Where has all the Chemistry Gone?

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From its title, it might be guessed that this will be a controversial paper, a polemic. Its substance is to consider why today the public display of chemistry is treated in such a cursory way in our larger public museums of science. It is true that there are many hidden, and semi-hidden, collections relating to chemistry. These are to be found in museum storage areas, in a variety of professional institutions, and in what might be called 'chemical shrines', but few are above ground or below attic level, and easily viewable by the public.[1] A number of universities have retained museums of chemicals, some in a decayed state, but these have never been intended for ordinary visitors.[2]

It has not always been thus. The neurologist and author, Oliver Sacks, died in August 2015. Shortly afterwards I received a letter from a colleague who was writing an obituary, who asked me about a passage in a book which Sacks had published in 2001. *Uncle Tungsten,* is an autobiographical account of how Sacks, when he was growing up in London in the 1940s, became intensely keen on acquiring chemical knowledge. He wrote:

> "In 1945 the Science Museum in South Kensington reopened …, and I first saw the giant periodic table displayed there. The table itself, covering a whole wall at the head of the stairs, was a cabinet made of dark wood, with ninety-odd cubicles, each inscribed with the name, the atomic weight, and the chemical symbol of its element …
> … I kept dreaming of the periodic table in the excited half-sleep of that night – I dreamed of it as a flashing, revolving pin-wheel or Catherine wheel, and then as a great nebula, going from the first element to the last, and whirling beyond uranium, out to infinity. The next day I could hardly wait for the museum to open, and dashed up to the top floor, where the table was, as soon as the doors were opened."[3]

Oliver Sacks was twelve years old when he had this exciting revelation. It is not an experience he would be able to have today. The periodic table in the Science Museum has gone and there is little chemistry displayed anywhere in the museum. This paper is concerned with the absence of history of chemistry in most his-

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tory of science museums at the present time. Whereas in the past museums had displays of chemical material, they have now nearly disappeared.

Early Museums and Chemistry

The question might be asked, how did chemistry as a subject come to be museums in the first place? The earliest museums were private collections, not public ones. A particularly early museum which displayed samples of stone, prehistoric tools, and metals was assembled by Michaelis Mercati (1541-93), whose book, *Metallotheca,*[4] published long after his death, contains an engraving of a museum hall with labelled cabinets containing his collection. Early assemblages such as these could be categorised as *Wunderkammern*, ‘cabinets of curiosity’, often possessing large sections of mineral samples and gems. These collections could certainly be described as ‘chemical’, being concerned with chemical species and crystal structures, and efforts were made to categorise their contents in objective ways.[5] The earliest public museums also contained mineral samples. Perhaps the very earliest was in Oxford. Two gardeners, both called John Tradescant who were father (ca.1570s–1638) and son (1608–1662), created a substantial collection of curiosities, antiquities and natural history in the first half of the seventeenth century. This collection was acquired by Elias Ashmole (1617–1692), a scholarly man who could be described as an antiquarian, a herald and an alchemist. Ashmole presented his collection to the University of Oxford, and a home was constructed for it, the first Ashmolean Museum. The building itself is the first purpose-built public museum, and it opened in 1683 for university scholars but also for any member of the public, on payment of sixpence.[6] It also functioned as the university’s first chemistry laboratory and anatomy theatre, which were situated in the basement. This marks the origins of public museum culture. The building survives in Broad Street, now as the Museum of the History of Science, and it contains some intriguing chemical material, mostly connected with an early writer on atomism and teacher at Oxford, Charles Daubeny (1795–1867). Material associated with the Tradescants and with Ashmole is now to be found elsewhere in other museums in Oxford.

The first national museum to be established was a product of the Enlightenment. Hans Sloane (1660–1753) was born in the north of Ireland, in the year which coincidentally was when the monarchy in Great Britain was restored and the Royal Society of London was founded. Sloane became deeply interested in natural history and trained to be a doctor in London and Paris. He developed almost an addiction to collecting, and as he lived to the great age of 92, his collection grew to

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be huge.[7] In his will, he left it to the British government, which initially rejected it, on the grounds that it would forever be a financial demand on public revenue. This inevitably proved true, but there was enough enthusiasm from parliamentarians to form a national museum from Sloane's collection.[8] To provide initial funding, a public lottery was held and enough money was raised to make the British Treasury temporarily happy. In January 1759, the British Museum opened its doors to the public for the first time. Curators were hired who, not unnaturally, kept on collecting, causing storage crisis after storage crisis. A large new building was proposed in 1823 and was built over the next quarter-century. Ultimately, even that didn't create adequate space. Towards the end of the nineteenth century the collection was split in two, and the natural history collections, including all the minerals and gems, were transferred to a new building in South Kensington for which Richard Owen had lobbied hard.[9]

Teaching Museums and Science

The background of the Science Museum, also in South Kensington, can be traced back to the Great Exhibition of 1851. It was Prince Albert of Saxe Coburg and Gotha, who was the consort of Queen Victoria, who promoted the idea of an international exhibition of industry. His concern was that other European countries, especially the German states and France, would overtake Britain as the world's major manufacturing nation. The Great Exhibition of the Works of All Nations opened on 1st May 1851 in Hyde Park in London. It displayed significant numbers of chemical samples and contemporary chemical apparatus . The Exhibition made a significant profit, which the British government used to purchase a large estate in South Kensington. As well as the land, a new government department was set up, the Department of Science and Art to promote public interest in industry and manufacturing,and set educational standards. It was this body which established, in 1857, the South Kensington Museum.

The Department was run as two sections. The arts part of the museum flourished, new buildings being constructed for its growing collections, and it is this part which is now called the Victoria and Albert Museum. The science side did much less well, the collections having to be stored in decaying, temporary buildings. This became a concern of the science community of the day, which wondered how the government might be persuaded to put more money into science, especially science education through the medium of a museum. Britain was compared unfavourably with France, where the Conservatoire National des Arts et Métiers, which had been set up shortly after the French Revolution, housed a scientific

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collection, hosted public lectures and provided a laboratory for working- class students. An attempt to remedy this was made in 1876, when a very large, though temporary, science exhibition was put together in South Kensington, called the Special Loan Collection of Scientific Apparatus.[10] The key organiser was Norman Lockyer (1836–1920), astronomer and founder of the journal *Nature*. The Collection was international in scope and was massive in scale, with 20,000 artefacts and specimens being displayed. In addition to Great Britain, eleven other countries contributed, including Germany.[11] The German Committee was divided into the Berlin Committee and what was called 'Other Cities and Towns of Germany' – the organisation of Germany's contribution had to take place quite soon after the 1871 unification but there was an overall President, August von Hoffman. The exhibition's approach was to show both historical and contemporary objects in five categories, one of which was chemistry, including metallurgy. Though the historic instruments were overwhelmed by the contemporary ones, there were 432 early examples displayed, many of them of prime importance, including the Magdeburg Hemispheres of Otto von Guericke, Galileo's telescope and Lavoisier's Calorimeter. A huge catalogue was published, of more than 1000 pages, and a German edition was also printed, *Bericht über die Ausstellung Wissenschaftlicher Apparate im South Kensington Museum zu London, 1876.*[12] In December 1876 the exhibition came to an end. All the historic objects were returned but some of the contemporary objects were not sent back and they became incorporated in the collection of the South Kensington Museum.

The Science Museum Emerges

This did not immediately have the desired effect of providing a purpose-built museum but from 1888 the science collections were provided with a distinct space on the West side of Exhibition Road, set apart from the art collections. In 1893 a separate director for science was appointed, Edward Festing (1839–1912), a chemist who had conducted some pioneering work on the application of infra-red spectroscopy on organic compounds. Construction of a new building did eventually commence in 1913, but then the World War intervened and what building had been completed by that stage was taken over by the civil service. After the War, things moved slowly but enough of the museum building had been finished by 1928 for King George V and Queen Mary to open the Science Museum at last. It is not an encouraging reflection on British attitudes that it had taken 70 years to construct its national science museum, and then only in part.

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The target audience of the first display was primarily the ordinary, largely uninformed public, followed by technical visitors, students and specialists, in that order. The collection had not been created in any systematic way. As well as material derived from the Great Exhibition of 1851, some came from the International Exhibition of 1862, also held in London, and from the Special Loan Exhibition of 1876, as mentioned. Already by 1910, a catalogue of the collection as it then stood had been published and some of the more recent items had been donated by instrument manufacturers. A number of models of chemical plants were constructed in the workshops of the Museum. The Science Museum then started publishing catalogues of the collection on quite a large scale, such as *Chemistry Teaching and Research Collection* of 1910,[13] the *Metallurgy* catalogue of 1925,[14] a text on *Industrial Chemistry*, based on the collections of 1929,[15] and the *Catalogue and the Brief Outline of the History and Development of Chemistry* of 1937.[16] As far as it is possible to tell from photographs, the display was not inspiring, the objects being jammed into cases with lengthy labels. Iconic, early historical material was sought, and when it couldn't be found or borrowed, copies would be made. For example, John Dalton's lecture diagrams of atoms and molecules, the originals of which belonged to the Manchester Literary and Philosophical Society. It is just as well that they were copied, because the real documents were destroyed by bombing during the Second World War.

The space provided for chemistry increased from 700 to 1105 square metres in 1964, and the presentation began to take on a more systematic approach. A series of reconstructed laboratories was established on the galleries, including part of the Laboratory of the Government Chemist. One very large exhibit was an ultracentrifuge for research on colloids and proteins, donated by the Swedish chemist, Theodor Svedberg (1884–1971) who had devised it. Following its installation, Svedberg wrote a letter to the Museum, saying, "I am very glad indeed that the oil-turbine ultracentrifuge has served so well during all these years and I feel much honoured that the Science Museum is taking it. I remember from my younger years when I visited the museum and took pictures of Graham's and Faraday's kolloids, but I did not dream of myself being represented there. I value it even more than my Nobel prize."[17]

The Good Years for Chemistry

Further development of chemistry displays took place in the mid–1970s, after the Royal Institute of Chemistry contacted the Museum and asked whether a complete revision of chemistry might be possible for its centenary in 1977. By this

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time I had joined the museum and I was given the task of creating the display in three large galleries. It is important to say that even in a history museum it is not possible to presenting a balanced account of a particular subject. A true museum display has to be based on objects. Some objects are of such importance that even if they are not visually stimulating and do not intrigue the audience, they still have to be shown. Curators try to avoid displays which are “books on the wall”, by which is meant there is no point in printing long texts for the sake of filling in gaps to be comprehensive in coverage. That means that even though they are vitally important aspects of the science, chemistry galleries have to leave out topics such as chemical thermodynamics, chemical kinetics, and quantum mechanics. I soon realised, though, in trying to develop a rational story using the collection as it stood, there was very little to represent the twentieth century. So I and my colleagues decided to create rapidly a collection which could tell chemical stories from 1900 to the then present time. Chemical stores and cupboards of various universities were raided, particularly those of Oxford and Cambridge, where curators had good contacts. An early infra-red spectrometer which my Oxford tutor, Sir Harold Thompson (1908–1983) had built from scratch and which had been used during the War to determine the composition of enemy aircraft fuel was handed over by him (not without difficulty). I also discovered that Sir Rex Richards (b. 1922) had wound his first NMR magnet by hand, and that it had been used as a research tool by physicists before NMR was taken-up by chemists turning its attention to chemistry. That was acquired, too. In Cambridge we were told that the original base-pair plates made by Francis Crick and James Watson for the DNA double helix model of 1953 had been sent to Bristol University many years earlier. They were recovered (but not the ball-and-spoke joints) and Crick and Watson’s model was reconstructed with as many original parts as possible by a graduate student at King’s College, London. James Kendrew and Max Perutz’s ‘forest of rods’, the model of myoglobin built by interpreting X-ray diffraction experiments, was acquired from Cambridge. Apart from the three pure chemistry galleries, a fellow-curator, Derek Robinson, was assigned a fourth gallery which concentrated on industrial chemistry. Because of the scale of industrial objects, this was an even greater challenge, though a nine-litre reaction vessel in which the first ton of polythene produced by ICI chemists in 1937/38 was displayed, and the associated Michels Bench which enabled the creation of very high operating pressures was shown alongside it.[18] Though there was little time and money to complete the project, all was ready on the Royal Institute of Chemistry’s celebratory night. One of the most challenging responsibilities of science curators is to ensure that significant objects are preserved for the future, even if their importance is not generally appreciated at the time. Creation of galleries such as we were developing stimulated ideas and discussion about what was important, and encouraged collecting and hence preservation.

Deciding on who the audience is to be is difficult for those preparing presentations, and often such questions are a matter of general museum policy, or for education departments, both unsatisfactory as they offer only a blanket decision for very different subjects and ignoring the fact that the public has widely varying levels of understanding and intelligence. Museum displays cannot equally please all categories of visitor all the time. If such an attempt to do so were made, the likely outcome is a display which pleases nobody. When challenged with the question about who the chemistry galleries were being developed for, the answer given by the Chemistry Department was that target audience was 16-year olds and above, who were not very well-informed but who were curious. That answer was not a popular one. The 'right' answer for science museums is first 'children', and secondly, 'families'. My view is that the hard sciences are conceptually difficult to understand, and that the objects themselves cannot have the immediate impact of, for example, steam locomotives. History of science galleries have to be more patiently worked at. That is not to say that one does not make every effort to make complex ideas understandable, but it is only realistic to admit to oneself that only a small proportion of visitors will come away with much understanding. But is that a reason not to try?

As a child growing up in London I visited the Science Museum many times by myself (like Sacks) and on the top floor I was intrigued by a model which tried to explain how a cyclotron worked, not that I even understood what the word 'cyclotron' meant. To begin with, the model was simply a spiral groove along which ball-bearings were accelerated by the up and down movement of two hinged, horizontal semi-circular plates, resulting in the balls shooting out at the end with great speed. It was simply fun to observe. As I grew older, and was being taught physics at school, I came back to that model time and time again and then it suddenly dawned on me what it represented. Would it have been better to have omitted that demonstration because it was too difficult for a child to understand?

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A former colleague at the Science Museum, Peter Morris, has written a history of the chemistry galleries in the Science Museum, adding some personal comments. I think that his interpretation is more or less correct. He writes:

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> "Chemistry was presented as a science with a long history of practical applications, stemming back to the ancient Egyptians, which had developed rapidly during the 20th century. It showed that British chemists had made a major contribution to its development, especially since the early 18th century. The gallery demonstrated the value of chemistry for our growing understanding of life's mechanisms, especially by the determination of increasingly complex chemical and biochemical structures. It used analytical apparatus and chemical balances to illustrate the importance of precise measurement. The overall impression was that the practice of chemistry required intricate skills from early 19th-century blowpipes to the latest electron diffraction. It promoted chemistry both as an intellectual challenge and a highly skilled craft, rather than concentrating on the benefits of chemistry to the public at large."[19]

The three 1977 pure chemistry galleries lasted until 1999, when they were dismantled, and replaced by a much smaller gallery occupying only thirteen per cent of the previous space.[20] It is difficult to understand why this was done, except that the director of the day seemed to be embarrassed by the complexity of some of the science galleries. Very little of the space which was freed was subsequently used for a number of years (it has been, now). The name of the modest new gallery was 'The Chemistry of Everyday Life', showing the contribution of chemistry to how we live, specifically through quality control, and how biochemistry adds to the understanding of life. It was an optimistic aim for so small a space. For the first time, interactive exhibits, operated by visitors, were introduced but these were soon removed because they became faulty only one year after their installation. Information panels replaced the traditional captions and the objects were not individually explained. The target audience this time was family groups with children more than fourteen years of age, independent adults and university students, in that order. Again, to quote the 2006 remarks of Peter Morris, the originator of 'The Chemistry of Everyday Life':

> "This gallery, probably the last of its kind at the Science Museum, stands in a long tradition of showing the importance of chemistry in understated terms of its basic utility rather than through spectacular achievements or amazing products. In historical terms, the 1999 gallery reverted to the late Victorian presentation of chemistry as a comparatively recent science rather than one with an ancient lineage. This was partly a result of severe lack of space but also stems from recent historiography which portrays chemistry as a largely 19th-century creation which sought legitimacy by claiming ancestry from alchemy, metallurgy, and natural philosophy."[21]

I would suggest that matters have been moving on even further in science centres, where there is a tendency towards triumphalism: today's science is an ultimate

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achievement and we need not be too concerned about where it has come from. With this approach, a cynic might say that scientific success must not be contaminated by history. The science centre should be regarded as a different species from the science museum. It eschews historical displays, presenting newly created interactives which demonstrate scientific principles. The first of this genre was undoubtedly Berlin's Urania,[22] though it could scarcely be regarded as a prototype as none followed on from it. The first modern centre was San Francisco's Exploratorium of 1969, and that was followed by a great expansion in their number in the 1980s and 90s.[23] Strangely, there appear to be no real, comprehensive science museums in the United States. The nearest thing to one, the National Museum of History and Technology (part of the Smithsonian Institution) turned into the National Museum of American History, more a social history museum, in 1980.There are, of course, plenty of science centres.[24]

There is now no gallery dedicated to chemistry in the Science Museum. Though there are some chemical exhibits embedded in a display opened in 2009 called 'The Making of Modern Science'. That gallery presents a large selection of the most spectacular of the museum's scientific and technological objects. There is no possibility that this approach (parts look uncomfortably like a shop window display) can develop the kind of ideas which were bound-in to the traditional displays of physical science, where one concept led to another and which were previously available in the Science Museum. The nature of the Science Museum was changed very substantially from the 1980s onwards. The Department of Chemistry ceased to exists after the last Keeper of Chemistry left in 1984. The previous long-existing disciplinary structure of departments, representing traditional categories of science and technology, was abandoned and this change was accompanied by a significant reduction in specialist curatorial staff from the 1980s onwards, including those with responsibility to chemistry.[25]

There are of course other large museums where chemistry might be expected. The main European ones are the Deutsches Museum in Munich and the Musée du Conservatoire National des Arts et Metiers in Paris.[26] Up to now, the Deutsches Museum has been one of the most enduring and unchanging of all European science institutions, holding on to the ideals of its founder, Oscar von Miller (1855–1934). Instituted in 1903, it has been through good times, and occasionally bad ones when politics have intruded. It sits solidly on its island in the River Isar and at its heart is von Miller's Ehrensaal, the Hall of the Fame, presenting scientists and engineers as heroic figures in society.[27] All the heroes of this original concept were, naturally, German. There have been changes since von Miller's time, many the result of reconstructing the room after it was damaged in the Second World War. King Ludwig I of Bavaria and Frederick the Great have been expelled, pre-

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sumably because they were not first and foremost scientists. Lise Meitner, the first female, was added in 1991. The French chemist, Antoine Laurent Lavoisier, recently slipped in, as did Leonardo da Vinci. It is unlikely that Sir Isaac Newton ever will join this Pantheon for as long as Gottfried Wilhelm Leibnitz is there ready to cast his black ball in the ballot for new members as long as Newton maintains his rival claim inventing the calculus. The pure chemistry galleries were created in an earlier building, right from the beginning in 1906, and these were developed by three leading chemists, Hans Bunte, Walther Nernst and Wilhelm Ostwald. The galleries were strongly supported by the German chemical industry, in contrast with the Science Museum, where nearly all funding came from the British Government. There were similarities between the two museums but the greatest difference was that right from the beginning, techniques were developed at the Deutsches Museum to allow visitors to perform simple experiments.

Significant resources were needed to maintain these interactive displays, and it was the German chemical industry which supplied these needs. In addition to this, there were straightforward historical presentations of instrumentation and apparatus, and three laboratory reconstructions, one not surprisingly being Liebig's Giessen laboratory. There was always a strong emphasis on the German chemical industry in the displays and in 1965 a chemical technology gallery was opened. This was replaced by another industrial gallery in 1979 which had more of an emphasis on chemical products. I remember discussing this when it was in its development phase with the head of chemistry, Otto Krätz. He told me that he was concerned that those funding the gallery had forbidden him to use the word 'pollution' (Umweltverschmutzung) in the labels and captions. How different things would be today, if such a presentation were being planned. With all the current public concern, treatment of the subject would be a required component. However, this cannot be checked as the gallery was closed in 1998 and replaced two years later with one dealing with pharmacy. There are at present no traditional chemistry galleries and the new ones, long in preparation, will be opening in 2019. The overall content has yet to be revealed. But a small preview of them was presented back in 2011. Called 'Chemistry in Recreation and Sport', it deals with materials which have particular properties of value to sportsmen and women such as waterproof, but breathable, jackets, and materials used in the construction of sports shoes and skis. Quite clearly, if the style of the other components is being developed with similar ideas in mind, this will move chemistry far away from the previous presentations based on the discipline of the subject.

Very briefly, at this point, the Conservatoire National des Arts et Metiers (CNAM) and the National Museum of American History will be considered. The

Paris museum could be said to be the oldest science museum in the world, claiming its origin in 1794, when the teaching of science and technology started in this institution of Napoleonic foundation.. As teaching was by lecture demonstration, and as redundant instruments were retained in cupboards rather than discarded, this claim is justified. Collecting came to be broadened out considerably from this early policy, and many iconic pieces, such as Nicholas Joseph Cugnot's steam carriage of 1769 and Clement Ader's steam-powered aeroplane of 1890 were put on display. In the modest space allowed for the chemistry galleries, there is no attempt to present the developmental structure of the subject. Part of the attic floor of the museum which is devoted to scientific instruments does show a small chemistry collection. In recent times, since the renovation of 2000, there have been efforts to present contemporary uses of chemistry by means of graphics.[28] But whatever might be done to deal with the subject, everything would be overwhelmed by the magnificent and extremely important collection of Antoine Laurent Lavoisier's instruments and apparatus, which was purchased by the Conservatoire as recently as 1952.[29] This deals with a range of Lavoisier's most important work, including the determination of the composition of water, calorimetry and experiments with oxygen, but only a small proportion of the 550 items in the collection are shown. The display does not lead on to 19th and 20th century chemistry galleries.

The National Museum of History and Technology was established in Washington in the 1950s from material which had long been part of the Smithsonian's collection, but the building did not open until 1964. It possessed a small chemistry section, perhaps the main interest being in apparatus used by the chemist Joseph Priestley, who emigrated to Northumberland, Pennsylvania, forced out of England in 1794; hostility and antagonism had been shown towards him because of his support for the French Revolution. There were also some interesting relics of early chemical technology, including the pressure vessel with which the Belgian Leo Baekeland had first prepared the plastic Bakelite in 1909. The Museum underwent a significant shift in 1980, indicated by its name change from History and Technology, to American History. Essentially, it turned into a museum of social history. The science content was reduced and the world outside the United States shrank to very little. Certainly that was the impression which specialist visitors took away with them. Curators and historians of science remained on the staff but their role in presenting displays was diminished.

There was just one major exhibit which did reflect on the influence of sciences and technologies on the American people: this was called 'Science in American Life', a diverse group of displays which was opened in 1994. To quote from a paper published in 1999, "It is the first major exhibit to examine critically, in a

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social and cultural context, such technological devices as the atomic bomb and such achievements of medical science as the birth control pill".[30] For some, the exhibition was too critical of science and it caused public protest. It had been supported by the American Chemical Society, who paid more than $5 million to fund it but it was immediately criticised by them and others as showing a negative view of science, instead of dwelling on the benefits provided for the American people. By the time it closed in 2011, it had probably generated more heated controversy than any other science exhibition created. It should be emphasised that not everything was controversial. In the small chemistry section, Ira Remsen's laboratory from the 1870s was recreated. Remsen (1846–1927) was the founder of the *American Chemical Journal* and a President of the America Chemical Society.

Why has Chemistry gone wrong in Museums?

Museums are visited in part, because of the visual and cerebral stimulation they provide for all visitors, and in particular, because they are educational establishments they are considered to be desirable places for children to visit. The problem is that for the most part, chemistry never generated objects which are stimulating to look at. Compare astronomy, horology and natural philosophy, with chemistry. Objects in the first three categories were often made from brass or ivory, were made by virtuoso craftsmen and can be aesthetically pleasing. For some objects, such as astrolabes, their very antiquity offers added mystery and interest. Although very occasionally chemical objects can provide the same kind of stimulation (consider the 16th century alchemical and metallurgical material discovered at Oberstockstall in Lower Austria)[31] in general they are mundane by comparison. Possibly the most intriguing chemical instrument-type from the visual point of view is the analytical balance, in part because it was developed over a long period of time and its evolution provides an interesting dimension, but that is exceptional.

Size can be an intimidating problem for museums, especially where industrial processes are concerned. The complexity of dismantling and re-erecting even a small chemical engineering plant may be exacerbated by conservation needs. However, not all material to do with chemistry and chemicals is neat and small, and if some representation of the overall picture is sought, solutions other than transporting heavy, decaying objects in town-centre museums have to be sought. Site museums are a possibility, though almost certainly a non-viable one economically. Photography and film are methods for recording when all else fails. A 19th

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century solution was to make models of industrial set-ups and some museums established workshops to produce exhibits in this way. Though most museums have consigned these models to stores, if not actually had them destroyed, they are becoming an interesting genre of object in their own right.

Instruments are no longer made of brass and glass and ivory, though even as one approaches the present era, there remains some visual excitement in physics as opposed to chemistry. Big science, as Derek de Solla Price called it,[32] can offer visual, and sometimes aesthetic fascination. Cockcroft-Walton generators have an almost 1930s sculptural quality about them, and their very largeness can be impressive in itself. Black box instruments hide their function. Moreover, with computer-run systems, the human dimension is missing from their operation. Occasionally a human touch appears: the synchrotron operating panel on display at the Harvard Science Center in Cambridge, Massachusetts, has an original pizza-order form attached to it which immediately makes one appreciate that the instrument's operators would have worked long hours and needed feeding with pizza slices from time to time. Curatorial staff should be congratulated that this little bit of social history was retained and not stripped off as being irrelevant; it is a part of the history of the instrument.

But it is not only chemistry that has suffered from under-representation in museums. The problem in trying to present any science history in museums is that physics and chemistry are conceptually difficult to understand to those who have not received specialist education. There is a vocabulary to be learnt and an associated mathematical language. As an example, chemists appreciate the importance of nuclear magnetic resonance (the Varian A-60 is a landmark instrument in the application of the technique) to increased understanding of chemical bonding, and now as a medical diagnostic tool, but is there any hope of being able to explain its mode of operation to a non-scientist who, having been excited by steam locomotives, is unlikely to be diverted by a black (or grey) box when he is intent on making his way to the coffee shop or museum shop? It has been shown that nowadays unless there is an immediate level of some understanding of a museum presentation very few visitors are likely to persist, as they might have done in past times. Concentration times are very short. So should museums even bother to display significant historic material if most people walk past it in a state of non-comprehension and indifference? This is a very basic question for museums to address. Simplification is not necessarily the answer: if museums try to make all displays comprehensible to everyone, they may be satisfying no one. And if displays are dumbed-down too far the messages they may be transmitting will be seen as vapid. Difficult though it is to admit it, the Public Understanding of Science movement has not been a great success. It may have

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taught a little about the application of science, the economics of science, the politics of science, the social consequences of science, but it rarely deals with basic scientific concepts. COPUS, a UK public understanding of science committee established in 1985 and essentially controlled by the Royal Society of London was disbanded in 2002 when its original purpose was felt to have been superseded by the need for better communication.[33] A realistic view would be that it was incapable of achieving what it set out to do and its purpose therefore had to change.

Is there then no hope for presenting chemistry in museums? Is there nowhere where chemistry is going right? I believe that there is, but not necessarily in the very large, publicly-funded science museums. The problem with public funding of science museums is that unless they are intellectually accessible to the bulk of the population, they are seen as élitist, and therefore are inappropriately funded through general taxation. This argument is undermined when considering art galleries, which are immune from criticism for taking an élitist approach. I cannot see the devotional paintings of the early Italian schools in the National Gallery being supplanted with 20th century street art.

Where is the Chemistry going Right?

It is the small, more independent museums where we have the best hope of having serious displays of chemistry. A few of them are to be found in chemistry departments of universities, though these are not really public museums. The most significant new presentation of chemistry over the past few years is the museum at the Chemical Heritage Foundation, or CHF, in Philadelphia. The CHF itself was founded in a complicated way in 1987 by an historian of chemistry at the University of Pennsylvania, Arnold Thackray (b.1939).[34] After significant endowments had been secured it split away from the University and in 1996 it moved into a 19th century bank building in the heart of Philadelphia's historic district, just behind the site of Benjamin Franklin's house. A chemistry museum was then planned, and it opened in 2008.[35] The collection started being created earlier and a special committee of pioneering analytical chemists had been established to decide which were the 50 most significant advances in instrumentation in the second half of the 20th century, and then to try to acquire them. It is likely that the CHF possesses the most significant collection of this kind and that it is one of the few institutions collecting chemical artefacts up to the present day. A lot of discussion has taken place about collecting contemporary scientific objects, but the results of this activity (if there are any) do not seem to appear on display

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in museums (as does the proliferation of contemporary art works on the galleries of museums of modern art).

Another newly presented history of chemistry museum, though of a very different kind, opened at about the same time – this was a redisplay at the Royal Institution in London. Like the CHF museum it is small, being focused entirely on the work at the Royal Institution, which was founded in 1799. Its major early figures were Humphry Davy, who isolated new elements by electrolysis, Michael Faraday, whose experiments led the first electric motor, and James Dewar, a spectroscopist, now remembered mainly for the vacuum flask. But there were also major figures in the 20th century – William and Lawrence Bragg, who developed X-ray crystallography, and George Porter, who developed flash photolysis. All three won Nobel Prizes, and the museum is a sort-of shrine to the greatness of the Royal Institution. In a similar vein is Liebig's Museum at Giessen, where the famous chemistry research laboratory is preserved and where so many major figures of 19th century trained in organic analysis. This, like the Royal Institution, could also be called a shrine. What these museums have in common is that they are all highly focused, without their visitors being diverted by steam locomotives. They might best be called, in the jargon of today, boutique museums.

In answer to the question, 'Where has all the chemistry gone', it may not be in our nationally-funded science museums (though probably most of what has previously been displayed in the past is likely to be preserved in stores), but in the small private ones. The question which leads from this is, 'Why should it be important that we still have chemistry preserved and on display in museums?' First, it is unquestionably part of our cultural background, our scientific heritage if you like. Museums are important for indicating to us where we have come from and how we have arrived at the present. Chemistry can scarcely be considered an unimportant factor of contemporary life. Secondly, museums are stores of research material for historians. They function like libraries, but instead of books there are artefacts, some of which are very difficult to 'read'. That is why a small, highly skilled staff is needed, who have learnt to understand the language of objects, and who can assist others to interpret the evidence. We also need these experts to make decisions about what new objects to acquire. It is a highly responsible job, because what is not acquired is usually discarded, most of it disappearing without trace. The nature of future history of chemistry studies will be influenced not only by what archival, but also by what three-dimensional material is being preserved today. It is much to be hoped that the policies of the larger science museums will return to the earlier situation, developing collection policies which reflect significance as being a heavy responsibility, and understand that popularisation, media attention and visitor numbers are not the only things which matter.

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When I was a young curator at the Science Museum, I was lucky to have as my boss a highly experienced chemistry historian called Frank Greenaway, who had started working at the museum back in 1949.[36] He died four years ago at the age of 95. I would like to finish my talk by quoting something he said at a conference in Oxford in 1961:

> "A curator has another role in the field of historiography, a service to the historian of the future. His policy of acquisition must look forward, guided by his own historical judgement. Modern records, particularly laboratory records, must be very much his concern, and it is hoped that it will be made easier for the curator to acquire important material. Without the record of experiment, and the means by which it is done, even the historian of scientific thought will lack essential material."

I remain grateful to Frank Greenaway for instilling in me the importance of preservation and also allowing me freedom to express my own ideas in writing. It was he who promoted the development of the four new chemistry galleries which opened in the Science Museum in 1977. I am also deeply grateful to the Hans Jenemann Foundation for awarding me the 2016 Paul Bunge Prize.

Revised version of the Paul Bunge Lecture given at a meeting of the Deutsche Bunsen Gesellschaft fűr Physikalische Chemie, Rostock, 6 May 2016.

[1] Jan W van Spronsen, Guide of European Museums with Collections on History of Chemistry and of Pharmacy, third updated edition (Antwerp: Federation of European Chemical Societies, 1998), lists 139 collections.

[2] Peter J T Morris, The Matter Factory: A History of the Chemistry Laboratory (London: Reaktion Books, 2015), see Chapter 8, 'Chemical Museums', pp.198–231.

[3] Oliver Sacks, Uncle Tungsten: Memories of a Chemical Boyhood (London: Picador, 2001), chap. 16, pp. 187, 191.

[4] Michaele Mercati, Metallotheca, Opus Postumum (Rome: Jo. Mariam Salvioni, 1719).

[5] Wendell E Wilson, The History of Mineral Collecting (Tucson, TX: Mineralogical Record, 1994).

[6] Arthur Macgregor, Ashmolean Museum, Oxford: Manuscript Catalogues in the Early Museum Collections, 1683 – 1886 (Oxford: Archaeopress, 2000).

[7] It is difficult to give any precise figure, but Sloane's collection certainly numbered in the high tens of thousands of specimens. See Arthur MacGregor (ed.), Sir Hans Slone: Collector, Scientist, Antiquary (London: British Museum Press, 1994).

[8] In his Will, Sloane had cleverly created a list of institutions which should be approached, in order, if the preceding one turned it down; a number of these were foreign learned societies.

[9] Richard Owen, On the Extent and Aims of National Museum of Natural History (London: Saunders Otley, 1862).

[10] Robert Bud, 'Responding to Stories: The 1876 Loan Collection of Scientific Apparatus and the Science Museum', Science Museum Group Journal 1 (Spring 2014) 1–18.

[11] Science and Art Department of the Committee on Education, Catalogue of the Special Loan Collection of Scientific Apparatus at the South Kensington Museum (London: Eyre and Spottiswood, 1877).

[12]Bericht über die Ausstellung Wissenschaftlicher Apparate im South Kensington Museum zu London, 1876, zusammengestellt von Dr. Rudolf Biedemann (London: John Strangeways, 1877).

[13] Board of Education, Catalogue of the Collections for Teaching and Research in the Science Museum, South Kensington. Part III. Chemistry (London: HMSO, 1910).

[14] A.J. Spencer, Board of Education Catalogue of the Collections in the Science Museum South Kensington: Metallurgy (London: HMSO, 1925).

[15] Science Museum, Handbooks of the Science Museum. Industrial Chemistry (London: HMSO, 1929).

[16] A. Barclay, Ministry of Education, Science Museum: Pure Chemistry. A Brief Outline of its History and Development, Part I – Historical Review (London: HMSO, 1937); A. Barclay, Board of Education, Science Museum. Handbook of the Collections Illustrating Pure Chemistry. Part II – Descriptive Catalogue(London: HMSO, 1937).

[17] This letter is reproduced in Anderson, Morris and Robinson (eds.), see below, note 36.

[18] I am grateful to Dr Derek Robinson for providing me with these details.

[19] Peter Morris, 'Presenting Chemistry at the Science Museum: its History and Practice', in Isabel Malaquias, Ernst Homburg and M. Elvira Callapez, 5th International Conference on History of Chemistry: Proceedings (Lisbon: Sociedade Portuguesa de Quimica, 2005), pp. 184–196; Peter Morris, 'The Image of Chemistry Presented by the Science Museum, London, in the Twentieth Century: An International Perspective', HYLE – International Journal for Philosophy of Chemistry 12 (2006), pp. 215–239.

[20] The Industrial Chemistry Gallery was dismantled in 1986, when it was replaced with a Chemical Industry Gallery, supported by Imperial Chemical Industries to mark the 60th anniversary of the creation of that company.

[21] Morris, 'The Image of Chemistry' [see note 19].

[22] Gábor Palló, 'Genres of Popular Science: Urania and the Scientific Theatre' in Faidra Papanelopoulou, Agustí Nieto-Galan and Enrique Perdiguero (eds.), Popularizing Science and Technology in the European Periphery 1800–2000 (Burlington VT: Ashgate Publishing, 2009), pp.157–174.

[23] Lutz Fiesser, Raum für Zeit, Quellentexte zur Pädagogik der Interaktiven Science-Zentren (Signet: Flensburg, 2000).

[24] Victor J Danilov, Hands On Science Centers: A Directory of Interactive Museums and Sites in the United States (Jefferson NC: McFarlane Co, 2010).

[25] To some extent this is charted in Timothy Boon, ‘‘Parallax Error?’ A Participants Account of the Science Museum, c.1980 – c.2000’, in Peter J T Morris (ed.), Science for the Nation: Perspectives on the History of the Science Museum (Basingstoke: Palgrave Macmillan, 2010). pp.111–35.

[26] Sometimes called the Museé National des Techniques.

[27] W Exner, Der Ehrensaal des Deutschen Museums, Abhandlungen und Berichte, 2. Jahrgang, Heft 2 (Berlin: VDI-Verlag, 1930). For a critical overview of the Ehrensaal see Lisa Kirch, The Changing Face of Science and Technology in the Ehrensaal of the Deutsches Museum, 1903-1955, Deutsches Museum Preprint 12 (Münster: MV-Wissenschaft, 2017).

[28] Dominique Ferriot and Nathalie Giuliana-Petyrard, Arts et Métiers: Chronique d’une Rénovation (Paris: Musée des Arts et Métiers, 2015).

[29] Marco Beretta, ‘Lavoisier’s Collection of Instruments: a Checkered History’, in Musa Musaei. Studies on Scientific Instruments and Collections in Honour of Mara Miniati, Marco Beretta, Paolo Galluzzi and Carlo Triarico, eds. (Florence: Leo S. Olschki, 2003), pp.313–334.

[30] Pamela M. Henson, ‘”Objects of Curious Research”. The History of Science and Technology at the Smithsonian’, Isis 90 (1999), pp. 249–269 (quotation on p.267); Sophia Vackimes, ‘Science and Anti-Science at the Smithsonian Institution’ Kroeber Anthropological Society Papers (February 1996), pp.88–105.

[31] Rudolf Werner Soukup and Helmut Mayer, Alchemisches Gold: Paracelsistische Pharmaka. Laboratoriumstechnik im 16, Jahrhundert, Chemiegeschichte und Archäometrische Untersuchung am Inventar des Laboratoriums von Oberstockstall/Kirchberg am Wagram (Vienna: Böhlau, 1997).

[32] Derek J de Solla Price, Little Science, Big Science (New York: Columbia Univ. Press, 1963).

[33] Helen Gavaghan, ‘COPUS Disbanded’, The Scientific Magazine (12 December 2002); House of Lords: Select Committee on Science and Technology, Third Report, chapter 3: Public Understanding of Science; ibid. – Fourth and Fifth Reports.

[34] ‘CHF: Yesterday, Today and Tomorrow’, Chemical Heritage 18.1 (January 2000), pp.16–22.

[35] I must admit to an interest in this project as I acted as a consultant to the Chemical Heritage Foundation in the museum’s development.

[36] Robert G W Anderson, Peter J T Morris and D A Robinson (eds.), Chymica Acta. An Autobiographical Memoir by Frank Greenaway ([Huddersfield]: Jeremy Mills Publishing, 2007).

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