage in such action: the Royal Society (founded in 1660), the Royal Institution (founded in 1799) and the British Association for the Advancement of Science (founded in 1826). Each goes about its business in different ways, though since 1985 they have acted as co-sponsors of a coordinating and facilitating body called COPUS (the Committee on Public Understanding of Science). In this lecture I would like to share with you some of the experiences of the Royal Institution in this endeavour, not only because at the moment I have the honour to be its Director, but because the way it was set up and the manner in which it carries out its tasks seem to me to carry some valuable lessons.

The United Kingdom is known for its administrative anomalies, and in science the Royal Institution ranks high in that category[5]. Among other things, it houses the oldest continuously operating research laboratory in the United Kingdom; founded in the Age of Enlightenment following the French and American Revolutions. In fact, it was founded by a North American who was very much a European, a remarkable man called Benjamin Thomson, otherwise known as Count Rumford. He came by his unusual title as a result of ten years working for the King of Bavaria, reorganizing the army.

Rumford was an energetic, inventive man. While in Munich, he devoted himself to useful inventions and, among others, invented a dish which, to this day, can be found in Munich restaurants, called Rumford Soup, which resulted from a research project to discover the cheapest and most nutritious form of sustenance for the poor. He took the matter of the usefulness of science very seriously. That was what he had in mind when after coming to London, he decided to found a research organization which would communicate its results to a wider public, a novel concept at that time. It is one which has a very contemporary ring to it – nowadays one would call it a 'research association', that is, the members paid their subscriptions to have the right to learn about the new results and come to the building of the Royal Institution, as it was to be called, to speak with the researchers and attend lectures. So the Royal Institution had a teaching function for the general public in addition to the individual communication of its research results to the subscriber.

One of the most important features of Rumford's building was what he called the Conversation Room. It still fulfils its original purpose which was, as the name implies, where people can go to talk to each other and where to this day one meets the research students and post-doctoral students over coffee. Rumford's other priority was a lecture theatre, which remains an integral part of the building up to the present time.

In the founding statutes of the Royal Institution, Rumford wrote that its aim was for 'diffusing the knowledge and facilitating the general introduction of useful mechanical inventions and improvements and for teaching by courses of philosophical lectures and experiments the application of science to the common purposes of life.' Apart from a broadening beyond the word 'mechanical', these phrases encapsulate the essence of what we continue to do till the present day. Before going on to describe how they have been put into practice since 1800, it is worth analysing these words a little more closely. Rumford believed most firmly that a knowledge of science should be deeply embedded in everyday life, and not something separate that was only of intellectual value. For example, his other inventions, based on sound physical principles, included a convector heater and cooking utensils, not to mention a novel cigar lighter. He also believed that those who were creating the new knowledge should be those who communicated it to the public, an obligation which present day scientists should be more widely aware of.

Rumford was never the Director of the Royal Institution (he was much too restless a man for that). He installed a body of Managers and then promptly had a

Figure 1. A public lecture at the Royal Institution: Humphrey Davy with the bellows is demonstrating the effect of laughing gas (N_2O). Cartoon by J. Gillray.

row with them and went off in a huff. Not only in a huff, but with the widow of the eminent French chemist, Lavoisier! Thus, he completed his European tour, having started in Bavaria and passed through London, by ending his life in Paris. In the event, the first Director of the Royal Institution was Thomas Young, who devised the double slit experiment which led him to discover the wave nature of light, and also, in quite a different sphere of intellectual activity, took the first steps to decipher Egyptian hieroglyphs.

Young was only Director for a short time when he was succeeded by Humphry Davy, the son of a tin miner, who became famous in London for the quality and interest of his lectures as well as the originality of his research. To this day he remains the person who discovered the largest number of stable chemical elements, in fact most of the alkali metals, the alkaline earth metals and two of the halogens. In addition, he was a charismatic lecturer: people came in large numbers to the Royal Institution's lecture theatre, and the lectures were even the subject of cartoons in the newspapers (Figure 1). It is not widely known that the reason Albemarle Street is a one-way street (the first to be so designated in London) is a tribute to Davy's skill in popularizing science for a general audience. The fact is that so many high society ladies came in their carriages to lectures that the street was blocked, so it had to be decreed that wheeled traffic should always come in at one end of the street and go out at the other! Even now, the lecture theatre of the Royal Institution remains little changed, and I am pleased to say that laughter is still heard there quite frequently.

Not only was Davy the discoverer of a large number of the chemical elements, but he was responsible for one of the most significant inventions in the whole of applied science, the miners' safety lamp. At the Royal Institution we have a beautiful gold cup presented to Davy by the Emperor of Russia in recognition of the number of lives which this invention had saved in the Russian coal mines, truly a potent example of 'the application of Science to the common purposes of life'. Nevertheless, towards the end of his life, Davy was asked what, among all these works, was his greatest discovery: he said 'I have absolutely no doubt that my greatest discovery was Michael Faraday'.

The story of Michael Faraday is among the most romantic in the entire history of science. The son of a blacksmith who lived in a very poor district of south London, Michael left school early and became an apprentice to a bookbinder. The turning point in young Michael's life came the day when one of the customers in the bookshop, a Member of the Royal Institution, gave him a ticket to hear Sir Humphry Davy lecture there on chemistry. Thus it was that he came one evening and sat, as he recorded in his journal, in the centre of the gallery behind the clock. Captivated by the experiments (and by the bangs and smells), he decided to make his career in science but he did not know how to, because he had no education, and he did not know anybody important. He wrote a letter to the President of the Royal Society but, sadly, the President (Sir Joseph Banks) did not reply, so there the matter rested till Faraday had another idea. He wrote a set of notes on Sir Humphry Davy's lectures in beautiful handwriting: we

Figure 2. Faraday on the twenty pound British bank note.

still have this book in the Royal Institution library. He bound it beautifully with his own hands and sent it to Davy as a present, with a letter saying he was so interested by the subject of the lectures that he wished to be employed.

That was the beginning of the story of Michael Faraday as a scientist and of the fifty years that he spent at the Royal Institution. It is probably fair to say that by the sheer range of his discoveries, Faraday was the greatest experimental scientist who ever lived. His stature among Britain's famous may be gauged by the fact that in 1991, to commemorate the bicentennial of his birth, the face of William Shakespeare was removed from the twenty pound bank note and replaced by that of Faraday (Figure 2). It has been reckoned that, had Nobel prizes existed in the nineteenth century, he should have won six for his discoveries: the laws of electrolysis, the isolation of benzene, electromagnetic induction, magneto-optical rotation, diamagnetism and dielectric permittivity. Furthermore, the name Faraday continues to be commemorated by scientists in being applied to many different phenomena: the unit of electrolysis, the unit of capacitance and, finally, the Faraday effect.

However, it is not on his research discoveries that I wish to concentrate in this lecture. Faraday never forgot the shattering effect on his life that had been brought about by listening to Humphry Davy, and watching the demonstrations that he carried out in front of the astonished audience in the Lecture Theatre of the Royal Institution. As the 'Chemical Assistant', he helped Davy in the preparation of his lecture-demonstrations, and also began to give lectures himself. Becoming more and more convinced how important it was for those who were working in science to spread enthusiasm and deeper knowledge of their work outside the scientific community, in 1826 he began two series of lecture-demonstrations which proved so enduringly successful that both continue up to the present day.

For adult audiences Faraday conceived the concept of the 'Friday Evening Discourse'. He described the aim and the ambience of these weekly lectures as follows[8]. 'They are intended as meetings of any easy and agreeable nature to which members have the privilege of bringing friends and where all may feel at ease. It is desirable that all things of interest, large or small, be exhibited here either in the library or in the lecture room.... The lecture may be long or short, so it contain good matter and, afterwards, everyone may adjourn for tea and talk.'

Over the years almost every scientist of stature has spoken about his work at a Friday Evening Discourse: Rayleigh and Rutherford, Braggs and Pauling have all been there. And not only scientists; men of letters, poets and philosophers too have been drawn in from time to time. The poet Coleridge, a great friend of Davy, used to attend the Royal Institution in order, as he put it, 'to improve his stock of metaphors', actually quite a good reason why poets might well continue to find interest in them. Of course, since 1826, the format of the Discourses has evolved, though one feature remains constant, the emphasis on lavish illustration through slides, videos and exhibits and above all, where appropriate, demonstrations of the phenomena being expounded. As Faraday said of the scientific profession: 'for tho' to all true philosophers science and nature will have charms innumerable in every dress, yet I am sorry to say that the generality of mankind cannot accompany us one short hour unless the path is strewed with flowers'[7]. The 'flowers' in question are, of course, the demonstrations and illustrations, a lesson that many of us could profit by today.

In their present day form the Discourses take place twenty times each year. They are reserved for the 1700 or so members of the Royal Institution who pay an annual subscription, and their guests. The sole qualification for becoming a Member is to have an interest in science; although many Members do indeed have some scientific training, many do not, and they are drawn from a wide variety of professions. An additional species of 'flower', to be added to the vivacity of the Discourse itself, is the fact that the evening has very much the character of a 'soiree': dress is formal, a bar is open at the start of the evening in the Council room, an exhibition on the subject of the Discourse is mounted in the Library and, when the Discourse is over, a buffet is served as part of the price of the ticket. Thus the occasion is also one at which people can meet one another, and also the lecturer. Within the last year or so, we have heard, among others, one of the protagonists of cold fusion, Martin Fleischmann, the new Director-General of CERN, Christopher Llewellyn Smith, and the most famous, living protagonist of Bach's keyboard music, Rosalyn Tureck.

The Friday Evening Discourses reach a relatively small, though influential, sector of the community. The other programme of lectures established by Michael Faraday in 1826 now reaches a much wider and (some might say) an even more important sector, young people. 'Lectures for a Juvenile Auditory', as Faraday called them, have been given at Christmas time every year since then, except for a brief wartime interruption. Faraday himself gave the Lectures no fewer than nineteen times but, in more recent years, though the Director of the Royal Institution has given them from time to time, it has been the custom to invite others: a few weeks ago I was able to introduce the 164th annual series, by Professor Frank Close, the Head of the Theoretical Particle Physics Division at the Rutherford Laboratory, on 'The Cosmic Onion'. This was an exploration of matter down to the level of the quarks and leptons, with a view of the Big Bang and the origins of matter. The audience in the Lecture Theatre, with average age about fourteen, is overshadowed nowadays by the enormously larger one accessible through television, and BBC Education regularly publish an illustrated booklet to accompany the series. Many other celebrated publications have arisen out of the Christmas Lecture series, perhaps the most famous being Faraday's 'Chemical History of a Candle'. The latter, a marvellous piece of scientific exposition, takes as its starting point

Figure 3. Professor Charles Sterling giving the Royal Institution Christmas lecture in Tokyo, 1993

that humble everyday object to be found on every table in the 1850s, and uses it to uncover most of the principles of chemistry and physics as they were then known: what it is made of, how it burns, how hot the flame is, why it is coloured, etc., etc. It remains in print to this day, the best selling edition being in Japanese! To give a flavour of Faraday's beautiful prose style, let me quote the opening of another famous course of lectures he gave 'On the Various Forces of Matter[8]:

'Let us now consider for a little while (he said to his youthful group) how wonderfully we stand upon this world. Here it is we are born, bred, and live, and yet we view these things with an almost entire absence of wonder to ourselves respecting the way in which all this happens. So small, indeed, is our wonder, that we are never taken by surprise; and I do think, that, to a young person of ten, fifteen, or twenty years of age, perhaps the first sight of a cataract or a mountain would occasion him more surprise than he had ever felt concerning the means of his own existence; how he came here; how he lives, by what means he stands upright; and through what means he moves about from place to place; and were it not for the exertions of some few inquiring minds, who have looked into these things and ascertained the very beautiful laws and conditions by which we do live and stand upon the earth, we should hardly be aware that there was anything wonderful in it.'

How evocatively he sets the scene for a series of demonstrations of gravity and electromagnetism: Frank Close's lectures a century and a half later addressed many of the same questions.

Many other famous scientists have given the Christmas Lectures since Faraday's time. For example, Faraday's successor John Tyndall, perhaps the first natural scientist to devote himself to environmental issues, and the person who first explained satisfactorily why the sky is blue, gave a course on glaciers, and more recently Sir Lawrence Bragg lectured on crystals, while Richard Dawkins, the evolutionary biologist, entitled his lectures 'Growing up in the Universe'.

Not only are the lectures reaching a wide audience nowadays through television, but they have been exported beyond the British Isles to South East Asia and, most successfully, to Japan. Figure 3 shows the scene last August in Tokyo when Professor Charles Sterling lectured on chirality in chemistry and biology under the title 'Left Hand, Right Hand'. The demonstration equipment devised for the London lectures is transported to Japan and set up in two separate centres, with sponsorship from the largest Tokyo daily newspaper *Yomiuri Shimbun* and the valuable help of the British Council. Plans are also afoot for the lectures to be given in California.

If continuing the tradition of Friday Evening Discourses and Christmas Lectures established by Faraday were the only current contributions the Royal Institution is making to enhancing public awareness of science, it would still be a major endeavour, but might be open to the accusation of remaining static, with one foot in the past. I hope I have said enough to justify the contention that, although established so many years ago, these programmes remain lively and relevant in the present day. However, though maintaining their status as flagships of our enterprise, they have been augmented by many others, and the process of innovation continues. A major development of the 1950s, initiated by Sir Lawrence Bragg, was to expand the programme of lecture-demonstrations for young people given in Albemarle Street, so that now they take place several times a week all through the school years. Separate lectures are given for primary and middle schools, and for sixth forms, including (a recent innovation) 'Sixth Form Conferences', at which different aspects of a broad subject are treated by three briefer presentations. Recent examples are 'Materials New and Old', with lectures on polymers, superconductors and cement, 'Chaos, Order and Fractals', and 'Energy and the Environment'. Significantly, the fastest growing part of the Schools Lectures Programme is in the primary school age group (8–11) which are regularly oversubscribed. At present, admission to all the lectures is free, although schools have to obtain tickets in advance, so that numbers can be estimated. We are extremely reluctant to introduce even a nominal charge for tickets, as that may turn away children who might benefit most. However, whilst the programme is partly supported by sponsorship from industry and charitable trusts, increasing costs may force us to charge for tickets one day. Information about the lectures is mailed to schools three times a year and, apart from members of the staff of the Royal Institution, many are given by a wide panel of outside lectures, drawn from universities, industry and schools. Over the last year more than 30,000 young people have attended lectures in Albemarle Street, while others have been given outside London.

In parallel with the lecture-demonstrations, workshops are organized for school teachers in which the content of the lectures is explained in more detail and information given on setting up the demonstrations in a school environment. Finally, it must be emphasized that, whilst the lectures treat subjects that lie within the school curricula, they do not aim to teach: the Royal Institution's function is not to mimic that of the schools. As my distinguished predecessor Lord Porter once said, we are not in the educational business, but the inspirational business. If, as a result of an afternoon spent in the Royal Institution Lecture Theatre, a young person's imagination is captured so that on return to school the curricula comes alive, then our talk would have succeeded.

Not only lectures but also classes given in smaller groups have taken their place in our armoury of activities for young people. Principal among these is the programme of Mathematics Masterclasses, started by popular request after a very successful series of Christmas Lectures by Sir Christopher Zeeman, the first ever given on mathematics. These classes, aimed at able young mathematicians nominated by their schools, have expanded from their beginnings at the Royal Institution to no fewer than twenty-six centres across the country. Another programme beyond the classical lecture format is that of 'Curriculum Enrichment' (RICE) in which, before they arrive at the age when decisions have to be made about examination subject choices or careers, young people are given the opportunity to spend short periods in research laboratories (usually industrial) in their neighbourhoods, to imbibe something of the spirit of the work carried on there.

In this lecture I have tried to convey how the wealth of activities undertaken by the Royal Institution to raise public consciousness of science, especially among young people, grew out of its history, and in particular the experience of the giants in our past. There can be little doubt that my story is one of successes. What lessons, then, can we learn from it? First and most important is to implant a scientific way of thinking in receptive minds, especially those of young people. Second, in pursuing that aim is to recognize that the message comes most potently from those who have been engaged in the scientific adventures themselves, that is, to combine the prosecution of research with exposition to the wider audience. (In this lecture I have deliberately not expanded on the current research of the Royal Institution's Davy Faraday Research Laboratory: suffice it to say that last year the three research groups, totalling some three dozen graduate students, postdoctoral workers and others, published more than eighty papers, a remarkable rate of productivity.) Turning to the means employed, I must emphasize how effective it is to have direct personal contact between the individual who is explaining a topic and the audience – live theatre beats television as a memorable experience. Demonstrations, too, are at the heart of our method. As Sir Lawrence Bragg, himself a master of the lecture-demonstration, said: the difference between being told about a scientific observation and seeing it demonstrated is like learning the character of a foreign country by looking at a map, and by going to visit it.

In conclusion, please allow me to offer some quite general thoughts. Not only does the world need to know more about the nature of the scientific endeavour, and its capacity to solve pressing problems, but science will not deserve to flourish unless it can succeed in explaining itself to the large group of people who have never had any professional contact with it. That is true whether one is seeking to capture the imagination of the young, as Davy did for Faraday, or to convince a reluctant Treasury of the support that is needed to continue a line of research. Scientists are members of society, and the fruits of their work underpin and shape it. Society requires and deserves that we enter into dialogue with it: communicating our science is as important as creating it.

1. *The Gap Widens, The Rede Lecture*, Cambridge, 15 May 1969, Cambridge University Press
2. *Science and Technology in an Unequal World, First Jawaharlal Nehru Memorial Lecture*, New Delhi, 13 November 1967, Indraprastha Press, New Delhi.
3. *Aspects of India's Development, The Fourth Nehru Memorial Lecture*, 7 December 1971, The Jawaharlal Nehru Memorial Trust.
4. *Realising our Potential A Strategy for Science, Engineering and Technology*, Cm 2250, London, HMSO, p 65, 1993.
5. The most readable recent account of the Royal Institution's foundation and story is that by Gwendy Caroe, *The Royal Institution An Informal History*, John Murray, London, 1985.
6. Royal Institution, *Faraday MSS*, Friday evening, 26 June 1827, 227.
7. *Warner MSS, Faraday to Abbott*, 4 June 1813.
8. Faraday, M , *Lectures on the Various Forces of Matter*, 3rd edn, London 1861, p 2.