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Wandering Seminar on Scientific Objects

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Of Wandering, Objects and Observers

The essays contained in this collection are the result of the Workshop on Scientific Objects held at the *Max-Planck-Institute for the History of Science* that took place in Berlin during August 16-18, 2007. This workshop was the outcome of the Wandering Seminar on Scientific Objects, which occurred during May 1 – June 25, 2006 and was organized by the International Max Planck Research Network "History of Scientific Objects". The principal aim of the project was to encourage young scholars to consider important European collections and the objects they contain as new modes and sites for scientific inquiry while also providing them with first hand information about the latest developments in the material culture of science. Overall it was an intellectually challenging and visually charged experience.

For two months, a group composed of junior and advanced scholars and museum curators, all at different stages of their careers, initially unknown to each other, traveled throughout Europe in what was a daunting adventure; visiting major scientific object collections in close to fifteen research stations. Such assemblages were to be found mainly in institutions that are traditionally known to harness, collect and care for objects which European culture considers precious: museums. The group of travelers, nominated from institutions across Europe – and two or three who joined from across the Atlantic – ventured into the cabinets of curiosity that characterize the grandest and most complex accumulations of objects known to research.

The *Max-Planck-Institut für Wissenschaftsgeschichte*, in Berlin, Germany, was our starting and ending point; here we would chart, revisit and upon return give academic shape to our experience through the essays presented here. As we progressed in our travel, a world of images, objects, curators, museum scholars and professionals opened before us. We were kindly guided into the most commonplace and the most arcane of collections, the most sophisticated and the subtle assemblages of memorabilia, the most inexplicable and inexorable of storage situations; from dusty cabinet of curiosities to the modern utopian experiment.

At the *Deutsches Museum*, in Munich, one of the grandest technological collections in the world, the museum's staff set before us an amazing array of objects. A large exercise in comparison and contrast encompassing human activity and curiosity became apparent; not only were to be lectured on contemporary curatorial issues such as the caring for objects too large for storage to handle; the problems of those so-called "black boxes" of physical science as well as care and storage for objects of scientific curiosity that are often overlooked in favor of shining astrolabes were not so different as those considered traditional. A collection of slide rules was part of those objects condemned to obscurity due to the birth of calculators and computers. The collection of books with *volvelles* made us reconsider what is not so new about books with pop-up illustrations; radio bulbs – catalogued in a process that has so far taken twenty years gave us pause to consider the work of the lonely museum volunteer ...

At the *Medical Museion*, Copenhagen, we had a glimpse of how a medical institution has evolved into research site and public forum. Their biomedical collection contains a profuse collection of chemical samples, potions, concoctions and poisons. Their alchemy laboratory, the collection of prosthetics, and other diverse medical objects – syringes, microscopes, surgical equipment, plus their anatomical theater, gave us great insight into how the medical profession has striven for centuries to heal man from physical ailment.

Our visit to the Department of History and Philosophy of Science, at the *University of Cambridge*, was an adventure into the sacred and the profane, the magical and the traditional. Not only did we engage in lively discussions on the nature of scientific knowledge, wax embryos, Goethe's color theory, visit time-honored libraries such as the Bodleian – where we saw manuscripts written by Charles Darwin – and visit world-famous anthropological collections – *Whipple Museum, Scott Polar Research Institute, The Museum of Archaeology and Anthropology* – but were treated to a visit to *The Eagle*, the pub where the discovery of DNA was announced. Besides such thrilling experiences we also got a glimpse of a tree that is said to be descended from that beneath which Isaac Newton rested when an bright idea descended upon him – both events inspired one of the essays in this compilation.

At the *Science Museum*, London, we spoke with curators who compared and contrasted state of the art exhibits to traditional ones and who engaged us in a conversation on what sort of information is actually conveyed to the general public via new installations; how traditionally collected objects can be utilized to give new meaning to different scientific research practices. While at the *Museum of the History of Science*, Oxford, various exhibits illustrated contemporary museographic challenges and missions; a traditional collection of astrolabes, a day long event designed for families that dealt with Marconi and the history of radio transmission, the presentation of a objects from the fabulous Tradescant collection in itself a landmark in the history of science.

In France, at the *Institute National de la Recherche Agronomique*, Versailles, we got a view of science in the making with visits to the wonderful *Arabidopsis thaliana* hybrid production facility. At the *Centre Alexandre Koyré* of the *Muséum National d'Histoire Naturelle* at Paris, we had the privilege of viewing objects from historical botanical collections such as the Cabinet du Roy and The Paris Herbarium. The work of classical botanists like Lamarque, Vaillant, de Jussieu appeared before our eyes; the complexities of botanical nomenclature, cladistics and the evolution of contemporary research were presented to us by staff, researchers and graduate students as "the moral economies of collecting natural history and biomedicine" were considered.

During a brief stopover in Berlin, we listened to discussions on the transition from classical to quantum mechanics, the history of gestual knowledge, early photographic processes – ambrotypes, cyanotypes, daguerrotypes. We also visited the *Berliner Medizinihstorisches Museum der Charité*, with its historical collections of anatomical pathology – jars and jars of body parts in formaldehyde – the *Helmholtz Zentrum for Kulturtechnik*, and the *Naturkundemuseum* – which was to undergo a rigorous and exhilarating renovation – and were amazed by the Archaeopteryx fossil in its collection. In turn, at the *Humboldt Universität* zu Berlin where we were treated, no more and no less than to a look at a lobster caught by Fidel Castro. This object can be found at their newly created Internet searchable database under the link Crustacea, and was the object of the month during May 2006.

After a brief weekend at our primary host institution we again departed, this time for Italy where we would witness time-honored collections but also listen to tales of *meraviglie* finely spun around labyrinths, botanical specimens and the obscure plots of Florentine royalty. We visited the *Fondazione Scienza e Tecnica* as well as the *Museo di Storia Naturale dell'Università di Pisa*, "La

Specola", the *Orto Botanico* with its comprehensive collection of botanical specimens, the *Instituto e Museo di Storia della Scienza*, and the *Galleria degli Uffizi*, where the exhibit "La mente di Leonardo" had recently opened. Nearby, at Fiesole, at an old cartusian monastery – which had a cemetery in its interior garden – we visited the *Museo di San Marco*, an old with its historical collections on paleontology, anthropology, botany and mineralogy; we wondered how a collection of dinosaur fossils made it to that isolated institution. Of note were the cabinet of curiosities, mineral samples, and a whimsical exhibit that included unicorns and mythological monsters. A definitive highlight was the *Museo di Storia Naturale*, in Florence, with its objects for astronomical research and perhaps the most astonishing object we saw in our two month long journey; Galileo Galilei's finger encased in a glass cupola.

Our final stop was at the Professur für Wissenschaftsforschung at the *Eidgenössische Technische Hochschule* (ETH), Switzerland. Our hosts led us to an insightful visit to the *Naturmuseum*, at Winterthur, which besides wonderful collections of natural specimens is an avant-garde institution with respect to its public programs, the *NFS Bildkritik/eikones* project in Basel – an exemplary stance in the approach to artistic iconography, plus an exploration on the workplace of the future as scientific object at the headquarters for the pharmaceutical concern *Novartis*.

Tired, and weary, but academically stimulated, the group decided to reconvene within a year with three distinct projects: the Workshop on Scientific Objects; an exhibit shown at the MPIWG from August 16 to October 2nd titled "Objects in Transition"; a web site that can be accessed at http://scientificobjects.mpiwg-berlin.mpg.de and which will contain the essays presented in the workshop. This volume is printed testimony of an unparalleled adventure.

Acknowledgements

The scholars who participated in the wandering seminar were: Gianenrico Bernasconi, *Humboldt University Berlin / University of Paris* I; Alison Boyle, *Science Museum London*; Terje Brundtland, *University of Oxford* ; Jean-Baptiste Fressoz, *IUE Florence / EHESS* Paris; Jean-Francois Gauvin, *Harvard University*, Cambridge; Johannes Grave, *NCCR Iconic Criticism* Basel; Hanne Jessen, *Medicinsk Museion*, University of Copenhagen; Anna Märker, *Max Planck Institute for the History of Science Berlin*; Daniela Monaldi, *Max Planck Institute for the History of Science Berlin*; Dario Moretta, *University of Pisa*; Susanne Pickert, *Max Planck Institute for the History of Science Berlin*; Nicky Reeves, *University of Cambridge*; Stefano Salvia, *University of Pisa*; Sophia Vackimes, *Max Planck Institute for the History of Science Berlin*; Konstanze Weltersbach, *ETH Zürich*.

We are grateful to our hosts at the *Max-Planck-Institute* in Berlin, as well as to the members of the International Max Planck Research Network "History of Scientific Objects", who conceived this complex, challenging and insightful experience. We are most thankful to Hannah Lotte Lund, program coordinator, for the care and energy she put into the myriad details that this project entailed. We are greatly indebted to the hosts, researchers, lecturers, museum curators and speakers who led us through the complex maze of collections and institutions we visited. We would also like to express special appreciation to those individuals who we met again in Berlin a year later and who chaired the sessions of the Wandering Seminar's Workshop. They followed us from beginning to end of our wandering onto the academic consequences of what had been a provocative and innovative adventure; Lorraine Daston, Michael Hagner, Anke te Heesen, Claudio Pogliano, Hans-Jörg Rheinberger, Simon Schaffer, and Hans-Konrad Schmutz.

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Sophia Vackimes, *Max Planck Institute for the History of Science Berlin*
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November 2007.

My Way to the Objects

Terje Brundtland

Today, there is much concern about using museum-objects and replicated instruments in studies of past science. This text presents two examples from this methodology, taken from works on two interesting characters within the history of science: the English instrument maker Francis Hauksbee (1660-1713) and the Norwegian physicist Kristian Birkeland (1867-1917). Both built instruments, performed spectacular experiments, and wrote interesting texts.

I describe how a thorough study of a constructional detail on Francis Hauksbee's double barrelled air-pump from 1705 led to a new view on air-pump practice in the early eighteenth century.[1] Further, I show how restoring Professor Kristian Birkeland's aurora-chamber from 1913 gave new meaning to known texts.[2] By using especially three techniques, I managed to go deeper into their experimental practice than any historian before me: perusing the texts with technical details in mind; applying my previous experience as a modern instrument-maker to understand these details; and to reconstruct the instruments, either physically in hardware, or as sketches and diagrams. In addition to give an excellent understanding of Hauksbee and Birkeland's devices, this undertaking has also proved to be a useful starting point for studies of their various theories, and issues like social and commercial matters.

However, there are series of theoretical and methodological issues involved with this kind of approach. Here I will concentrate on the practical examples, and relate to Stefano Salvia's paper contained in this volume, and to coming texts for the contextualization of Hauksbee's and Birkeland's activities.

Hauksbee

So far, historians of science have mostly based their knowledge about Francis Hauksbee's air-pump by the text and the images in his book *Physico-Mechanical Experiments on Various Subjects* from 1709,[3] (Figure 1). However, during my doctoral work, it became clear that issues on how this pump worked in practice, for example how easy it was to operate, or what kind of experiments that were possible to perform with it, could not be fully understood by textual and iconographic sources only, nor attempts to understand its role in public and private demonstrations, but through the reconstruction of the actual experimental procedures that demanded studies of the object itself.

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1 T. Brundtland, 'Pneumatics Established: Francis Hauksbee and the air-pump'. D. Phil. thesis (University of Oxford, 2006).

2 T. Brundtland *The laboratory work of professor Kristian Birkeland* (University of Tromsø, 1997), ISBN 82-90487-90-8.

3 F. Hauksbee, *Physico-Mechanical Experiments on Various Subjects* (London,1709).

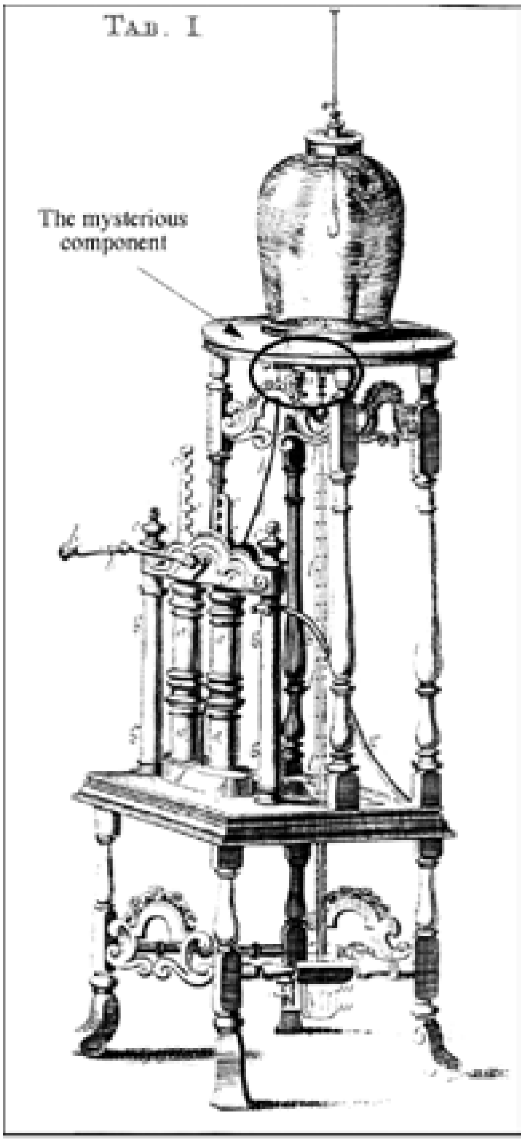

Figure 1: Francis Hauksbee's double-barrelled air-pump. London, 1709.

Today, at least eight double-barrelled air-pumps of the Hauksbee-type are found in museums and collections, now regarded as valuable objects that demonstrates the high standard and aesthetics of instrument-making in the eighteenth century. In September 2004 I had the opportunity to undertake a thorough examination of the exemplar in the Deutsches Museum in Munich (Figure 2). Before doing this examination, I was well known with Hauksbee's text on the air-pump and had studied the images carefully. Further, I had read his fifty articles in the *Philosophical Transactions*; the material on him found in the Royal Society in London; as well as his newspaper-advertisements and lecture-syllabuses. However, by standing next to the device, being able to take photographs of smaller and larger pump-components from all possible angles, and making sketches (Figure 3) and taking series of measurements, I realized that there where important aspects of this device that not could be inferred from a study of the text and illustrations only. Going back to the library, I re-read the text, re-examined the images, studied my new photos, and turned my sketches into functional diagrams.

During this process, I realised that my physical examination of Hauksbee's own machine gave new and extended meaning to known material, explaining both texts and images. As an example I will point to a component located immediately under the pump plate. In Hauksbee's account, we find terms like 'a piece of perforated brass which lies along horizontally', 'another piece of perforated brass which screws on underneath the Plate', 'a Brass Head, which fits into the fore mentioned Brass Piece', etc. Further, he describes something he called an 'Air-cock, which let in the air, mounted on the same perforated brass-piece in which the upper part of the Gage and the hollow wire are inserted (...)'. Despite a thorough reading of the text and study of the images, even from a technical viewpoint, the idea that the brass-piece could be characterized as a manifold and the brass-head as a demountable flange did not come to my mind. (A manifold is a small chamber or pipe with several openings for receiving and distributing air or gas). I was not able to imagine the exact form or function of these particular components, or understand their importance for the operation of the pump. In fact, the reading itself did not suggest that such complicated gadgets were present with the pump at all. By inspecting the hardware, it turned out that the brass piece was a carefully manufactured device that connected the receiver (the space where the experiments were performed in vacuum), the pump-barrels, the barometer, and the air-inlet cock to each other, using special de-mountable flanges with leather seals for making the whole device leak-proof. (Figure 4). In a vacuum-system, demountable flanges are necessary for easy maintenance, barometers for pressure monitoring, and the air-inlet valve for neutralizing the pressure so that the receiver can be lifted of after an experiment is over and the next experiment being prepared. All these features were crucial for a simple operation of Hauksbee's pump[4] (Figure 5).

Figure 2: Extant Hauksbee-pumps.

During my initial study of the original images, I had recognized a few details of a component partly visible under the upper pump-plate, which included a strange, small rhombic element (circled in Fig. 1). These were not visible on the available photos of the different pumps, and it was only after my examination of the Munich-exemplar that it proved to be a depiction of the 'brass-head' discussed above. Comparing Hauksbee's own illustration and the modern photos, it became clear that the image of the pump is 'distorted' in a very clever way, so that it displays a series of details which could not all be seen from a fixed position or picked up in one a single shot by a modern camera. (This is because the photos are captured through a single lens, while the engraving is an artistic representation, allowing the engraver to include more details).[5] Despite this sophisticated technique, a thorough study of the engraving with all its details, as well as of the text and the eight photos, were not adequate to get a full understanding of all the functions and features of this machine. By examining it, the object was allowed to speak for itself.

4 These facilities are now standard with all modern vacuum-systems.
5 The rhomb-shaped detail is now identified to be the square-headed tightening nut on the manifold.

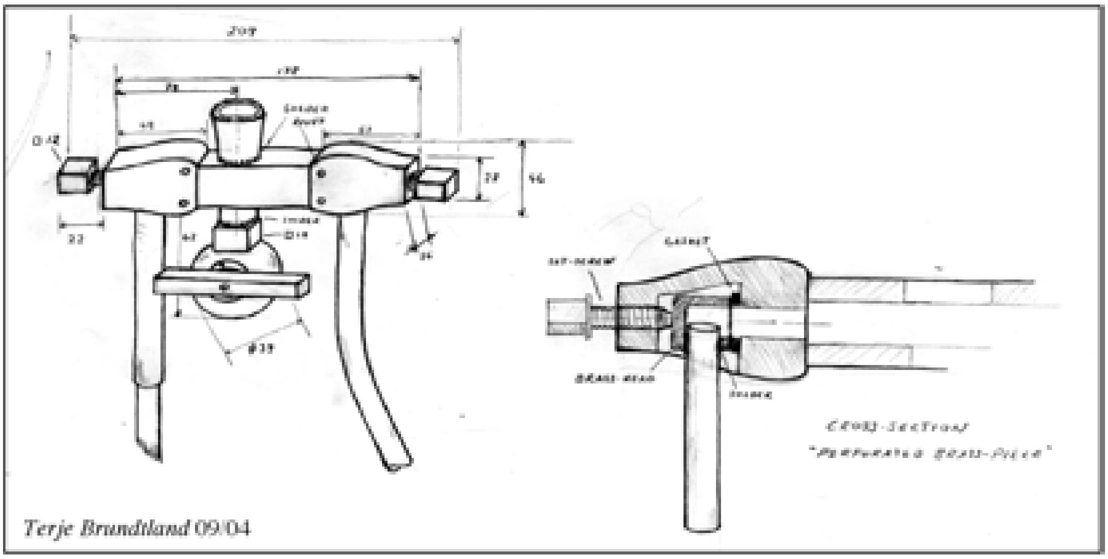

Figure 3: A perforated brass-piece.

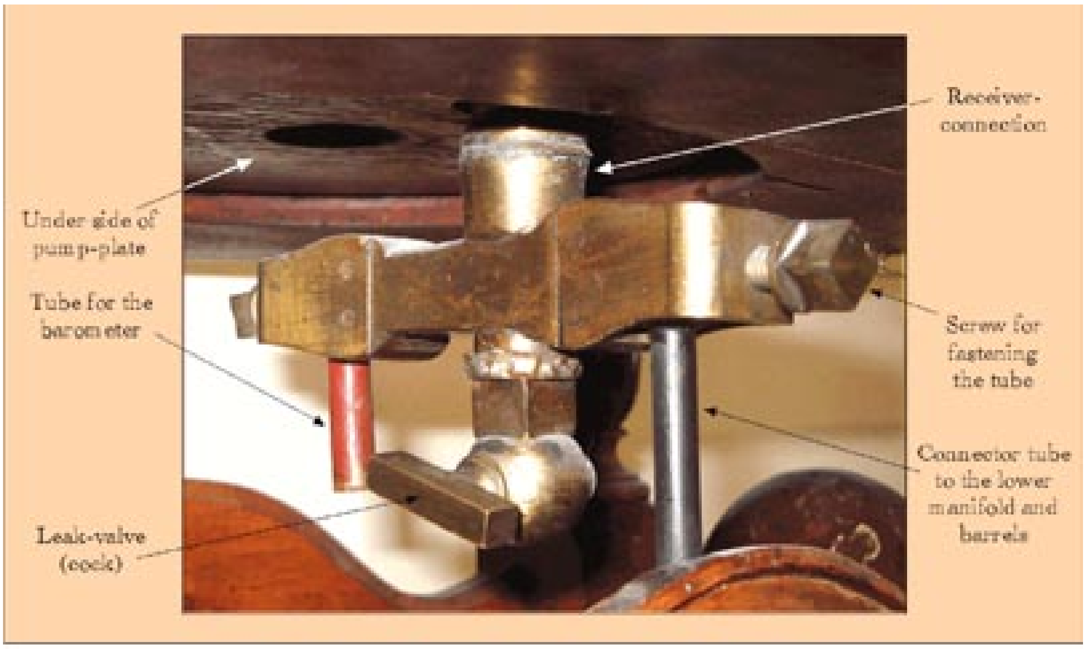

Figure 4: Upper manifold. Photo: Terje Brundtland.

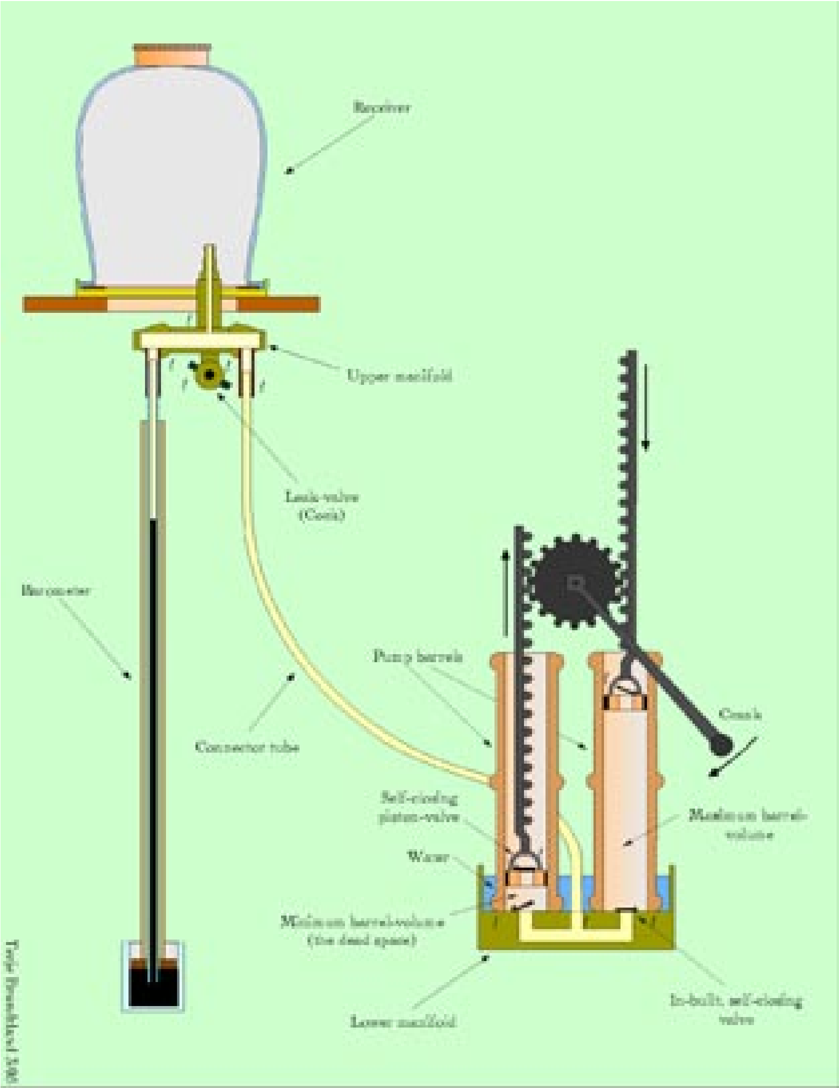

Figure 5: Functional diagram.

Birkeland

The next example is taken from my studies of Norwegian professor Kristian Birkeland (1867-1917). Birkeland lived an active life, doing laboratory physics, made expeditions to the Arctic, established an observatory on the mountain of Haldde in Northern Norway, founded industries and took out more than 50 patents. His main publication, *The Norwegian Aurora Polaris Expedition 1902-1903* of more than 800 pages is a wonderful mix of experimental and theoretical physics, technology, calculations, laboratory practice and travel descriptions.

In 1995, I was asked by the Physics Department at University of Tromsø, Norway to put one of his devices, a large vacuum-chamber for simulations of the Aurora Borealis from 1913 into working order. The physicists' intention was simply to use it as nice showpiece on a national physics-conference, honouring the 'Father of Norwegian physics'. To me it became my introduction to history of science.

To be able to undertake the work, I had to embark on a long journey into old scientific reports, past laboratory techniques, correspondence and unpublished shop-notes. Here I would like to show how the study of these textual sources proved insufficient to get a picture of what in fact had gone on in the laboratory eighty years ago.

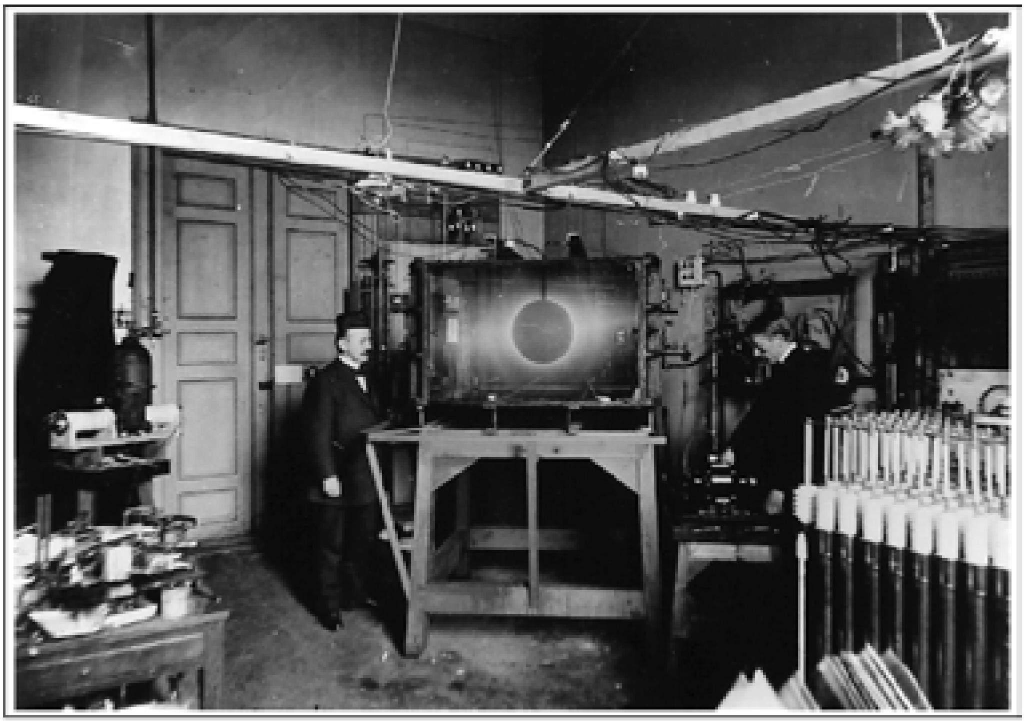

Figure 6: Professor Birkeland's Terrella Experiment. Christiania (Oslo), 1913.

Birkeland performed a long series of laboratory simulations of the Aurora Borealis and other cosmic phenomena. Starting in 1895 with experiments in small discharge tubes made from glass, he developed and sophisticated these techniques so that in 1913 he could watch his self-made auroras in a chamber shaped like a big aquarium (Figure 6). The chamber, with a capacity of about 700 liters (Birkeland described it as his '1000 liter-Space' (Verdensrom/Weltraum), had sides made from glass, the top and bottom from brass plates, and was kept together with four vertical corner posts. Each original glass side (window) was a flat, solid glass block, 4·7 cm thick, 100 cm in width, and 70 cm in height (Figure 7). There was an oval inspection hatch in the top-plate, large enough for an assistant to pass though in order to carry out repair and maintenance work. The experiments were performed by first emptying the chamber for air by an air-pump (vacuum-pump), and then setting up an electric discharge between an electrode in the corner and the surface of a magnetized sphere suspended in the middle of the chamber. The chamber acted here as a miniaturized Space and the sphere as a model of the Earth (a terrella). The electrode represented the Sun, the electric current between them the Solar wind. In turn, the light-phenomena that took place on top and bottom of the sphere were interpreted as small Aurora Borealis and Australis.

Due to the internal vacuum, the chamber was exposed to an enormous external pressure from the surrounding air, ten metric tons on the top and bottom plates, and seven metric tons on each glass window. To avoid breakage, the top and bottom plates were enforced with two brass beams each, which were fastened by through-going copper rivets. To stop air from seeping in along the rivets, as well as around the glass plates, huge amount of a tar-like substance, called pitcein had been used. With a total of 250 rivets and long fissures along the windows (55 meters altogether), this construction gave a lot of opportunities for leaks (Figure 8).

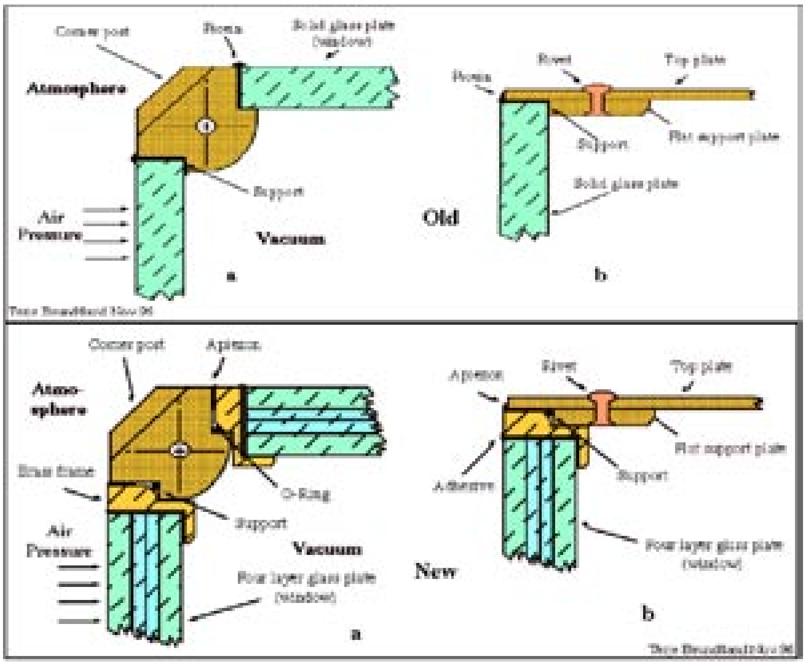

Figure 7: Old and new windows. **a**: top view. **b**: side view.

One point in this example is the difference in attitude to these leaks by the professor and the technician, and how I became aware of it. To me, as well as for Carl Devik (Figure 9), the technician who originally run the experiment for Birkeland, these leaks caused a lot of trouble. Birkeland himself, however seems to have been unaffected. In his book, this particular chamber is described as working perfectly, enabling him do all the experiments that he wanted to do, as well as to experience the pure joy of watching the colourful artificial auroras (Figure 10). The impression that emerges by reading his main publication is that this was his biggest and most successful experimental device ever. Before starting the restoration work, I was well known with his books and articles and some original lab-journals, notes, sketches, drawings and letters found in the archives. I had also undertaken an extensive examination of the actual chamber, as well as of all the extant hardware left by him, now found the Museum of Science and Technology in Oslo.

However, the reading and the examination did not prepare me for the fact that two weeks of hard work lay ahead of me when I switched on the vacuum–pump for the first time to evacuate the restored chamber. There were leaks everywhere and the air-pressure would not go down.

The original leak-tightening process is lively described in a few letters by Devik and in a newspaper article. In a letter to Birkeland, he described the problem of the tar cracking up and creating leaks during cold nights;[6] the difficult and time-consuming task of localising a crack, and the various methods to heat and apply more tar to stop the leaks. According to the newspaper, a search for a leak could take as much as eight days, inspecting the surface with a magnifying glass to localize the crack.

6 (The heating was closed off due to coal shortage)

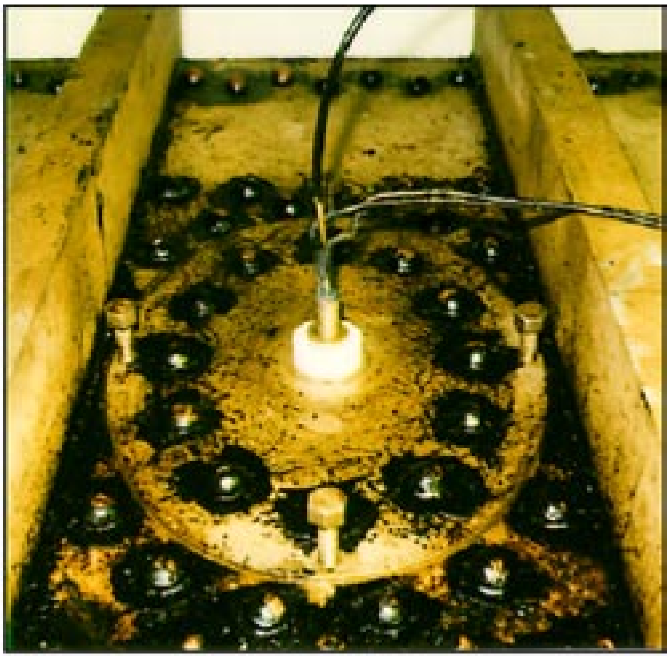

Figure 8:Tar on rivets and along fissures. Photo: Terje Brundtland.

It was only after the restoration work was done and I had gone through series of problems with setting up an experiment that the texts 'came to life'. Like Devik, I had to work for days to find and mend small leaks, by applying new tar with a small spatula and melting it with a torch on the actual rivet or fissure, watching the barometer to see if the pressure did go down. This was long and tedious process, especially with leaks on the underside of the chamber, with hot tar constantly dripping off. In this case, the restoration work both explained known texts as well as put me on new ideas about what must in fact have been going on in the lab more than eighty years ago.

Figure 9: Carl Devik cleaning the Universe. Due to oil deposits, the windows had to be cleaned regularly on the inside. Photo: University of Christiania,1913.

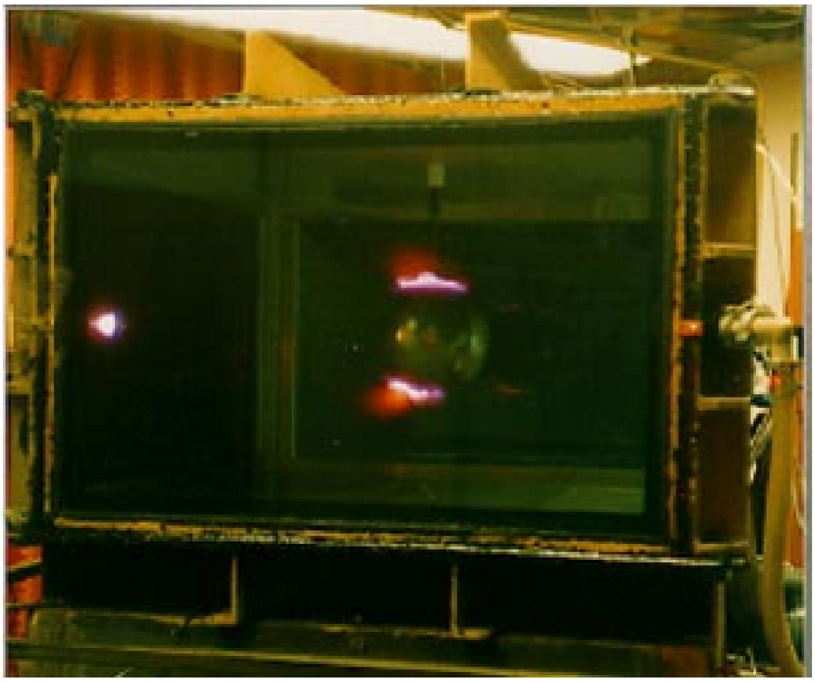

Figure 10: Aurora in the restored chamber. Photo: Terje Brundtland.

Discussion

Through these two examples, I have described how a study based only on texts and images fell short regarding understanding the function and use of two old scientific instruments.

However, there are many questions about theory and methodology that are embedded in the present approach. Regarding the terrella experiment, I started from scratch (I was at that that time working as a technician in a modern physics lab), without much knowledge about methodological problems in history of science. Now I have the possibility to go back and use these experiences to illustrate series of theoretical questions concerning restoring and replicating old scientific instruments and redoing former experiments. For example, during my work, the progress halted over and over again because of series of problems that came up. If the original sealing agent not were available, should I use a modern type? What about original versus modern manufacturing techniques? What to do when contemporary safety regulations prevented me from making the glass walls as thick (or in fact as thin) as the old ones? What to do when I had to make compromises to be able to proceed? These, and many other problems had to be acknowledged, discussed and solved, as well as documented during the work.

Generally, if experiences from a restoring or replication process are included in arguments about past scientific activities, every such encountered problem must be described and discussed, and every decision must be explained and made available to the reader. Further, I also experienced that it is possible to build replicas of old instruments in the physical sense only. The same effects might be demonstrated, but historical aspects like old manufacturing methods, use of materials, and developments of experimental skills will remain hidden, as well as sensuous experiences perceived by the operator and his audience. There is also a danger with this approach that the reworker will build his instrument to display only those functions he believes the original one possessed. The replica will then be a projection of ideas and opinions from before the work started, which will reduce the value of it as a historiographic tool.

The air-pump and the vacuum-chamber were separated by 200 years. Both, however, became important symbols: Hauksbee's air-pump as a model for the pump in Joseph Wright's painting *Experiments on a bird in an air-pump*, and Birkeland's terrella-chamber (circled) as an emblem on the Norwegian 200 kr. bank note (Figures 11 and 12).

Figure 11: *An Experiment on a bird in the Air pump.* Joseph Wright, 1768.

Hauksbee's double-barrelled pump is a well known example of a commercialized scientific instrument of its period. But how could it become a such? Other historians have pointed to social, economical and political issues to explain the 'rise of public science', including the possibilities for instrument-makers like Hauksbee to participate in this process.[7] However, to become an instrument that achieved such a status, the right political, economical and social conditions and timing were not enough. Also, characteristics as reliability and user-friendliness of the hardware itself had to be developed to a high degree to achieve a position like the one depicted by Wright. A component like the 'brass-piece' was crucial for such features. The pump had to be able to operate without a technician or instrument-maker present. To understand how it worked like it did, and thus why it could achieve such a position, a thorough study of technical matters was required. In this case, reading the text carefully and looking for technical details, like a

7 L. Stewart, *The rise of Public Science* (Cambridge, 1992).

technological exegesis, were not enough. The visual inspection yielded important information that enlightened and supplemented the text. However, it acted as more than a supplement. The examination was more like one task among others (for example studies of texts and images), used in a mutual process where the different elements explained and complemented each other. Only a reliable and easy-operational pump would have become commercialized and get a role in eighteenth-century public science. *Why* it was so simple to use can only be understood by inspecting the pump itself.

Figure 12: The Norwegian 200 kroner bank note.

The difference between published and unpublished material regarding scientific experiments has often been pointed out. Here, the story about Birkeland is a good example on how different a professor and a technician can portray the same experimental equipment. Of course, the texts were written for a different public and with different aims, but both are needed to get a full picture of Birkeland's laboratory work. Also in this example I had subjected the written material to an extensive study, here not so much to learn about Birkeland's physics, but more to understand the technical aspects of his experiments. As with Hauksbee, I had read and studied all the various texts and images that I could find. I had also undertaken a detailed examination of all the available hardware. At this stage, the visual information obtained from these objects played the same role in the process of establishing a new and firmer picture as with Hauksbee. Here I took this process one step further, by restoring the equipment and redo some of the experiments. In this case I felt I was able to come even closer to the original activities.

However, and opposite to Hauksbee, Birkeland's device did not become a technological success. Despite his terrella-experiments were appreciated and adopted by other scientists; the chamber where they took place was never copied or commercialised. Now I now why: the actual construction was too leaky and cumbersome to use, requiring the constant presence of a keen and loyal assistant, and unsuited for reproducible experiments. Neither Birkeland's text, the technician's letter or the examination of the chamber itself brought me to this conclusion. It was the long and tedious leak-tightening process that became my way to this particular object.

"Some Thoughts for Non Modernist Science and Technology Museums"

Jean-Baptiste Fressoz[1]

This is a talk about museography. Or rather about the master narratives presented in science and technology museums. It is a talk about their politics of display which I believe is partial, harmful and outdated. It is a talk about how we could change these narratives. But first of all, since I have hardly any experience in the field of museography I want to apologise to museum people if what I say appears to them a bit naïve. I will not study the ways these new narratives can be put into practice in the concrete space of the museum. The (numerous) images I present here are only poor substitutes to this work which can be achieved *in situ* only. The aim of this paper is different, more abstract in a way. What I will do is to use my experience as an assiduous visitor of science and technology museums (and god knows how assiduous we have been in visiting science museums for two months across Europe!) to analyse the current master narratives of these museums and propose new ones.

Figure 1: The steam engine as a ready made museum piece.

1 This paper stems from a paper delivered at the Max Planck Institute for the History of Science, Berlin during the final workshop of the Wandering Seminar. It retains its oral character. I have only added some references. I want to thank Lorraine Daston to have initiated this program, Hannah Lotte Lund for the organisation. Many thanks to my fellow wanderers for the discussions and remarks on this paper, and more generally for the talks and fun we had during these two months of travelling.

The current crisis of science and technology museums

The main feeling I got from visiting science and technology museums and discussing with curators was that of a deep crisis. At the roots of this crisis lies a temporal gap: because science and technology museums were conceived in the 19th century as repositories of technological and national pride and as a material illustration of the heroism of progress, the consequence is that they are now completely at odds with our present experience of technological innovation. Nowadays, innovations are obviously a major subject of social, ethical and risk controversies. But at the same time museums still present innovations as milestones on the long road of progress.

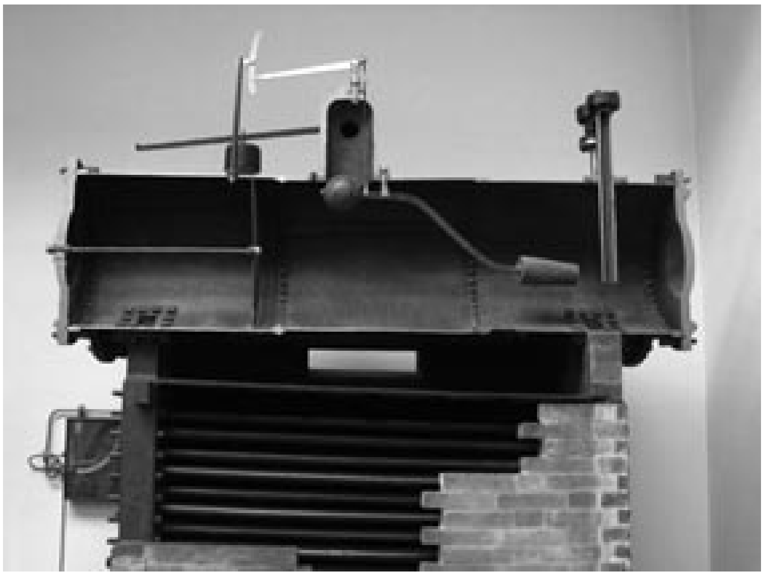

Figure 2: The pedagogic boiler.

What are basically science museums? To put it very simply they are museum objects put in galleries. And both the gallery and the object are highly problematic notions. First, the gallery. In big, often national museums, (all what I say applies rather to these museums, not to smaller, more focused collections or specific exhibition where there is much more freedom and originality), the most common way of displaying objects is to place them in different galleries according to their types and in chronological series. The result is typically: flight from balloons to the space shuttle, or energy from the steam engine to the nuclear plant. This is doubly convenient: the architecture of the museums structured in galleries parallels the disciplinary structure of science and technology. The gallery embodies the vision of technological progress as an autonomous process, a quasi Darwinian process with technological objects nearly engendering one another and getting towards perfection.

The other problem is the notion of the "museum object", of the masterpiece worthy to be displayed.[2] The idea of a museum masterpiece necessarily induces a certain politics of display. For instance let's take the steam engine section in the *Deutsches Museum* Munich. There are very

2 Actually technological masterpieces are not obvious masterpieces. At the *Deutsches Museum* in Münich a sign would be added saying: "Watch out masterpiece!"

beautiful steam engines. Some convey a feeling of solidity and robustness through their neo classical style. They are ready-made museum pieces: they affirm their importance as major events in the history of mankind at par with Greek temples (Fig. 1).

Or you may also have this pedagogic *écorché* which displays to the visitors its analytical rationality: pressure increases, the safety valve opens, pressure decreases. It is simple, it works and it is perfect (Fig. 2).

Figure 3: The exploded boiler. (Boiler explosion, Paris, 1858, Archives nationales).

But museum curators should be conscious that choosing these objects for representing steam technologies is a perfectly arbitrary act dictated by the idea of the museum piece as the masterpiece. It is a political choice. As many 19th century steam boilers finished their lives in an explosion (finishing at the same time the lives of a few humans standing nearby), it would be perfectly legitimate to choose this photograph as representative of the experience of steam technologies (Fig. 3).

Of course curators live in the 21st century, and they are perfectly aware that technologies are now subjects of intense social debate. From what I could see, the solution they have adopted is to keep a staunch modernist display for old technologies (older than two generations roughly) and to add a few elements on controversies for more recent ones. So at the end of the energy wing of the *Deutsches Museum*, after the nuclear power section, you can find a small panel about the pros and cons of nuclear plants, the importance of environmental issues, the role of public participation, the fact that other technological solutions can be proposed, etc. It does not look very enticing does-it? (Fig. 4).

Or even worse: let's consider this panel: (Fig. 5). The title is fascinating: "Environmental topics are short lived." It is located in the environment section of the *Deutsches Museum* and faces a showcase displaying various instruments for tracing and measuring chemical pollutants. The short notice explains that since environmental issues are constantly changing, any panel on environment would become quickly outdated, and thus the museum prefers to pin up newspapers articles on environment as they come out. And indeed, the visitor could notice that the older paper clips started to turn yellowish… One could comment endlessly on the assumptions made by this notice: assumptions about the nature of the environmental issues, the role of the media as creating undue and passing fears, of public controversies generating a waste of ink and paper… But also assumptions about the role of the museum and its relation to time: museums are institutions that deal with long temporality and technological essences whereas civil society is the realm of fluxes and cultural accidents. This panel and the environment room in general contribute in building up several boundaries: between nature and culture (instruments in front of caricatures and newspapers), between stable reality and variable cultural meanings, between numerical measurement and words, between experts and laymen.

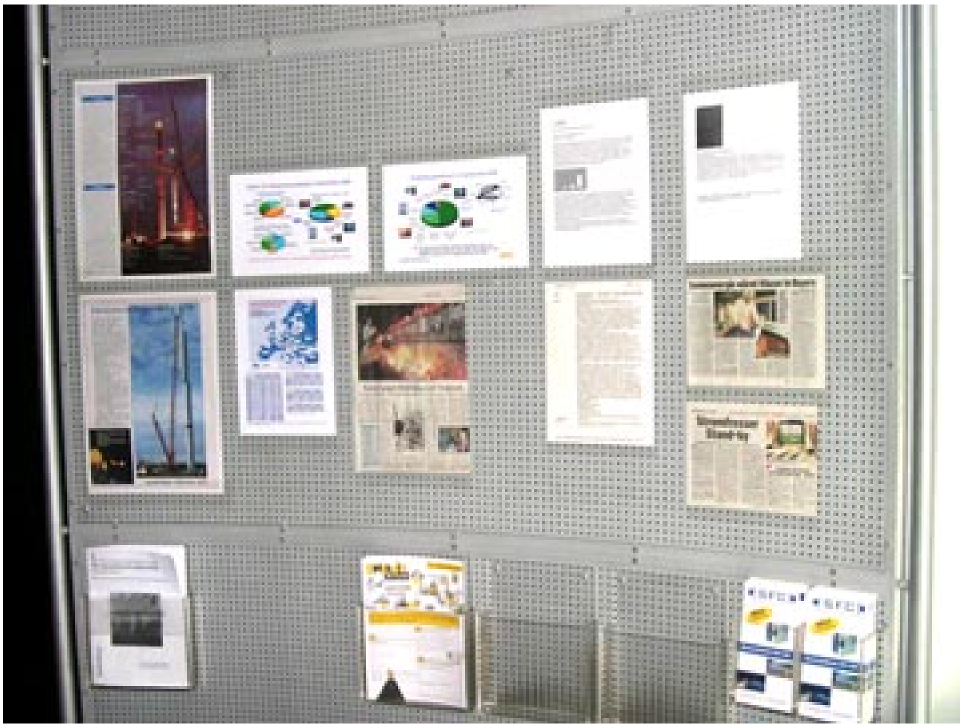

Figure 4: The energy debate panel.

You can also have a slightly better strategy: it is to "involve the visitors." For example in the Wellcome Wing of the Science Museum in London, the public can vote for or against biometry… This strategy seems to me unsatisfactory. It gives the visitor the illusion of participation. It reduces the complex notion of public opinion to its statistical ersatz. Polls, as everybody knows, frame questions and impose categories, whereas the main interest of public participation is rather to multiply the possible frames of reference, to put, on the political agenda, problems and concerns that were not taken into account by dominant discourses. It is rather a prescriptive display of what public involvement should be (a rather quiet and apolitical one), rather than a description of the various forms that technological controversies now take around the world from the availability of AIDS medicines to the impact of low doses. "Public participation" is sometimes highly polemical, violent, or subversive, sometimes heuristic, sometimes both, but is not limited to polls.

I am not going to discuss these attempts, as probably far more convincing strategies exist. *What I want to argue is that in any case it would be misleading to limit them to contemporary* *technologies. If the public starts to be involved, if technologies are shown to be debated, if the environment is referred to only in the very last rooms of the museums, it will necessarily remain anecdotal compared to the grand narrative of progress proposed in all the other rooms. One crucial problem for science and technology museums is to integrate controversies in all the rooms, to make it understandable that environmental problems, technological risks and controversies are not something radically new but have existed all along.*

Figure 5: Environmental topics are short lived.

Actually this way of displaying controversies as recent phenomena only reflects the current sociology of technological risk. Most of the important and visible authors (Ulrich Beck, Anthony Giddens, Niklas Luhmann, Hans Jonas) tend to present technological risk, the awareness of environmental degradation, and the social reflexivity towards innovations as a radically new phenomena characteristic of our modernity. And I believe that this way of narrating or displaying the history of the relationship between technoscience and society is first historically misleading, and second, politically unsatisfying. First as historians of technology have demonstrated and redemonstrated, technologies are socially shaped and what I would like to add immediately is that technological safety is perhaps the most socially shaped aspect in technology. Debates, resistances, oppositions were absolutely essential in the shaping of safer technological systems. So if the museum visitors could get a more realistic history of technologies they will be able to reflect upon their own role as "technological citizens" in the shaping of safer or environmentally friendlier technologies. Second, insisting on the radical novelty of risk society leaves us hoping that now, because we are conscious of its dangers, aware of its environmental problems, we shall be able to manage technoscience. This way of presenting the problem has the defect of framing the question in cognitive terms: the main problem of *risk society* is about knowing risks. But if the history of technoscience is in fact the long history of awareness without much action, a long series of unheeded warnings and environmental degradation, the question is reframed in more political terms. It is no more about knowing risks but about deciding what to do to about them.

The museum I would like to propose in this talk, the museum I would dream to visit, seriously takes into account the fact that technologies were always matters of controversies. Social studies of science have taken controversies as a heuristic tool because they provide a powerful way to display the networks that innovations create, and through which innovations come to existence. I will argue that they would also provide the museum with a way of radically broadening the range of objects and persons that can be displayed together. They would break the tragic isolation of the museum piece. In the rest of my paper I will proceed in three steps.

First, I would like to show that such a museum of controversies would not be a purely retrospective construct. It is only a come back to a forgotten historical root of the museum. Of course, as Paula Findlen has demonstrated, museums were born in the Renaissance cabinet of curiosity.[3] And then, in the 19th century they became centres for research and teaching. But there is a third genealogy (of minor consequence, I concede) which I would like to trace from the *musée technologique* invented in post-Revolutionary France. The musée technologique's aim was to organise public controversies so as to select the best technologies.

Second, I will explore one way of "demodernizing" science and technology museums which is to display not technologies but technological controversies and I will take as an example the gas lighting controversy which raged in the 1820's Paris and London. Third, I will show that another powerful way of changing the narratives displayed in science museum would be to propose a museum of *representations*. Its aim would be to consider political and scientific representations as the two faces of the same coin. And I will take as an example the cases of inoculation and vaccination.

The invention of the "musée technologique" as a space for technological controversies

In the French technological press of the early 19th century, it is obvious that the "musée technologique" (that is industrial exhibitions) is a national invention. Victor de Moléon, organizer of the 1819 industrial exhibition tells us its genesis.[4] Part of the story is quite unoriginal: it started in 1798 when François de Neufchateau the interior minister had the "truly national idea" of establishing a "Temple of Industry" at the Champ de Mars in Paris. The place was not innocent as it was where troops were trained. The aim of the Musée de l'industrie was to parallel the glory of the the Revolutionary and Napoleonic wars with the celebration of the inventors. According to Moléon, the Musée technologique was French (and not English) because in France technology was

3 Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy*, University Of California Press, 1994.

4 Victor de Moléon, « Discours préliminaire », Annales de l'industrie nationale et étrangère ou mercure technologique renfermant la description du Musée des produits de l'industrie française, exposés au louvre en 1819, Paris : Bachelier, 1820.

a public concern: "L'anglais sous le rapport des arts, est jaloux et envieux; son égoïsme l'écarte toujours de la communauté ; et on serait tenté de croire, en le voyant se renfermer en lui-même, qu'il a pris pour modèle la nature qui a circonscrit son île ». Whereas in England, technology was a purely private and economic endeavour, French technology was the heir of science, it was "vraiment éclairée" and therefore public.

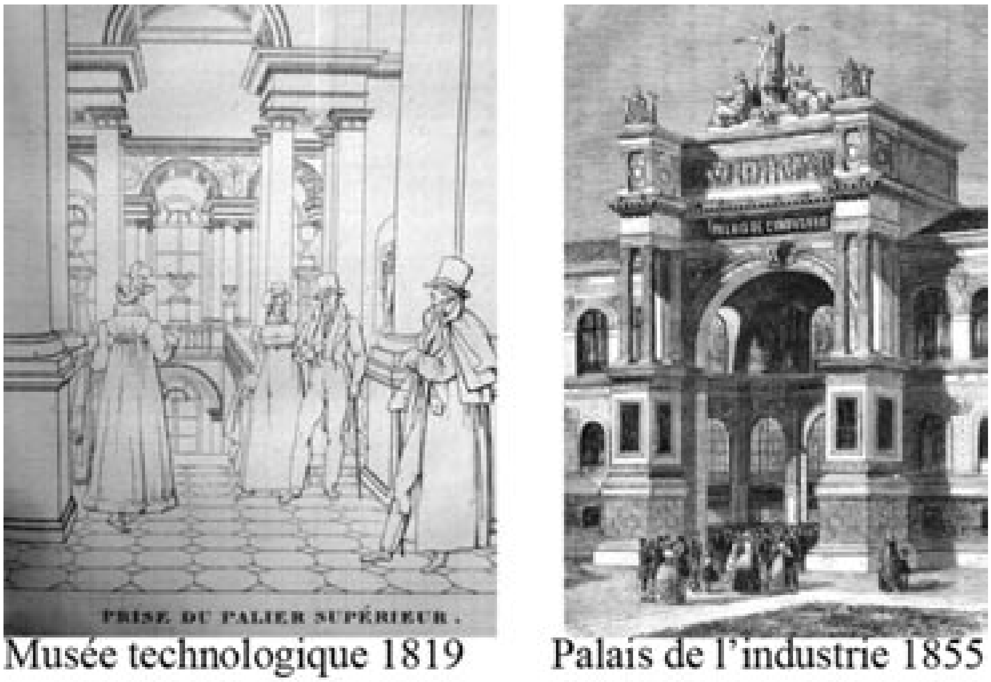

Figure 6: The dismissal of the musée technologique.

The other reason given for the establishment of the Musée technologique is more interesting. According to de Moléon the market is not able to select the best inventions. The history of invention is crowded with solitary geniuses deprived of public recognition and thus without access to the market. Or the market tends to create technological bubbles, crazes and fashions, because capitalists are not able to judge the worthiness of inventions. Financiers are in the claws of charlatans. Innovations are dangerous because they can make fortunes disappear. The Musée technologique is an alternative to the market: it is a rational and public way to select the best, the most useful invention. First, because objects and people are placed in the same room: "In this place are reunited people and things which can only gain the greatest advantages of this reunion. The useful discoveries, or the one which brings the well being of mankind, make it possible to judge the useless or even harmful ones".[5] Because technologies are put together, the public can compare. Second, the public is the best judge. It is praised according to the 18th century discourse of the public sphere: "an impartial and inflexible power puts every man and every object at their right place: this power is public opinion, it levels everything. As soon the public enters the rooms, being independent of names and titles, it examines with impartiality, compares with fairness…" And third, the Musée technologique will foster debates on technologies which are useful for the

[5] Idem, p. 43.

government: “The 1819 exhibition has attracted many spectators and has thus fostered many controversies… These discussions have their positive side. They allow the authority to profit from the advice of some and the critiques of others. It is an arena in which the constitutional government likes to see disputants because it brings lessons so as to improve the future.” In short, the Musée technologique was conceived as a place for creating a public sphere for technological choices.

It failed lamentably. The industrial exhibitions became “Temples of Progress”, where the crowds gathered to be impressed. The ideal of an enlightened public debating and judging innovations for the common good disappeared.

A museum of controversies

But controversies disappeared from museums only. In the real world, innovations were disputed: their advantages, their profitability, their environmental consequences and risks triggered intense controversies all along the nineteenth century. What could a museum gain in displaying these controversies? I will start answering this question by focusing on the case of gas lighting.[6]

Gas lighting, because it was established in operas, salons, theatres and streets, because it was a public technology, was one of the most debated innovations of the first industrial revolution. Whereas a steam boiler explosion in a faraway industrial district did not cause a stir, the slightest inconvenience, smell, or accident in the centres of the social life of Paris or London was immediately noticed and resented. In Paris particularly, pamphlets, journal articles, theatre plays, even operas were written so as to discuss the pros and cons of lighting by gas.

Arguments proliferated. I would like to underline the richness of this debate and the variety of entities it mobilised. First, it involved interesting reflections on long term resource management. Such prominent industrialists as Chaptal or Clément-Desormes argued that it was unwise to distil coal so as to produce light. Coal is not a renewable energy and should be spared for casting iron. Gas light was acceptable only if Colza oil was used instead of coal. But this, in turn, could cause other problems as good farm land would be wasted for the convenience of the urban elites. On the other hand, proponents of gas argued that by distilling coal, the industry would produce coke available for heating. It would in turn replace wood and therefore preserve French forests. And as the deforestation following the revolutionary troubles was accused of having caused climate change and bad harvests (the rigorous winters of the 1820s), gas light was presented as a solution for saving the temperate climate of France. For the opponents, gas light had a rather different climatic consequence. It would render the climate of Paris insalubrious and create epidemics. Because gas originated from coal (that is putrid matter buried deep underground), it could reintroduce into the heart of Paris the miasmas which depopulated the marshlands.

Gas lighting also made explicit what it meant to live with a technical network. It put individuals into new chains of dependency: the *maître du foyer* had to rely on the correct working of distant manufactories for his very light. This feeling of dependency was strongly resented, and an advertisement for gas lighting emphasized contrariwise the new mastery it would confer to customers over their own illumination. In this 1823 poster, one can see the man jumping out of

6 See for references: Jean-Baptiste Fressoz, « The gas lighting controversy. Technological risk, expertise and regulation, in nineteenth century Paris and London”, *Journal of Urban History*, July 2007.

his bed, turning up gas light and aiming at smugglers with his gun all in the same instant. Thanks to the swiftness of gas light illumination, the *maître du foyer* is able to defend his wife against the menacing intruders.

Figure 7: Controversy and the proliferation of arguments.

But the critique of technical dependency went further. Gas lighting threatened security because all lamps could be extinguished simultaneously from a distant manufactory and create sudden darkness in a whole city. Gas could thus be a tool for rebels. In 1823, in London, this possibility was taken very seriously by the House of Commons Select Committee on Gas Lighting which debated at length to discover if "a workman or a rioter in possession of the premises might produce explosions": How long would it take to make a gasholder explode? How many rebels would be necessary? Would it be a suicidal attempt? In 1820s France, marked by a succession of failed plots against the monarchy such a possibility was very threatening. It seemed that gas lighting was making the security techniques of nineteenth-century police obsolete: "What does the new system do but open galleries under the soil over which eight hundred thousand people walk during the day and rest during the night, and laying under the palaces of our monarchs, permanent mines [...] which, for destroying everything, only wait for one mistake. And how easily could a faction engineer such a mistake." To counter this critique, proponents tried to demonstrate the resilience of the network. Accum explained in an early book on gas lighting that gas could not be extinguished so easily: if a pipe was broken, the gas could still find its path through the other mains of network (*A practical treatise on Gas light*, 1815).

In 1823 the controversy focused on the risk of explosion of a gasholder because the entrepreneur Antoine Pauwels had built in Paris the biggest gasholder in the world, it was ten times bigger than the biggest one in London. The opponents advocated for a kind of precautionary principle: the explosion of the gasholder, though improbable, would have so dire consequences that it would be wiser to forbid gasholders from the centre of Paris. The magnitude of the possible explosion was obviously exaggerated by the opponents, who imagined Paris completely razed to the ground: "six hundred thousand citizens are at the mercy of an error." "A million lives are suspended to an error or an act of folly". After long and tortuous legal battles, the government decided to legalize the gasholder but ordered the academy of science to devise a regulation for the new industry.

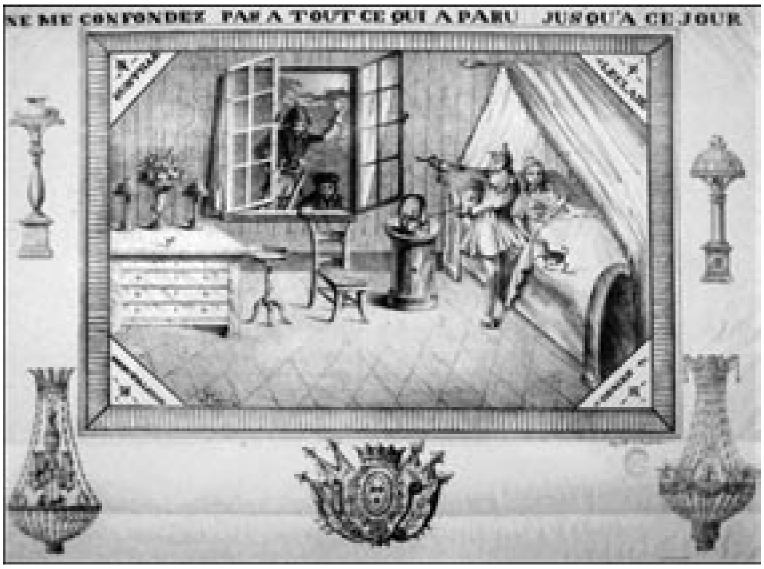

Figure 8: The *maître du foyer* and gas lighting.

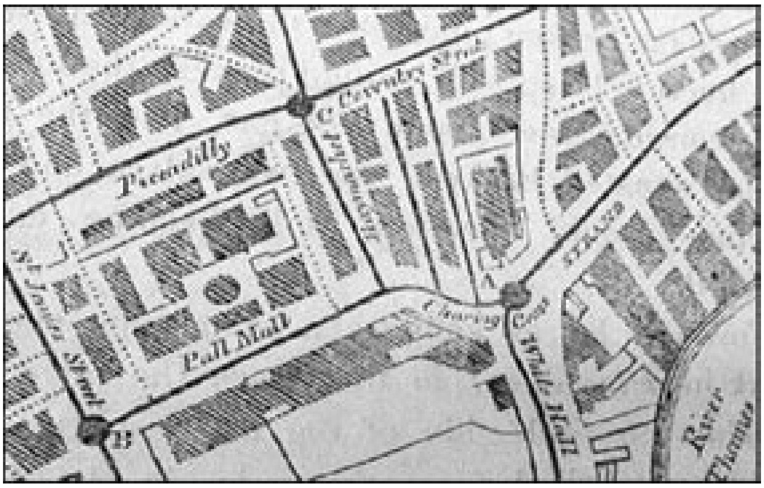

Figure 9: *The resilience of the gas network.*

A museum display showing these controversies would have several advantages. First, the public would no longer be absent or presented as a passive consumer or user of technology. Mobilisation around gas, judicial battles and petitions fostered the implementation of the first regulation on gas lighting (which by the way was one of the very first safety regulations of the industrial age).

Technological safety does not come from nowhere. In England, where the government did not regulate the industry, gas technology remained particularly insecure well into the 1850s.

Second, such a display would give back its ecology to gas technology: through the controversy, the ontology displayed in the museum suddenly broadens: climate, hygienists, deforestation, whales fisheries (which supplied the candle manufactures threatened by gas), enigmatic miasmas, rebels, colza fields, academicians, MPs (in England the problem was tackled by a parliamentary committee) etc. etc. are mobilized in the controversy. Such a museum of technology would also be a history museum.

I truly believe that presenting technologies through the lens of controversy is a powerful way to make them far more talkative to the current audience. It “re-presents”, i.e. puts in the present again, the technology in the sense that it connects it with our present experience of living in a technological age.

Representation and its networks

Focusing on the question of representation could be another strategy. It was often heard during the seminar that objects should not be auxiliary to texts. The exhibits should let them speak by themselves. I think this idea is misleading. Scientific objects (whatever that means) have precisely the peculiarity of not speaking by themselves. They are mute; otherwise, there would be no need for scientists and their expensive apparatuses. The alternative is not between letting the objects speak by themselves or speaking for them through museum panels. A third way is possible: it is to give back to them their companions, their voice, their networks. Science and technology museums could emphasize that the representation of objects is a highly historical and highly political question. It is intrinsically linked with the question of the representation of people.

I will take an example suited to my argument: inoculation and vaccination against smallpox which are necessary milestones in museums of the history of medicine.[7] The showcases for these immunization techniques tend to contain lancets, lancets cases, beautiful ones, adorned with silver, gold, or mother of pearl…

This obsession with lancets is linked to the obsession of the “museum object”. The museum object must be beautiful and precious. (History of medicine museums have also a fad for objects carried by famous physicians). In fact lancets don’t matter at all for inoculation and vaccine (the same were used for bleeding). A showcase about inoculation or vaccination should rather display the means of representation used at that time to make these very peculiar medical procedures talk to doctors and public (Fig. 10).

In the 1720s, for the first time, numbers were used for assessing a medical procedure. Risk, this now ubiquitous word, emerged as a technique of representation for inoculation. And at that time it was highly controversial. Saying inoculation risk is 1/200 posed problems ranging from theology, casuistry and politics (Fig. 11). Is it moral to risk my life? Since it belongs ultimately to God, am I allowed to risk it as rational as it may seem to me? 1/200: does it mean that the one who dies during inoculation was sacrificed for the well being of the 199 others?

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7 For refrences see Jean-Baptiste Fressoz, « Comment sommes-nous devenus modernes ? Petite histoire philosophique du risque et de l’expertise à propos de l’inoculation et de la vaccine », (Forthcoming).

Figure 10: Lancets don't talk.

Anticipating Rawls' argument of the « veil of ignorance » the propagandists explained that inoculation was moral because before the operation nobody knew who was going to die. Everyone accepted freely a risk in the hope of maximising his safety. It is quite remarkable that Rousseau who wrote the *contrat social* right in the middle of the controversy used the same argument so as to justify the right of life and death of the sovereign:

> Le traité social a pour fin la conservation des contractants. Qui veut la fin veut aussi les moyens, et ces moyens sont inséparables de quelques risques, même de quelques pertes. Qui veut conserver sa vie aux dépens des autres doit la donner aussi pour eux quand il faut… La peine de mort infligée aux criminels peut être envisagée à peu près sous le même point de vue : c'est pour n'être pas la victime d'un assassin que l'on consent à mourir si on le devient.[8]

For some, risk threatened the political body. Hobbes argued against Boyle that experimentation threatened civil peace because a small group of natural philosophers could escape the common experience and the common ontology. Risk introduced the same kind of division because it built a moral grounding for a personal action which differed from the natural law; or rather it introduced a new natural law expressed by probabilities. For some opponents, the dangers of inoculation were not medical but political. Leaving the management of body and health to personal choice, threatens the sovereign: « If a Man makes free with his own Body-Natural, because in Conscience he thinks he ought to do so… it is a considerable step towards making free with the Body-Politick e.g. he foresees something like to be amiss in the State which in Conscience he is obliged to prevent by a lesser Illness or Commotion; as has happened in several Places in Europe in former times by the Instigation of some who call themselves Religious[9]. "

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8 Rousseau, *Du Contrat social ou principes du droit politique*, 1762, livre II, chapitre V, « du droit de vie et de mort ».

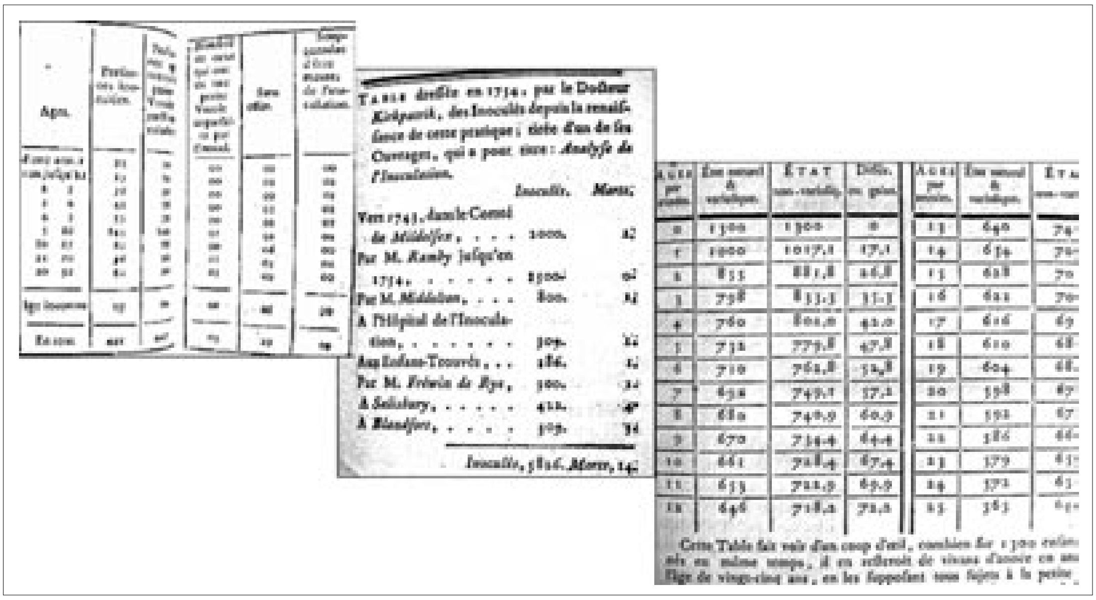

Figure 11: Risk as a means of representation.

Risk was also a political tool. It was used as such by French philosophers and geometers who waged a war against the monopoly of expertise of the doctors of the Faculty of medicine of Paris. For the traveller and academician Charles Marie de La Condamine who popularised inoculation in France, once the inoculation problem was formulated in terms of risk it was not medical any more but "un pur problème de calcul des probabilités… le docteur en médecine est plus capable d'embrouiller que d'éclaircir la question …s'agit d'une question compliquée qui ne peut être résolue que par la comparaison d'un grand nombre de faits et d'expériences d'où l'on puisse tirer la mesure de la plus grande probabilité… et l'on sait que le calcul des risques appartient à la géométrie ». Risk toppled doctors and legitimated new experts. It also created a public sphere for judging a medical procedure. Thanks to risk, reasonable men could decide upon the question. At the same time, risk excluded the mothers from a domain (the health of children) where they were assumed to be competent. Because women in general and mother in particular obeyed to their sensibility and not to reason, they could not decide for their children: « de cent femmes, de cent mères, il ne s'en trouvera pas une qui ait assez de lumières pour voir qu'elle doit inoculer un fils chéri ». Risk defined a very narrow and sexist public sphere dominated by geometers. It excluded other discourses: medical, religious and ethical. A museum focusing on representations could stress the many links between science and politics, between scientific and political representations. In the eighteenth century risk was at the heart of the struggle for medical authority and for some involved a redefinition of the sovereign

Because risk was controversial as a means of representation, in any case, it failed to convince: few people were inoculated in France in the 18th century. With the advent of Jennerian vaccination in 1800, other technologies of representation were used. Because vaccine had no ontology before the advent of bacteriology, its representation was necessarily made through the representation of the vaccinated bodies. The vaccine pustule was described with an amazing

9 Douglass W. (1722), *Inoculation of the Small Pox As practised in Boston*, Boston.

wealth of details: its evolution, colors, consistence and anatomy were related in chapter long descriptions. This clinical description was at the root of medical power (Fig. 12). As Foucault argued, power resides in the details. And it is through their mastery of details that vaccinators could justify vaccine failures. Vaccine had one obvious problem: many vaccinated people had smallpox. The solution for the vaccinators was to create a new category: the false vaccine. Only the TRUE vaccine was preservative of smallpox. If a vaccinated person got smallpox it was answered to him that his previous vaccination must have been a false one. Graphic representations of pustules created this distinction between true and false vaccines.

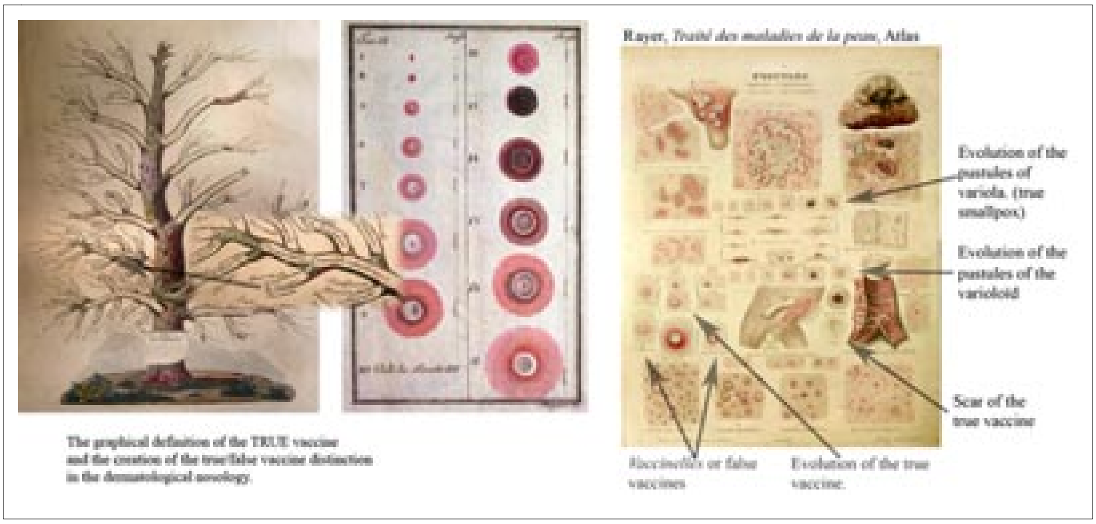

Figure 12: The graphical nature of medical power.

This kind of graphical representation (exceptional in the early 19th century) was the material source of medical power. These images were the "immutable mobiles" of clinical medicine (B. Latour). They unified doctors' definition of the true vaccine and created the vast ensemble of false ones to justify vaccination failures. The more detailed the representation of true vaccine was, the more it was possible to invoke a slight difference in the actual pustule: colored and serial drawings were used so as to expand the numbers of false vaccines.

But at the beginning of the 1850s this kind of graphical definition of disease became problematic as mechanical objectivity rendered these true to life drawings less "objective" (Fig. 13). Doctors now reproduced vaccine scars mechanically with wax imprints. It appeared that there was no such thing as the scar of the true vaccine, but hundred of different kind of scars, all of which resulting from a seemingly good vaccine. The subtle distinctions which justified vaccine failures collapsed. At the same time revaccinations started to be enforced.

Finally, these wax models of vaccine accidents should also be considered as a representation of what vaccine was (Fig. 14). Vaccination until the very end of the 19th century was performed from arm to arm, thus transmitting with the cowpox virus many other diseases from syphilis to various staphylococci. A vaccine was far from being a benign procedure until animal vaccine was generalised at the end of the century and bacteriology could figure out *beforehand* what was inoculated. The laboratory which appeared in the "offices vaccinogènes" proposed yet another representation of vaccine which had the great advantage of using microscopes, cows and rabbits instead of human babies for representing vaccines.

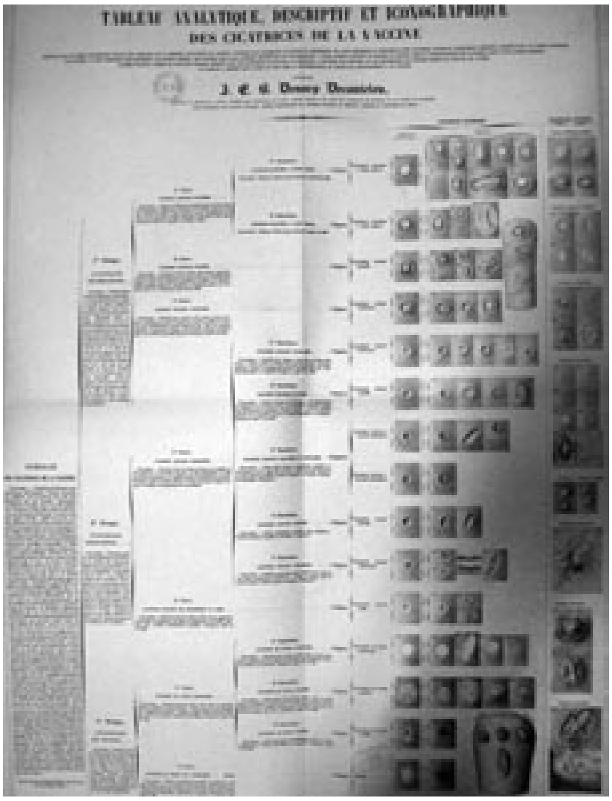

Figure 13: Mechanical representation of vaccine scars.

The problem of representing an object in the museum is not fundamentally different from the problem of representing it anywhere else, in the public sphere or in a laboratory. Technologies do not speak by themselves: many other techniques are necessary to make them talk and the museum object is rendered mute by its artificial isolation. In the case of inoculation and vaccination these means of representation were very varied from numbers to drawings and microscopes. Each one involved a different way of linking the individual body with the political one.

Conclusion

The museum I propose is neither a museum of accidents, nor a museum of the horrors of progress, nor a museum of its errors (to use Bachelard's phrase). On the contrary, the examples I have chosen (vaccine and gas lighting) were incredibly successful technologies. This would be a messy museum. It would be open to the many entities involved in technological networks. With gas lighting and vaccine only it would already include : various technical devices from gasholders to microscopes of course, but also hygienists, doctors, epidemics, climate, landscapes, romantic writers, judicial courts, lawyers, parliaments, insurance companies, statistics, faculties, academies, theologians, casuists, god and providence, risk, graphic representation of pustules, cows and rabbits etc. etc. (Fig. 15).

Figure 14: Ulcerous vaccines (circa 1880).

OFFICE VACCINOGÈNE CENTRAL DE L'ÉTAT

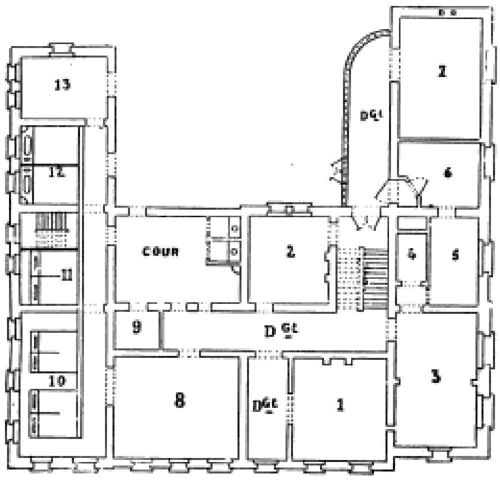

Fig. 1.

1. Laboratoire. Les travaux effectués dans le laboratoire ayant pour but de contrôler la composition bactériologique et la virulence du vaccin, la salle est pourvue des instruments et appareils nécessaires aux recherches microscopiques, aux cultures microbiennes et à l'inoculation des animaux de contrôle.

Figure 15: The bacteriological representation of vaccine.

By focusing on controversies and representations, such a museum could display the progressive mangle of technology and society. It would be a museum able to convey the feeling that the political, the natural and the technical are more and more intricate. It would be the history museum of our current state as technologised humans living on a technologised planet.

On the Aesthetics of Scientific Objects. Three Case Studies

Johannes Grave

In what sense can we say that things are talking or talkative? In the introduction of the anthology *Things That Talk,* Lorraine Daston does not question whether things can actually talk. Instead she offers two examples of things that talk: those generally regarded as "untrustworthy" and "intended to manipulate and deceive" (idols)[1], and those which are able to speak for themselves and stand for an ideal of self-evidence (*res ipsa loquitur*).[2]

In both cases, the things that talk seem to imply a more or less well-defined intention. Independent of the actual viewer, be it worshipper or scientist, the thing represents a particular true or deceptive "message". But what would it mean if things talked in a hardly understandable way, if they were stuttering or saying something totally absurd? Things of this kind can often be found in literary works. E. T. A. Hoffmann's novel *The Golden Pot* impressively illustrates how encounters with things that talk can be quite uncanny and inconvenient. The story about the young student Anselmus and his fateful experiences begins with a collision with an apple merchant's stall. Several hours later, Anselmus stands in front of a house belonging to the archivist Linthorst. Again, and even more exasperating than before, Anselmus has to struggle with the stubbornness of things:

> … the Student Anselmus was at the front-door before the stroke of twelve. He stood here, and was looking at the large fine bronze knocker; but now when, as the last stroke tingled through the air with loud clang from the steeple-clock of the Kreuzkirche, or Cross-church, he lifted his hand to grasp this same knocker, the metal visage twisted itself, with horrid rolling of its blue-gleaming eyes, into a grinning smile. Alas, it was the Applewoman of the Schwarzthor! The pointed teeth gnashed together in the loose jaws, and in their chattering through the skinny lips, there was a growl as of: 'Thou fool, fool, fool! – Wait, wait! – Why didst run! – Fool!' Horror-struck, the Student Anselmus flew back; he clutched at the door-post, but his hand caught the bell-rope, and pulled it, and in piercing discords it rung stronger and stronger, and through the whole empty house the echo repeated, as in mockery: 'To the crystal, fall!' An unearthly terror seized the Student Anselmus, and quivered through all his limbs. The bell-rope lengthened downwards, and became a white transparent gigantic serpent, which encircled and crushed him, and girded him straiter and straiter in its coils, till his brittle paralysed limbs went crashing in pieces, and the blood spouted from his veins, penetrating into the transparent body of the serpent, and dyeing it red.[3]

Of course, Anselmus' experience can be explained as pure literary fiction, as part of a typical romantic novel that deliberately transgresses the limits of probability. Readers of Hoffmann's

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1 Lorraine Daston: "Introduction. Speechless", in Lorraine Daston (ed.): *Things that Talk. Object Lessons from Art and Science.* New York: Zone Books, 2004, 9-24, 12.

2 Daston, 2004: 12.

3 E. T. A. Hoffmann: "The Golden Pot", trans. by Frederic Henry Hedge, in Frederic Henry Hedge: *Prose Writers of Germany.* Philadelphia: Carey and Hart, 1848, 522-543, 527; E. T. A. Hoffmann: *Der goldne Topf. Ein Märchen aus der neuen Zeit.* Stuttgart: Reclam, 2004 [first printed 1814], 20-21.

Golden Pot might say that the irksome encounter with the knocker and the bell-rope is merely a product of Anselmus' imagination, a problem which perhaps deserves psychological or psychoanalytical treatment. Yet referring only to Anselmus' subjectivity would ignore the most interesting point of Hoffmann's episode. It is neither a specific "objective" quality of things nor an idiosyncratic view of the subject, but an occurrence, a specific kind of encounter in which things talk to the protagonist. Anselmus arrives a few minutes too early for his appointment with Linthorst, which explains why he does not immediately grasp the knocker or the bell-rope, but consciously looks at them. This unusual gaze initiates a cascade of transformations. It is the primary reason why things of everyday life, such as a knocker and a bell-rope, become strange and unfamiliar.[4] The aesthetic features with no essential function, the "metal visage" of the knocker and the long, white rope, make all the subsequent transformations possible, but they are not the only decisive factor. What enables these things to talk is a specific kind of encounter between aesthetic qualities and a gaze that looks at familiar things in a new way.[5] At least in this case, whether things can talk, depends on the *process* of this encounter and is not a quality necessarily inherent in the objects.[6]

Anselmus' encounter with the knocker and the bell-rope actualizes a surplus or excess of visual perception that is generally characteristic of every visible and material thing. In order to know how to deal with things, we usually use our eyes to identify them as specific and distinct objects. However, Anselmus' experience points to a much richer, potential "visibility" that is inherent in every object *before* our perception focuses on its identification. Phenomenologists like Maurice Merleau-Ponty and Bernhard Waldenfels have argued that our usual way of seeing things is only a type of response to a primordial excess of visibility.[7] This excess is neither directly nor totally accessible to our perception, but can only be partially actualized. Therefore, that which is "seen" is accompanied by that which is "unseen". The primordial "excess of visibility" can be felt at moments of irritation or disturbance. From this point of view, Anselmus' incident is much more than a fantastic episode in a romantic novel. Rather, we can regard it as the literary treatment of a fundamental problem that is of crucial significance for the phenomenology of perception.

Art historians and scholars of visual culture who look at scientific objects[8] are – to some extent – comparable to Hoffmann's protagonist Anselmus. They do not ask what purposes and functions the scientific object had, but regard it as an unfamiliar thing with specific and perhaps strange

4 On objects that become unfamiliar things, see, e.g., Bill Brown: "Thing Theory", *Critical Inquiry* 28, 2001: 1-17; Bärbel Tischleder: "Objekttücke, Sachzwänge und die fremde Welt amerikanischer Dinge. Zu Dingtheorie und Literatur", *Zeitschrift für Kulturwissenschaften* 1, 2007: 61-71; and Dorothee Kimmich: "'Mit blasiert eleganter Frivolität'. Von der Begegnung mit fremden Dingen", *Zeitschrift für Kulturwissenschaften* 1, 2007: 73-82.

5 For interesting observations about seeing common things, 'the ordinary stuff of life', in a new, unfamiliar way by concentrating one's attention on things of everyday life, see James Elkins: *How to Use Your Eyes.* New York: Routledge, 2000, VIII; see also James Elkins: *The Object Stares Back. On the Nature of Seeing.* San Diego: Harcourt Brace, 1997.

6 See Mieke Bal's criticism of 'visual essentialism': Mieke Bal: "Visual Essentialism and the Object of Visual Culture", *Journal of Visual Culture* 2(1), 2003: 5-32.

7 See, e.g., Bernhard Waldenfels: *Sinnesschwellen.* Frankfurt/Main: Suhrkamp, 1999; Merleau-Ponty described a rivalry or 'incompossibility' of visible things, see Maurice Merleau-Ponty: *La prose du monde. Texte établi et présenté par Claude Lefort.* Paris: Éditions Gallimard, 1969, esp. 73-76; and Bernhard Waldenfels: "Das Zerspringen des Seins. Ontologische Auslegung der Erfahrung am Leitfaden der Malerei", in Alexandre Métraux and Bernhard Waldenfels (eds.): *Leibhaftige Vernunft. Spuren von Merleau-Pontys Denken.* Munich: Fink, 1986, 144-161.

aesthetic qualities. The phenomena, in which they are interested, could tentatively be subsumed under the category "aesthetics of scientific objects". But as we see from the example of Anselmus, aesthetic phenomena are not uniquely characteristic of scientific objects. Therefore, one could be tempted to conclude that they are not relevant to things insofar as they are regarded and used as scientific objects. From this point of view, the aesthetic dimension would seem to be of no interest when investigating what scientific objects are and how they emerge.[9] Obviously no scientist would ask Anselmus to think about the essence of scientific objects. If we consider the concept of the object in the scientific field as the core of interest, or as *ergon*, then the aesthetic qualities of scientific objects can be regarded as being of minor importance, as *parergon*. But is it, therefore, meaningless to ask what the role of aesthetics for scientific objects is, or, in other words, what the role of *parerga* is?

The following considerations will address this question by consciously focussing on aesthetic *parerga*. I wish to examine their relevance for scientific objects by referring to three examples. With our introductory remarks in mind, it is particularly important to be attentive to possibly unstable relationships between objects, their aesthetic qualities and viewers. In this case, looking at the objects implicitly means imagining potential encounters between things and their viewers. Therefore, my primary goal is not to explore what object-subject relationship was intended for scientific purposes. Rather, we shall focus our attention to aspects that potentially distract the viewer from these purposes. The following remarks can only serve as an initial step to address the question of whether there can be any specific "aesthetics of scientific objects". This initial step will be confined to tangible, material objects and does not include the notion of "epistemic things" (Hans-Jörg Rheinberger) or the vast field of scientific visualizations and pictorial representations. To extend the reflection to these fields would result in many additional complications.

King George III's Lodestone in a Casket: Semiological Aspects of Scientific Objects

King George III's scientific collection is displayed in the Science Museum in London like a unique treasure. It is no coincidence that the design of the exhibition highlights the precious character of the objects, as these instruments combine technological functionality and a great deal of aesthetic qualities. The King's collection can be characterized as an extraordinarily impressive example of "artful science".[10]

But are there no references to the King's political status? One example, a lodestone (Fig. 1), reveals how the objects in King George's collection were situated within a triangle of science, aesthetics and politics. This lodestone was part of the mechanical apparatus created by George Adams for George III around 1762.[11] Adams encased a piece of natural magnetite in a silver casket and decorated it with a small lion's head that served as a handle. Its aesthetic appearance, however,

8 Bruno Latour offers several interesting suggestions concerning the relationship of science studies and art history in: "How to Be Iconophilic in Art, Science, and Religion", in Caroline A. Jones and Peter Galison (eds.): *Picturing Science. Producing Art.* New York: Routledge, 1999, 418-440; see also Ludmilla Jordanova: "Material Models as Visual Culture", in Soraya de Chadarevian and Nick Hopwood (eds.): *Models. The Third Dimension of Science.* Stanford: Stanford University Press, 2004, 443-451.

9 On the coming into being of scientific objects, see Lorraine Daston (ed.): *Biographies of Scientific Objects.* Chicago: University of Chicago Press, 2000.

10 See Barbara Maria Stafford: *Artful Science. Enlightenment, Entertainment and the Eclipse of Visual Education.* Cambridge, MA: MIT Press, 1994.

was by no means relevant to the scientific function of the device. The lodestone served as a source of force that was measured by means of a beam. When a piece of iron or steel was brought into position beneath the lodestone on one arm of the beam, the resulting downward force, i.e., the magnetic attraction, was balanced by weights added to the other arm. In this way, two different forces could be compared; the magnetic force, which is more difficult to measure and perhaps less perceptible, could be quantified by "weighing" it. The underlying purpose of making a formerly hidden force measurable and comparable seems to fit very well in the concept of Enlightenment. By making magnetic force calculable, it lost its magical character.

Figure 1: Lodestone in silver case, by George Adams, about 1762, Science Museum, London.

However, George Adams deliberately concealed the natural magnetite in a small silver casket[12] and thereby presented a measurable, but invisible force. This withdrawal of visibility enabled him to both enhance the value of the stone and encode it with new allusions. He symbolically represented the force of the lodestone with a lion's head. More importantly, the entire composition of the powerful stone, the lion's head and the silver box makes reference to King George III, whose coat of arms decorates the central part of the casket. Obviously, this coat of arms is not only a mere indication of the lodestone's possessor, but links a natural force with a social and political authority.

11 See Alan Q. Morton and Jane A. Wess: *Public and Private Science. The King George III Collection.* Oxford: Oxford University Press, 1993, esp. 294.

12 In the 17th and 18th centuries, lodestones used for (public) demonstrations were often kept in ornate silver cases, though many of these decorated lodestones were still partly visible. See Frances Terpak: "Objects and Contexts", in Barbara Maria Stafford and Frances Terpak: *Devices of Wonder. From the World in a Box to Images on a Screen.* Los Angeles: Getty Research Institute, 2001, 143-364, esp. 172-180.

In this context, the concept of hiding a source of power and putting it in a "black box" becomes especially interesting. Adams' design indicates that forces can be compared and measured, but that, in this case, the real source should not be visible or accessible. The increase of "transparency" is counteracted by an aesthetic strategy that re-establishes some "opacity". Although the magnetic force was measurable, the opacity made it an invisible, latent power. What seems at first to be an "enlightening" scientific experiment proves to be a demonstration of hidden power. The viewer only sees the effect and the scientist only measures the force of this effect. But the source of power remains latent. It is encoded with the King's arms and lies beyond the scope of visibility.

This strategy of retaining the source of effects is essential for the representation of political power, especially the power of absolutist kings. As Louis Marin explains in his book *Le portrait du roi*, kings generally rely on effects of representation that transform their pure, actual force into a form of power that does not exhaust itself in actualization, but is characterized by a latent reserve.[13] A king's power feeds on the power of his portrait, on the power of images and texts that use effects of opacity and latency. By hiding a lodestone in a casket, George Adams obtained a comparable effect. His apparatus may be regarded as a clue to the political ambitions of the young King George III, who was attracted to the idealistic concept of the "Patriot King", conceived by Henry St. John, Viscount Bolingbroke.[14] George III tried to forcefully emancipate his royal authority from the cabinet and the parliament. In 1762, only two years after his accession to the throne, these ambitions reached a critical point when William Pitt the Elder resigned as the Secretary of State and the king used the opportunity to appoint his former tutor John Stuart, Earl of Bute, as First Lord of the Treasury.[15]

In view of this political context, ignoring the aesthetic qualities of George Adam's device would mean neglecting an important aspect of the object. The appearance of the scientific object is by no means accidental. Rather, it establishes a sort of hybrid in which the aesthetics of science and the representation of the king are intertwined. The strategy of the encasement established a powerful latency, which could have been of interest for a king who wanted to emancipate his royal power from other political institutions.

The political implication of the lodestone's aesthetic appearance certainly does not change the scientific core of the experiment. The magnetic force of the lodestone can be measured regardless of whether it is hidden in a casket or not. It seems the object's socio-cultural context determines its aesthetic features. From this point of view, the "aesthetics" of scientific objects can be regarded as one part of a more essential semiology of things. According to Roland Barthes, every single thing inevitably acts as a complex, often ambiguous signifier; there are no "pure" objects without signification or connotation.[16] However, does this semiology of things generally mean there is no

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13 See Louis Marin: *Le portrait du roi.* Paris: Éditions de Minuit, 1981; and Louis Marin: *Des pouvoirs de l'image. Gloses.* Paris: Éditions du Seuil, 1993, 9-22; Dirk Setton: "Mächtige Impotenz. Zur 'Dynamo-Logik' des Königsportraits", in Vera Beyer, Jutta Voorhoeve and Anselm Haverkamp (eds.): *Das Bild ist der König. Repräsentation nach Louis Marin.* Munich: Fink, 2006, 217-244.

14 See Henry St. John Bolingbroke: *The Idea of a Patriot King* [1738], in *Letters on the Spirit of Patriotism, on the Idea of a Patriot King, and on the State of Parties. A New Edition.* London: T. Davies, 1775, 57-218.

15 See Hans-Christoph Schröder: "Georg III", in Peter Wende (ed.): *Englische Könige und Königinnen. Von Heinrich VII. bis Elisabeth II.* Munich: Beck, 1998, 220-241.

16 See Roland Barthes: "Sémantique de l'objet", in *L'aventure sémiologique.* Paris: Éditions du Seuil, 1985, 249-260.

specific relationship between *scientific* objects and aesthetics? A second object may serve as an example to reflect on the specificity of the "aesthetics" of scientific objects.

A Plaster Model of a Malformed Embryo on a Classical Base: The Aesthetic Domestication of Monstrous Objects

Collections and museums define themselves by regimes of structures, orders, systems and comprehensible displays, and consequently, possess similarities to characteristic features of classical art. Some older arrangements and settings at the Copenhagen Medical Museion refer to traditional, "classical" modes of presentation where long series of symmetrically arranged, technical instruments resemble exhibitions of coins, gems and other precious objects in art collections. One can find a wax model of the inner structure of the female body, framed by wooden profiles and reminiscent of conventional iconographic formulas (e.g., the death of Lucretia). A partially mummified head with coloured veins and muscles is mounted on a classical base, which is traditionally used for busts of gods, heroes or celebrities.

In the gynaecological section of the Museion, the use of classical plinths gains a critical quality. Two glass cases contain an astonishing collection of conserved embryos and foetuses characterized by various deformities. These glass cases are "crowned" by five small plaster models of malformed embryonic heads which were manufactured by the Medicinisches Waarenhaus Actien-Gesellschaft[17], a medical department store in Berlin. In light of their origin, their classical-looking bases and their position at the top of the showcases, these plaster models represent a strange, but by no means unique, combination of medicine, economy and popularized classical design.

One plaster bust (Fig. 2), and in particular, the posture of its head, is especially interesting in terms of the aesthetic dimension of scientific objects. The bust shows a striking similarity to classical sculptural representations of suffering mythological heroes, like Laocoon or the sons and daughters of Niobe (Fig. 3, Fig. 4).[18] In the late 18th century these works were at the centre of heated debates on the representation of emotions and pathos in art.[19] Johann Joachim Winckelmann, Gotthold Ephraim Lessing, Alois Hirt and Johann Wolfgang Goethe, among others, discussed to what extent pain, suffering and disgust could be shown in works of art. One basic strategy to legitimate the representation of pain in sculptures or paintings was the differentiation between natural and artificial beauty (*Naturschönes* vs. *Kunstschönes*). Naturally disgusting expressions could be subjects of art if they were treated in an aesthetically satisfactory manner. Laocoon and the Niobids – sculptures which were well-known and widely-reproduced in plaster – were regarded as exemplary works of art that subdued and domesticated human emotions and sensations.

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17 It is not possible to ascertain the exact date of origin of the plaster model. The 'Medicinisches Waarenhaus Actien-Gesellschaft' was in business at the turn of the 20th century in Berlin.

18 Galleria degli Uffizi, Florence, Inventory No. 290.

19 See Martin Dönike: *Pathos, Ausdruck und Bewegung. Zur Ästhetik des Weimarer Klassizismus 1796-1806*. Berlin: de Gruyter, 2005.

Figure 2: Plaster model of a malformed embryo's head, about 1900 (?), Medical Museion, Copenhagen.

Figure 3: Son of Niobe, Copy after a work of the 4th century BC (?), marble, Galleria degli Uffizi, Florence.

Figure 4: Bust of a daughter of Niobe (?), about 1776 (?), Porcelain (Fürstenberg), Herzog-Anton-Ulrich-Museum, Braunschweig.

The plaster bust of the malformed embryonic head not only resembles these works of classical ancient art, but also seems to pursue a similar project of domestication. It makes the malformed human head appear more familiar and, by mounting it on a base, allows it to be included in a predetermined structure. A decision on the formal appearance of this base was inevitable, as it would have been unthinkable to use the plaster model without any base or plinth. The choice of a classicizing, ancient-looking base was probably encouraged by the material used for the reproduction of the model. Plaster was and still is connotative of the reproduction of ancient masterpieces of art, and therefore, the adaptation of a classical base probably seemed a good choice. Every classical base implicitly refers to a norm, i.e., the typical busts of celebrities or heroes. Thus, it is clear that the malformed head of the embryo marks the deviation from this standard. By characterizing the head as a deformity, the plaster model re-affirms the normative ideal. It is doubtful, however, that the producers and users of the plaster model were fully aware of these implications. In any case, the bust's resemblance to some of the children of Niobe does not seem to be deliberate. While George Adams most likely designed the lodestone casket for George III with political implications in mind, this example shows that decisions regarding the aesthetic appearance of scientific objects are not always intentional.

In many cases, aesthetic features of scientific objects are not meant to bear any deeper significance. Nevertheless, these features are of crucial importance for the status of things as objects in a scientific context. In general, there is no way to avoid making a decision about the aesthetic appearance of tangible scientific objects. Things regarded as distinct objects have to be distinguished from other things. By separating and placing them in a new context, objects can be imbued with features which tell us what belongs to them and what is not part of them. Very basic aesthetic features like bases, frames and boxes can help define an object as an entirety. In this way, it can become part of a scientific environment and gain a specific position in the new framework. In order to deal with tangible things in a scientific manner, aesthetic markings are practically indispensable. Without them, it would be difficult to know what is being discussed and in what respect the object is of interest. Thus, aesthetic markings are fundamental in making things become objects, yet, at the same time, make the objects become more complex.

Focussing on sociological aspects of scientific objects, Bruno Latour argues that there are no "pure" objects without any relation to subjects. Each object is characterized by a certain anthropomorphic "contamination", or, as Latour put it, "things do not exist without being full of people".[20] Objects are always part of dispositions, practices and discourses, and in these contexts, they can serve as actors and mediators. They influence the actions of human subjects and modify their world. In this way, they dodge the subject-object distinction.

Aesthetic markings that help constitute things as scientific objects are of special importance for this phenomenon. Such markings are responsible to a large extent for anthropomorphic contamination as described by Latour.[21] Every aesthetic feature is characterized by a surplus that inevitably exceeds its original function. As we see in the case of the plaster model, aesthetic decisions always involve an abundance of potentially ambiguous connotations. Marking objects by means of pedestals, frames, caskets or other kinds of contextualization is essential for defining tangible things as objects of science, yet the same aesthetic qualities can be the source of misleading conclusions. How can we more accurately describe the aesthetic operations at work in scientific objects? A third example can help us better understand the fundamentally ambivalent character of the "aesthetics" of scientific objects.

Framing the Microscope Slide: Looking through and at a Window

Why would anyone frame microscope slides? Scientists of the 19th century may have raised this question when they encountered decorative microscope slides, such as those preserved in the collections of the Whipple Museum of the History of Science in Cambridge. These slides were most likely produced for enthusiasts of popular science. Nevertheless, the artificial framing had at least one obvious function. It served as a label for a short description of the preparation.

The practical functions and possible economic and cultural motives of the practice of framing slides should not prevent us, however, from taking a closer look at one example from the 19th century containing a slice of elm root (Fig. 5)[22]. Obviously the rich ornamental design of its frame provides no added benefit to the original function of the slide. When placed under a microscope, the decorative frame of the slide becomes irrelevant; it disappears. However, in addition to this usual scientific view of the slide, one can perceive the frame in another way. The moment its ornamentation attracts the viewer's attention, she or he looks at it without using a microscope.

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20 Bruno Latour: "The Berlin Key or How to Do Words with Things", in Paul M. Graves-Brown (ed.): *Matter, Materiality and Modern Culture.* London: Routledge, 2000, 10-21, 10.

21 A similar argument can be found in an essay by Georg Simmel, who pointed out the relationship between the 'cultivation' of things and their anthropomorphic status. See Georg Simmel: "Persönliche und sachliche Kultur", in Georg Simmel: *Aufsätze und Abhandlungen 1894-1900. Gesamtausgabe*, vol. 5, ed. by Heinz-Jürgen Dahme and David P. Frisby. Frankfurt a. M.: Suhrkamp, 1992, 560-582; see also Anke te Heesen: "Verkehrsformen der Objekte", in: Anke te Heesen and Petra Lutz (eds.): *Dingwelten. Das Museum als Erkenntnisort.* Cologne: Böhlau, 2005, 53-64.

22 Whipple Museum, Cambridge, Accession No. 3208.

While the usual view through the lens of the microscope constitutes a framed "image" of a little part of the object, the ornamental frame makes the slide of the root appear as an integral entirety. Not only does the viewer's perception of the root change. The neutral glass plate, which we usually ignore, becomes a kind of framed window that opens a view beyond its borders. As a result, the frame, which initially seems to be an insignificant decorative feature, causes interference of two different and, in some ways, contradictory modes of visual perception – one optically mediated, concentrated only on the botanical object, and the other directly perceptible, constituting a window by framing a glass plate. In this context, the term "object" is characterized by a fundamental ambivalence. It can refer to the botanical object, the root of the elm, but to the slide itself.

Figure 5: Microscope slide, 19th century, Whipple Museum of the History of Science.

This characteristic of the frame is especially obvious in pictures. The operation of framing is almost indispensable for the constitution of the modern concept of the picture. The famous picture-window comparison, outlined for the first time by Leon Battista Alberti, is unconceivable without some kind of frame. It is the specific modern concept of the frame that allows us to understand pictures as windows that open views to a world behind or beyond the surface of the picture.[23] Of course, most artists did not aim to achieve total transparency in their pictures. Rather, the picture-window analogy was counterbalanced by a regard for the picture as a flat, opaque surface. Framed pictures show something that is physically absent, yet, at the same time, the framed picture reveals itself as a thing in its own right. Louis Marin pointed out that pictorial representation can be understood as intertwining transitive and reflexive references.[24] The practice of framing pictures is essential to both the transitive and reflexive dimension of representation.

The microscope slide can be regarded as a hybrid descendant of this tradition of representation. It presents an object in the framework of a “window”, but is not limited to the classical view through a window since this mode of visual perception cannot open the differentiated and detailed insights, which make the microscope so attractive and valuable. The more recent concept of gaining insight into previously hidden microscopic structures of objects struggles with the older ideal of immediate visual perception which is directly related to the metaphor of the picture as an open window. At first glance, the ornamental frame emphasizes the transparency of the “window”, but then distracts our view through it and prompts us to look *at* the glass sheet, making the microscope slide to some extent opaque.

These observations indicate that frames do not merely serve one specific function, but are fundamentally characterized by ambivalent and vacillating operations. In his close, critical reading of Kant’s *Critique of Judgement* (*Kritik der Urteilskraft*), Jacques Derrida analyzed these unique operations of the frame on the basis of the notion of *ergon* and *parergon*.[25] As the frame divides and excludes, it separates the outside from the inside and controls the relationship between the intrinsic and extrinsic. The frame itself – like a *parergon* – is attached to the object which it defines as *ergon*, but the frame must not be an integral part of the *ergon*. In this way, it supplements a “lack” that is inherent to the object it frames. It constitutes the inside as an entirety and sustains its integrity. However, at the same time, it undermines that which is intrinsic to the framed object, as it implies a potential excess. As Derrida noted, the frame can stand apart from the work of art or object and merge into the surroundings, but simultaneously, with respect to the surroundings, it can also disappear into the *ergon*. Furthermore, the frame is able to exceed its original separating function and attract attention to its own surface or materiality. Therefore, on closer inspection, the frame does not prove to be a solid boundary, but is characterized by its endless operations and unstable effects.

Derrida himself did not restrict this notion of *parergon* to frames, but extended its relevance – following Kant’s lead with his reference to columns and draperies as *parerga*. A multitude of very different kinds of *parerga* can serve to establish inevitably fragile relationships between an inside

23 See two recent books on the window-picture comparison: Gérard Wajcman: *Fenêtre. Chroniques du regard et de l’intime*. Lagrasse: Verdier, 2004; and Anne Friedberg: *The Virtual Window. From Alberti to Microsoft*. Cambridge, MA: MIT Press, 2006.

24 See, e. g., Louis Marin: *De la représentation*. Paris: Gallimard, 1994, esp. 251-266.

25 Jacques Derrida: “Parergon”, in *La vérité en peinture*. Paris: Flammarion, 1978, 19-168, esp. 44-94.

and an outside. Although Derrida's notion of *parergon* is not restricted to visible material *parerga*, aesthetic markings like frames are of special importance.[26]

Aesthetic Markings and the Logic of the Parergon

The three examples I have briefly described above – the casket, the classical base and the frame – have one basic strategy in common. They serve to constitute things as distinct objects so as to situate them in a scientific context while offering rich material for other, distracting impressions and connotations. Considering the operations and effects of frames and other *parerga*, aesthetic markings of scientific objects in general gain a more essential relevance. Practically every tangible scientific object is constituted by fragile *parerga*, i.e., frames, bases, caskets, etc., which do not necessarily imply artistically sophisticated forms. Regardless of how extravagantly or simply they are designed, the aesthetic markings are essential factors in the process of changing a thing into a scientific object. By aesthetically isolating the thing, these markings help define what belongs to the object and what has to be regarded as its outside. Without this basic operation it would be impossible to establish a scientific discourse with clear references to the object

As Martin Heidegger pointed out, science can regard things only as objects. It has no alternative but to ignore or fail to notice the "thingness" ("Dinglichkeit") of the thing.[27] A closer look at the aesthetic markings of scientific objects could help us gain deeper insights in this critical relationship between the thing and the object. The parergonality of these markings does not only explain the process in which the thing becomes an object, but also gives us some idea as to why the status of objects remains inevitably fragile and unstable. The same frame, casket or base that makes the thing a separate, identifiable object potentially diverts the viewer's attention away from the scientific function to other possible cultural, political, aesthetic, individual or idiosyncratic connotations.

In view of these considerations, the aesthetic dimension of scientific objects proves to be a nearly indispensable *parergon* of science in general. This *parergon* cannot be dismissed as mere decor or as a belated supplement to the object; in fact, it cannot be separated from science at all. In many cases, the existence of an aesthetic marking enables us to talk about clearly defined objects. Therefore, analyzing scientific objects irrespective of their aesthetic qualities would not necessarily mean focussing on the core of their scientific value. Instead, it would force us to remain within the restricted boundaries of science and ignore the process which establishes the fundamental structure of the object, subject and surroundings that makes science possible.

From this point of view, E. T. A. Hoffmann's student Anselmus can be regarded as a model for someone who is interested in the fundamentally fragile status of objects. It is no coincidence Anselmus is standing at a threshold when he encounters the uncanny and irritatingly talkative knocker and bell-rope. Anselmus' situation in front of the door is perhaps the most striking model

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26 Even removing things from their 'original' contexts and placing them in new surroundings – on a desk, onto a shelf, in a laboratory, etc. – can be regarded as an operation of aesthetic marking. Although these operations do not necessarily change the appearance of the thing itself, they redefine the visible and physical relationship between the object and its surroundings.

27 See Martin Heidegger: "Der Ursprung des Kunstwerks", in *Holzwege*. 8th ed., Frankfurt a. M.: Klostermann, 2003, 1-74; and Martin Heidegger: "Das Ding", in *Vorträge und Aufsätze*. 10th ed., Stuttgart: Klett, 2004, 157-179, esp. 162.

for a reflection on the parergonality of the aesthetic dimension of objects. When we are aware of the logic of the *parergon* that constitutes the scientific object, we can truly encounter things that talk in a variety of ways – and not as objects that only repeat what others have said about them before.[28]

[28] The unstable *processes* that characterize the aesthetic *parerga* of scientific objects seem to be underestimated even by recent concepts of a “reformulated materialism” and a “thick description of things”; see Ken Alder: “Introduction”, *Isis* 98(1), 2007: 80-83; and Bruno Latour: “Can We Get Our Materialism Back, Please?”, *Isis* 98(1), 2007: 138-142.

The Emergence of New Objects of Scientific Inquiry
The Case of Bose-Einstein Condensates

Daniela Monaldi

> [Robert Boyle] states the rationale of laboratory science – for 1660 and for 1990: 'such are our experiments, in which one discovered cause can be fitted to an infinite number of common phenomena'. Hobbes cynically asks, 'and what are they', these common phenomena infinite in number? Today we would add, as sardonically as Hobbes, 'and tell us more about how you do this wondrous fitting'.[1]

Introduction

In September 1995, as the conference titled "The Coming into Being and Passing Away of Scientific Objects" was opening at the Max Planck Institute for the History of Science, a very new scientific object was coming into being in a physics laboratory at the Massachusetts Institute of Technology. It was a Bose-Einstein condensate of sodium atoms, the second atomic Bose-Einstein condensate ever produced; the first had been obtained just a few weeks earlier from rubidium atoms by another experimental team at the University of Colorado in Boulder. The two teams were awarded the Nobel Prize in Physics in 2001 for this achievement. Since then, an increasing number of laboratories have been making and studying their Bose-Einstein condensates from an enlarging number of chemical elements and with an ever more refined arsenal of tools. A new field is developing at a pace that is often described as "explosive". When I visited one of the two labs that are working on Bose-Einstein condensation at the University of Toronto, the one nicknamed by its members "Nanokelvin of the North", I asked a researcher in what area of physics she considered herself to be working. "Cold atoms", she said.

Bose-Einstein condensates are the scientific objects of my study. In what follows, I shall first make my case of why, although my objects are somewhat off-centre with respect to the Wandering Seminar, they are nevertheless central to our project on the history of scientific objects. Then, I shall attempt an explanation of what they are and why physicists find them exciting. Finally, I shall sketch a possible angle from which it might be fruitful to investigate their coming into being, drawing on Ian Hacking's ideas of the creation of phenomena and the laboratory style of reasoning.[2]

1 Ian Hacking, "Artificial Phenomena", *British Journal for the History of Science* 24 (1991), 235-241, on 236.
2 Hacking's own discussion of the philosophical aspects of Bose-Einstein condensation is Ian Hacking, "Another New World is Being Constructed Right Now: The Ultracold", Max-Planck-Institut für Wissenschaftsgeschichte, Preprint 316, 2006.

Bose-Einstein Condensates and the History of Scientific Objects; The material culture of science and the coming into being of epistemic things

Being interested in the material culture of science, we concern ourselves with a broad spectrum of material items that might be called “scientific objects”: instruments, technological products, architectural spaces, science-related collectibles and memorabilia, symbolic and aesthetic items that make reference to science, and so on. We are also concerned with objects of scientific inquiry, or epistemic things.

Our Research Network follows two lines of historical reflection. On the one hand, it studies the material culture of science. Studies of material culture rest on the premise that the permanence of material things can help us to recover systems of knowledge and values across time. On the other hand, it acknowledges that the objects of scientific inquiry are transient, that they emerge and disappear in the course of history. Thus, their instability can guide us to the contextual forces that shaped their historical trajectories, such as social and practical pressures, cultural sensibilities, and politics of knowledge. The project to explore the history of science following the routes of scientific objects presents itself as “applied metaphysics”. It assumes that to reduce epistemic objects to the binary categories of either real or non-real is an impoverishment of understanding. A richness of connections and insights can be recovered if we treat the reality of scientific objects as “a matter of degrees”, with the degrees determined by factors such as productivity and embeddedness.[3] This approach also aims at overcoming other problematic oppositions that are modeled upon the dichotomy of real versus non-real, such as real versus historical, discovered versus invented, natural versus artificial. Lorraine Daston reminds us that these oppositions are themselves historically emergent and in need of historical clarification. In particular, she suggests investigating how the broad and complex notion of “object” is related to the core intuition of a “material object” as something external, persistent, independent of mind. Focusing on the intersection of the two lines of historical reflection, that is, studying the coming into being of *material* objects might contribute something in both directions.

Salient and emergent objects, artifacts, and microphysical entities

Some objects come into being qua objects of inquiry by becoming salient for a scientific community under given circumstances. Others are truly emergent: they did not exist in any form before becoming objects of scientific attention. Typical examples of emergent scientific objects are mathematical entities in disciplines as astronomy, mechanics, and statistics, and objectified notion in the social sciences. But material things also can be emergent. Obvious examples are artifacts and technological ware. No transistor existed before Bell Laboratories charged a team of physicists and chemists with the task of making a solid-state device to replace the vacuum tubes in telecommunication systems; no nuclear weapon before the Manhattan Project. The history of twentieth-century technology, which plays so large a role in the history of the twentieth century, is in large measure a history of scientific objects. Nevertheless, ontologists describe artifacts as having a dual nature. One side of their nature is determined by their material basis and their

3 Lorraine Daston, “The Coming into Being of Scientific Objects”, in L. Daston, ed., *Biographies of Scientific Objects* (Chicago: University of Chicago Press, 2000).

physical structure; the other by design, functions, and contexts of use.[4] Design, functions, and contexts of use are referred to as “mental” properties because they are intrinsically relative to mental states and intentional actions. The coming into being of an artifact involves its functional and relational side, not the material basis. If pressed, the ontologists will specify what the material basis of an artifact is by pointing to its microphysical structure.[5]

The entities of microphysics, atoms and particles, are the preeminent instances of objects that cannot be real and invented at the same time, and a history of which can only be a history of discovery.[6] Can we attempt unpacking the trope of discovery in the case of material objects that share with quarks and atoms the essential quality of being what they are independently of mental properties? Can objects like these be found at the intersection of material culture and the coming into being of epistemic things? I would like to submit the case of Bose-Einstein condensates, scientific objects that are unambiguously material and uncontroversially emergent.

Bose-Einstein condensates; What are they?

We are familiar with gases, liquids, and solids, and with the fact that a substance will pass from the gaseous state to the liquid and the solid, and back, according to conditions of temperature and pressure. We attribute this behavior to the possibility for the same set of molecules to be in different states of aggregation, held together more or less strongly by intermolecular forces. Many of us will also know a fourth state called plasma, which is the normal state of more than 99% of the matter in the visible universe. Only twelve years ago scientists found the way to force atoms into a fifth state. This new state is called Bose-Einstein condensation. In the words of Eric Cornell, one of the first makers of Bose-Einstein condensates,

> This state could never have existed naturally anywhere in the universe. So the sample in our lab is the only chunk of this stuff in the universe, unless it is in a lab in some other solar system.[7]

An atomic Bose-Einstein condensate is a special fluid that forms from a cloud of atoms when the right conditions of density and temperature are reached. Furthermore, the atoms have to be of then right kind, as we will see. The methods currently in use achieve the right conditions by trapping a diluted cloud of the right kind of atoms by means of magnetic fields, and cooling it to ultracold temperatures. Physicists find Bose-Einstein condensates alluring not only because they have the charm of the extreme, but also because they display on a macroscopic scale quantum

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4 See, for example, Peter Kroes and Anthonie Meijers, eds., *The dual nature of technical artifacts*, special issue of *Studies in History and Philosophy of Science*, 37 (2006), 1-158.

5 Wybo Houkes and Anthonie Meijers, “The ontology of artefacts: the hard problem” and Lynne Rudder Baker, “On the twofold nature of artifacts”, in P. Kroes and A. Meijers, eds., *The dual nature of technical artifacts* (note 4), 118-131 and 132-136.

6 There are a few developed arguments for the emergence of microphysical entities, the best known of which is Andrew Pickering’s *Constructing Quarks. A Sociological History of Particle Physics* (Chicago: University of Chicago Press, 1999).

7 “Physicists Create a New State Of Matter At Record Low Temperature. Joint Release By The National Institute of Standards And Technology And The University Of Colorado on 7/13/95”, at http://jilawww.colorado.edu/www/press/bose-ein.html.

features that were hitherto only observable in submicroscopic particles. How cold is "ultracold", and how large is "macroscopic"? Here are some data:

> Most BEC experiments reach quantum degeneracy between 500 μK and 2 μK, at densities between 10^{14} and 10^{15} cm^{-3}. The largest condensates are of 100 million atoms for sodium and a billion for hydrogen; the smallest are just few hundred atoms. Depending on the magnetic trap, the shape of the condensate is either approximately round, with a diameter of 10 to 50 μm, or cigar-shaped with about 15 μm in diameter and 300 μm in length.

The temperature of the human body is about 310 K above absolute zero. At 273.15 K water freezes. Temperatures around 180 K have been recorded in Antarctica. (I do not know for sure, but my guess is that at this point the nerves in our skin have stopped registering any thermal sensation.) Below 77 K, air liquefies; that is how cold it is on Neptune. Helium, the most stubborn gas because of its very low intermolecular forces, was first liquefied in 1908 by Kamerlingh Onnes in his cryogenic laboratory, at 4 K. That is one degree higher than the background temperature of outer space. In these regions, where no sensorial imagination can stretch, physico-mathematical temperature is still defined thanks to a theory called kinetic theory, according to which the temperature of an assembly of particles is proportional to the average kinetic energy of the particles. The slower the motion of the particles, the lower the temperature. The molecules of air at room temperature shoot in every direction at speeds of about 4000 km/h (approximately 1000 m/s). Since the speed-temperature relation is not linear, the temperature decreases much faster than the speeds. This means that temperatures of only a few degrees above zero correspond to molecular speeds that are still of the order of hundreds of km/h. Only in the environs of a millionth of a degree the velocities drop to around 1 km/h. The last few degrees, and even the last fractions of one degree correspond not only to a wide range of molecular speeds but also to the physical conditions for a variety of phenomena that cannot take place at higher temperatures.

> I imagine experimental physicists must often look with envy at men like Kamerlingh Onnes, who discovered a field like low temperature, which seems to be bottomless and in which one can go down and down.[8]

These were the opening words of a famous lecture titled "There is Plenty of Room at the Bottom", with which the star of post-war theoretical physics, Richard Feynman, invited young physicists in 1959 to enter the budding field of nano-science. He was recruiting students to the development of techniques to "manipulate things on a small scale", all the way down to the manipulation of individual atoms, predicting that the effort "would have an enormous number of technical applications." Feynman used the example of low temperatures to impress upon his audience that much happens within dimensions that are minuscule on a human scale. Low temperature physics is another kind of nano-science, one in which the smallness is in temperature rather than in size.

Bose-Einstein condensates are large relatively to atoms. Their spatial dimensions range from tens to hundreds millionths of a meter. The resolving power of the human eye is a fraction of a

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8 Richard Feynman, "There is Plenty of Room at the Bottom", Talk delivered to the American Physical Society, 1959, at http://www.zyvex.com/nanotech/feynman.html.

millimeter. Ten micrometers are not far below the threshold of visibility with the naked eye. You can see a Bose-Einstein condensate with a medium-power microscope. This is what physicists mean when they talk of "displaying quantum effects on a macroscopic scale".

Einstein's prediction

The field of cold atoms has its origin myth. The history of Bose-Einstein condensation, in fact, can be traced back to the heroic dawn of quantum mechanics itself, to no less figure than Albert Einstein. In 1924, Einstein, already at the summit of theoretical physics, received a paper from Satyendranath Bose, then an unknown physicists at the University of Dacca, India. Bose had been able to derive Planck's law of black-body radiation by applying Einstein's hypothesis of light quanta. The hypothesis of light quanta postulated that electromagnetic radiation, which Maxwell's theory described as waves, would also be, in certain respects, like a gas of particles. Einstein believed in a "deep kinship" between light and matter, but he had been quite cautious in asserting the validity of this analogy only within certain limitations. Bose, instead, had modeled without reserves the radiations as a gas of quanta. He had then found a way to arrive at the radiation law through simple mathematical steps, by starting with a non-canonic count of the microscopic arrangements of the quanta in their possible states. Einstein appreciated the result, and immediately extended the light-particle analogy further: he applied Bose's method of counting to an ideal gas of atoms. An "ideal gas" is an idealized assembly of particles, in which the particles are imagined to move freely within a given volume and to interact only by elastic collisions. It is widely used as a simplifying approximation of real gases, the accurate model of which is instead that of an assembly the particles, each moving in fields of forces generated by the other particles. Einstein was able to derive several important results. In particular, his new theory could account for the "degeneracy" of gases at low temperatures, that is, their observed deviations from the classical law of gases. Studying the degenerate gas as described by his new theory, Einstein came to the conclusion that there was a condition of maximum degeneracy, and that in this condition there would be an upper limit on the density of the gas at each temperature. Nevertheless, one could always imagine compressing the gas while keeping the temperature constant. What happened then, if any further increase in density was forbidden? Einstein found an answer by constructing another analogy, this time between his ideal gas and a real vapour:

> I assert that in this case a number of molecules, a number increasing with the total density, passes into the first quantum state (state without kinetic energy), while the remaining molecules distribute themselves according to the parameter value $\lambda=1$. This assertion means that there occurs something similar to what happens when isothermally compressing a vapour above the saturation volume. A separation takes place; a part 'condenses', the rest remains a 'saturated ideal gas'.[9]

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9 Albert Einstein, "Quantentheorie des einatomigen idealen Gases. Zweite Abhandlung", *Berliner Berichte* (1925), 3-14, on 4.

The Bose-Einstein statistics

There was, however, a crucial difference between the real and the ideal gas. The condensation of a real gas is caused precisely by the intermolecular forces that are supposed to be absent in an ideal gas. The sole cause of the condensation imagined by Einstein was a spontaneous tendency of the gas particles to collapse into the state of lowest energy. This was a consequence of Bose's unorthodox method of counting. Experts in statistical mechanics were perplexed by the method because it contradicted the commonsensical assumption that non-interacting molecules would be statistically independent from one another, that is, that the probability for each of them to be in a quantum state would be independent of the number of other molecules in the same quantum state. Hence, the method was correct only if one presupposed a statistical behaviour quite unlike what was regarded as the "natural" statistics. One of the specialists who were mystified by Bose's method was Erwin Schrödinger, who communicated his doubts to Einstein. Einstein's reply was a little masterpiece of clarity. Bose's method, he explained, was the application of a "special statistics *[besondere Statistik]*", which at the moment could only be justified a posteriori through its success. In it, the particles were indeed not treated as independent from one another; rather, each of them exhibited "a predilection *[eine Vorliebe]*" to be in a state together with others. He illustrated the point in the simple case of two particles having two possible states:

> In this procedure, the molecules do not appear as localized independently from one another, but they have a preference to be in the same cell together with another molecule. This can be made clear easily in the case of small numbers. For example, 2 quanta, 2 cells: [...]

Bose Statistics

	cell 1	cell 2
case 1	• •	–
case 2	•	•
case 3	–	• •

Independent molecules

	cell 1	cell 2
case 1	I II	–
case 2	I	II
case 3	II	I
case 4	–	I II

> According to Bose, the molecules are found relatively more often together than in the hypothesis of statistical independence of the molecules.[10]

How different this propensity to group together is from what we normally expect becomes more evident with higher numbers. Imagine, for example, ten socks falling randomly into two drawers. It is much more likely to find five socks in one drawer and five in the other, than to find ten socks in one and none in the other; 252 times more likely, to be precise. But if the socks distributed themselves according to Bose's statistics, then it would be equally likely to find an even distribution in the two drawers as to find that all the socks have fallen together in the same

[10] A. Einstein to E. Schrödinger, Berlin 28 Feb. 1925.

drawer.[11] The only way Einstein could explain the preference of Bose's particles to congregate was to postulate a mutual influence among the particles of the gas, an influence that he admitted was for the time being of an "entirely mysterious nature". For his part, Schrödinger soon metabolized Bose's statistics. He came to the conclusion that particles were actually waves, and formulated wave mechanics, one of the two roots of the new quantum mechanics. He thus attributed the strange distributions of Bose's statistics to the wave nature of particles.

Bosons and fermions

But if Bose's method was the correct one for the atoms of Einstein's gas, it was also clear that it would not apply to every kind of particles. Electrons, for example, displayed a behaviour opposite to the gregariousness postulated by Einstein. They distributed themselves so that no electron was ever in the same state as another electron. Wolfgang Pauli first pointed out this feature, and formulated it as a principle that became known as the principle of exclusion. For particles that obeyed Pauli's principle, case 1 and 3 of Bose's statistics in Einstein's example would be impossible. Enrico Fermi and Paul Dirac developed the statistics appropriate to particles like the electrons. Not only did quantum statistics imply a departure from natural statistics, it implied two departures in opposite directions, to the Bose-Einstein statistics for some particles, and to the Fermi-Dirac statistics for others. Dirac found that the two statistics were related to a mathematical feature of quantum mechanics. The mathematical variables that represented the observable quantities of a system of two or more particles remained unchanged if any of the particles was exchanged with any other. This property of invariance was interpreted as a fundamental impossibility to distinguish one particle from another particle of the same kind. In quantum mechanics, the two logically distinguishable case 2 and case 3 of the statistics of independent particles became absolutely indistinguishable from one another; hence, they were to be counted as a one. The counter-intuitive character of the quantum statistics was attributed to the no less counter-intuitive quantum indistinguishability of particles, and Einstein's "mysterious influence" was considered thereby explained.

All the particles were divided into two classes: either they followed the Bose-Einstein statistics, and were called "bosons", or they followed the Fermi-Dirac statistics, and they were called "fermions". Electrons evidently obeyed the principle of exclusion and were therefore fermions. Light quanta, or photons, were evidently bosons. But, apart from these two obvious cases, it remained unclear to which class the other particles and atoms belonged. Only at low temperatures, when a gas becomes degenerate, does it become experimentally appreciable whether it will deviate from the behaviour of distinguishable particles in the sense of Bose-Einstein statistics or in the sense of Fermi-Dirac statistics. It was later found that the statistical class to which a particle belongs is univocally related to its spin, a quantum-relativistic property that together with mass and charge identifies the particle but that, unlike mass and charge, has no simple classical analogue. Every particle has a spin that is either an integral or an half-integral multiple of a common unit. Electrons and quarks, the components of atoms, have spin $^1/2$. Photons and other elementary particles have integral spins. The spin of composite systems such as atomic nuclei and

[11] The example is from Eric Cornell and Carl A. Wieman, "Bose-Einstein Condensation in a Dilute Gas; The First 70 Years and Some Recent Experiments", in Tore Frängsmyr, ed., *Les Prix Nobel. The Nobel Prizes 2001*, (Stockholm, Nobel Foundation, 2002), 77-108, on 79.

atoms is determined by the composition and configuration of the constituents. Hence, some atoms have half-integral spin, and the others integral. The physical world is divided into two classes according to the spin, and this division is coextensive with the statistical division. All the particles with integer spin are bosons; all the particles with half-integer spin are fermions. That is why to make a Bose-Einstein condensate you need the right kind of atoms. You need atoms that are bosons.

How to make a Bose-Einstein condensate

Making a Bose-Einstein condensate requires a diluted gaseous sample of boson atoms, and the combination of two techniques, laser cooling and forced evaporative cooling from a magnetic trap. The gas must be a hundred thousand times less dense than air, so that it takes a long time (seconds to minutes) for the atoms to stick together in ordinary condensation. The gas is then put in a cross-fire of laser beams of the right wavelength. Thanks to an effect called Doppler shift, it is possible to adjust the wavelength of the lasers so that the light in average carries away momentum when colliding with the atoms, as if hitting them more often frontally than from the back. The net result is that the atoms are slowed down to speeds that correspond to microkelvin temperatures. At this point, the lasers are switched off and a magnetic field is turned on that holds the atoms like a container. This is called a magnetic trap. The most energetic atoms can escape the trap, just like the most energetic molecules of hot tea evaporate from the cup. By suitably lowering the height of the trap, the energetic molecules are let out and the slowest remain, with the result that the remaining gas is cooled down, until the critical temperature is reached for the onset of Bose-Einstein condensation.

What are Bose-Einstein condensates for?

What drove physicists to achieve Bose-Einstein condensation? A simplistic answer is what Don De Lillo called "technology's irresistible will to realize in solid form whatever becomes theoretically allowable." The point is, however, that Bose-Einstein condensation itself was not theoretically allowable from the beginning. Everybody, starting with Einstein himself, was convinced that the temperatures required were so low that the molecules of any real gas would unavoidably stick to each other by effect of intermolecular forces, and form an ordinary liquid or solid much before Bose-Einstein condensation could take place. Only in the late 1970s did the scientists start to believe that ordinary condensation could be prevented, and only then actual experimental efforts toward the goal started. A more accurate answer is that at each step in the descent toward lower temperatures the physicists found something interesting to investigate further, as well as the technical means to do it. In fact, the history of cold atoms is characterized by a richer and more assiduous interaction between experiment and theory than what is told by the origin myth of Einstein's prophetic prediction. Among the lines of research that converged into the realization of Bose-Einstein condensation, an especially fertile one was the study of the interactions between light and atoms, a study that was vastly enhanced by the development of lasers. This, in turn, made laser cooling possible, and this technique pushed the temperature limits even further than anyone had expected. Another decisive line of research was the detailed study of atomic collisions, which disclosed the possibility of pre-empting ordinary condensation by means of a delicate balance of density and atomic speeds. Only when Bose-Einstein condensation appeared within reach did physicists start to believe that realizing it in solid form was a worthwhile experimental goal.

One of the motivations most often quoted by cold-atom specialists for their work is the possibility of control and manipulation they have over ultracold atoms. In fact, they say that a cloud of atoms in their lowest energy state affords "ultimate control", limited only by Heisenberg's uncertainty relations. The other motivation is that this cloud of atoms is a macroscopic quantum system, which means that it is a matter wave of almost visible size. According to a suggestive, if inaccurate, paraphrase of quantum mechanics recurrently employed to educate non-specialists about the formation of such a "giant matter wave", each particle can be thought of as a localized wave packet, with the extension of the packet depending on the temperature. At high temperatures, the packet is very small and compact, and the particles behave like miniaturized marbles. As the temperature decreases, the packets spread out, until their extension becomes comparable with the distance between atoms. Then, the waves begin to overlap, until they merge into a single extended wave. A Bose-Einstein condensate is a new raw material that not only can be totally controlled, but also has different properties from any material we know. For example, if two Bose-Einstein condensates produced in the same conditions are brought together, they do not mix as ordinary fluids do, but interfere with one another like waves. Another example is that if a Bose-Einstein condensate is stirred – which can be done by means of a rotating laser beam – it does not form a single vortex but many small vortices arranged in a regular lattice. As for what will be done with this new material in practical terms, the physicists point to future applications by mentioning high-precision measurements and lasers that emit matter beams instead of light. Rather than definite applications, these are open fields of potential applications.

What is being done, however, can be answered more precisely. Bose-Einstein condensates are used as physical, interactive models for other, less controllable, quantum systems. Not only can they be manipulated and fine-tuned at will experimentally; they are also systems that can be fully described theoretically from fundamental theory, without having to resort to the approximated phenomenology that is normally indispensable to connect the laws of microphysics to experimental observations on complex systems. All of this makes Bose-Einstein condensates ideal simulators of complex phenomena that are forbiddingly difficult to attack by theory or direct experimentation. They can be made to simulate other states of matter, and physicists expect to use them to investigate poorly understood phenomena, as for example superfluidity, high-temperature superconductivity, and neutron stars.

> Condensates have become an ultralow-temperature laboratory for atomic optics, collisional physics, and many-body physics. […]
> An attractive feature of Bose-Einstein condensation in dilute atomic gases is that it can be described theoretically from first principles. Therefore, condensates have become a valuable testing ground for the study of interacting many-body systems. […]
> The trapped ultracold vapour has emerged as a new quantum system which is unique in the precision and flexibility with which it can be manipulated. Our field is now at a historic turning point, in which we are moving from studying physics in order to learn about atom cooling to studying cold atoms in order to learn about physics.[12]

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12 James R. Anglin and Wolfgang Ketterle, "Bose-Einstein condensation of atomic gases", *Nature*, 416 (2002), 211-218, on 211-212 and 213.

Conclusion

Many of the objects of inquiry of modern physics are made objects that would not exist outside the laboratories and their technological extensions. According to S. S. Schweber, the unraveling of atomic structure and the advent of quantum mechanics persuaded physical researchers that

> the laws behind the phenomena had been apprehended, that they could therefore control the behaviour of simple microscopic systems and, more importantly, that they could create new structures, new objects, new phenomena. [...] Condensed matter physics has indeed become the study of systems that have never before existed.[13]

However much the scale and pace of the enterprise may have changed, physics' habit of creating its own objects of inquiry is not a twentieth-century novelty. Many would trace it back to Galileo's claim to demonstrate the natural law of falling bodies by means of polished bronze balls rolling in a parchment-lined groove. Ian Hacking locates its beginning at a more advanced stage of technological sophistication and social integration. For him, it started when Robert Boyle began experimenting inside the vacuum pump, and won the debate with Hobbes about whether the scrutiny of artificially produced phenomena by an elite of specialists was the proper way of learning about nature.[14] Modern microphysical experimentation, as well as experimentation with multi-particle systems like Bose-Einstein condensates, are in a line of direct descent from Boyle's experiments on the vacuum. They are prototypical practices of laboratory sciences, dedicated to the design, operation, and examination of specialized contrivances in controlled environments. They instantiate a form of scientific argumentation that Hacking identifies as one distinct style of reasoning, the "laboratory style", among others that have emerged in the history of science.[15]

The technological, social, and cultural landscape of early modern Europe created the preconditions for a full affirmative articulation of the analysis of artifacts, conducted in mathematical language, as a dominant resource in natural philosophy. The ancient practice of constructing mechanical or geometrical models to simulate natural processes evolved from a skeptical exercise of self-conscious analogy into a confident way of achieving effective knowledge about nature. Albeit irreducibly hypothetical, the construction of models came to count as true knowledge because it engendered intellectual clarity and sufficed to direct action. Emulating the success of the rational artists and engineers, the mathematico-experimental natural philosophers embraced the equation of understanding with construction and of explanation with reconstruction. They rationalized and then internalized the need to interfere with nature in order to extract her secrets.[16]

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13 Silvan S. Schweber, "Physics, Community and the Crisis in Physical Theory", *Physics Today*, November 1993, 34-40, on 35. Schweber's own overview of twentieth-century physics adumbrates a chasm between the source of physicists' confidence in their creative powers, and the reasons of the "crisis" that has resulted from the exercise of those powers at their most productive, namely, at the juncture between high-energy physics and condensed-matter physics. On the one hand, Schweber identifies the fountainhead of confidence in the persuasion that the "laws behind the phenomena" had been discovered. On the other hand, he highlights the effective "decoupling" of the description and control of complex phenomena from the laws that are supposed to be behind them.

14 Ian Hacking, "Artificial Phenomena" (note 1). On the vacuum pump and the Boyle-Hobbes debate, the landmark reference is Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton University Press, 1985).

Along with the metaphor of the world-machine and the master analogy between the divine and the human mind, this epistemological shift presupposed the Galilean composition of causes as the form of explanation for natural phenomena. Ordinary phenomena were resolved into complex aggregates of causes, the resultants of separate natural laws. Precedence was given to those occurrences that could be decomposed into one effect, governed by one law, essential to the phenomenon under investigation, and other minor effects, governed by other laws, accidental in the given circumstances, acting as disturbances. The accidental effects could be analyzed away in the conceptual model of the phenomenon, and physically removed or reduced in the execution of the experiment, so that the law in question could be made manifest . The experimental laboratory counted therefore not as a workshop of artificiality, but as a site to distill the essence of the phenomena. Likewise, artificial objects and effects ceased to be forced deviations from nature and became demonstrations of understanding and mastery of nature's laws.

The cult of material effectiveness and the thirst for material novelties of industrialized societies offered congenial ground to the growth of forms of knowledge structured as decomposition and re-composition. The laboratory style reached maturity in the nineteenth century, most spectacularly in chemistry and electromagnetism. The advance of techniques for the production of vacuum was essential to experimental research with electrical discharges, which opened the way to twentieth-century results on the structure of matter. Corpuscular theories of matter, according to which macroscopic appearances were literally the resultant of a few laws applied to myriads of micro-components, were especially suited to the vision of uncovering the laws of nature by purification of phenomena, and of explaining the world by gradual reconstruction. The model of the ideal gas is a clear illustration of the hypothetical modeling that, joined by the creation of phenomena, constitutes the laboratory style. It is also a powerful illustration of how styles of reasoning complement one another. Reasoning around the gas model was vigorously enhanced by the cooptation of another style, which emerged during the nineteenth century, the statistical style.[17]

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[15] The idea of a plurality of historically emerging "styles of reasoning" is obviously not exclusive to Hacking. One can recall, for example, Ludwik Fleck's articulation of "Denkstil", a term commonly in use in German culture, and Alistair C. Crombie's exegesis of the "Western scientific movement" in terms of six historically distinguishable "styles of thinking". Ludwik Fleck, *Genesis and development of a scientific fact* (Chicago: Chicago University Press, 1979); Alistair C. Crombie, *Styles of scientific thinking in the European tradition* (London: Duckworth, 1994). Hacking has expounded his notion of styles of reasoning most extensively in "Language, Truth, and Reason" (1982) and "Style for Historians and Philosophers" (1991), both reprinted in *Historical Ontology* (Cambridge, MA: Harvard University Press, 2002), 178-199 an 159-177. In "The Accumulation of Styles of Scientific Reasoning", in D. Henrich, ed., *Kant oder Hegel* (Stuttgard: Klett-Cotta, 1983), 453-465, he addressed how the plurality of styles of reasoning responds to the question of stability in the sciences, and examines the relations between style of reasoning and other categories of analysis of scientific development. His most detailed analysis of the laboratory style of reasoning is "The self-vindication of the laboratory sciences", in A. Pickering, ed., *Science as Practice and Culture* (Chicago:University of Chicago Press, 1991), 29-64.

[16] Alistair C. Crombie, *Styles of scientific thinking in the European tradition* (note 15), Chap. 12, "The Imitation of Nature", 1081-1241. Also, Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), 30-64 and 96-106.

[17] Ian Hacking, "Statistical language, statistical truth and statistical reason: The self-authentication of a style of reasoning", in E. McMullin, ed., *Social Dimensions of Science* (Notre Dame, IN: Notre Dame University Press, 1992), 130-157.

Theorists formulate laws that apply to ideal models, and experimentalists create artificial effects that approximated ideal models, with effects, models, and laws in dynamical relations of mutual adaptation. According to Hacking, the laboratory style of reasoning is characterized by

> the building of apparatus in order to produce phenomena to which hypothetical modeling may be true or false, but using another layer of modeling, namely models of how the apparatus and instruments themselves work.[18]

Bose-Einstein condensates are model systems that are used to investigate other systems, for cases in which the traditional layers of modeling are insufficient. We might regard the coming into being of Bose-Einstein condensates as the latest chapter in the historical development of the laboratory style of reasoning.

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[18] Ian Hacking, *Historical Ontology*, 184-185.

Preservation and Representation of a Geological Object "Natural Monument" as a Legislative Definition[1]

Dario Moretta

Foreword

During the *Wandering Seminar* the question: "*What does the definition* scientific object *define?*" was recurring. Middling territories of history and epistemology, the definition *scientific object* can be considered as a mere historical fact, but its ontological potentialities are explicitly stated[2].
The invitation to use the idea of *scientific object* as an hermeneutical tool which is able to translate a cognitive attitude acting in different contexts, either to adapt to different conceptions of "science", assumes to cross over the distinction if the definition itself is a "discovery" or an "invention" of modern historiography.

Regardless to whether it is intended as a display or as a construction, the concept is consequently called to describe a persistent though ever-changing model of the relationships between man and "things" through "science". Once the *grand narrative* categories have been so deconstructed to pass away, the concept is asked to lead into new scenarios, whether unexplored or un-built.

When the idea of scientific object was launched into the scholar community, the focusing point seemed to be that kind of historicized relationships of interest established between "producers of knowledge" and "objects of scientific enquiry". But as a community wandering from one museum to another, we needed to decline the definition *scientific object* looking at those historicized relationships of interest set up between those "environments of picked-up things" that are museums, and the "receivers" of scientific knowledge (i.e. visitors). "Do museums display only dead knowledge?", "Is it necessary to distinguish between a display and an historicized display?" "How to represent environment in the mass-consumption society?", these are all examples of questions presented during our tour[3]. How can one narrate stories through objects? Do things have particular qualities in representing and establishing knowledge? Why are some things intended to represent the current sensibility of the average visitor, better than others?

After the Wandering Seminar, I co-ordinated the visit to a cave of an environmental association teenage work camp. This cave has been declared, by regional law, *geotope of particular interest* first and *natural monument* later. Despite this, the area surrounding the cave is characterized by an intensive activity of extraction that compromises both the biological and geological particularities of the site. During the visit, I realised that the contrast between what "the preservation of a monument is expected to be" and the actual conditions of the site probably was

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1 For informations, help and suggestions thanks to: Irene Amadei, Paolo Catterina, Linda Chiodi, Peter Carlo Kugler, Vincenzo Ondei, Emanuele Pellegrini, Walter Robbiati, Paolo Schirolli, Dante Vailati, and Jan Von Brevern.

2 Daston ed. 2000: 1-14.

3 All these questions refer to specific objects edited (or: that are going to be edited as rotating objects) in the website of the Wandering Seminar (http://scientificobjects.mpiwg-berlin.mpg.de: "Wandering Seminar").

able in catching the teenagers' attention. And definitely increased their interest in the topics that were discussed.

So the meeting between a "community of receivers" and the cave was seemingly oriented by a specific definition. As an art historian, I always considered Francis Haskell's approaches to art reception and to the history of taste helpful in attempting to describe the ways we perceive things through time[4]. Clifford Geertz' ideas on the way we conceive ourselves through the filters of legislative definitions – by presenting a field in which precise definitions are very important – helped considering the way we name things as part of the process[5].

So is a geological object the same if it is indicated by legislation as a *geotope* or as a *natural monument*? And, more generally: when a new definition enters a community, does it change the objects it defines?

The following pages discuss these questions, by means of an object of scientific enquiry, a cave, a (legislative) definition, *natural monument*, and some of the relationships that link science to lawmaking and ecology to communities.

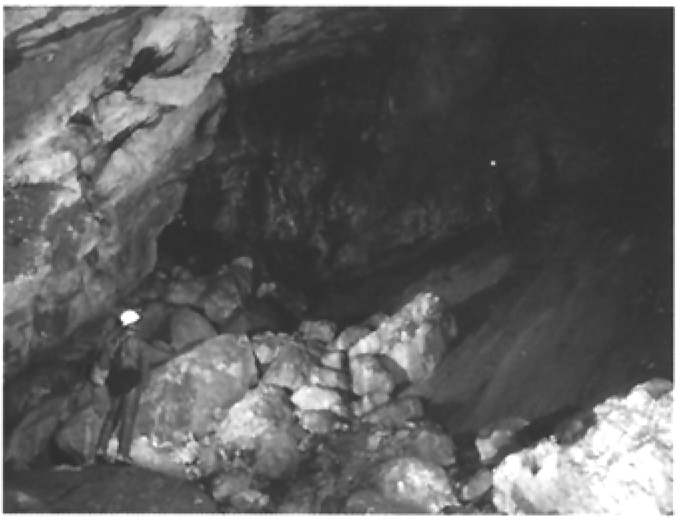

Figure 1: Internal view of the *Friar's hole* as it appears today. Object of scientific enquiry from the 1920s to the 1970s, the cave has been defined "biotope", "geotope" and "natural monument".

The "coming into being" of a natural monument

When Leonida Boldori (1897-1980), nearly 70 years old, started to write down his bio-speleological memories – for the journals of the Italian Society of Natural Sciences first and of the Natural Science Museum of Brescia some years later – it was impossible for him not to complain about the risks that the *Friar's hole* ("*Büs del fra*" – "*Buco del Frate*") was experiencing[6]. A cave in an area between Brescia and the Garda lake known as *Carso bresciano* (because of his Karstic morphology) the *Friar's hole* was (and still is) threatened by the same geological material that

4 See especially: Haskell 1978, 1987, 2000.
5 See especially: Geertz 1983.
6 Boldori 1963: 180-84; Boldori 1967: 26-28.

made it an object of scientific enquiry: the almost pure and crystalline calcium-carbonate nature of the rocks. The characteristics of the rocks condition the morphology of the area, as do the economic activities of marble extraction.

Boldori's fear was related to the almost new arrogance of what he called "*marmofilia imperversante*"[7] ("raging marblephilia"). Traditional techniques of extraction and a limited business were replaced by explosive mixtures and uncontrolled quarries opened without planning. Italy was experiencing its economical boom. Boldori wrote in 1963:

> In the last two years the situation get worse: more streets ploughed the slopes where a weak reforestation of cypresses has been attempted to give strength to the oaks scrub (…). And after the streets, came the quarries and the explosive mixture (…). These quarries are extending and are now dreadfully quickly reaching a cave that (…) is called "Friar's hole" (…). It is of high importance that the cave is rescued, meaning that it won't be destroyed by the quarries' advance, nor filled by debris, and we would add (…), nor shaken by mine explosions[8].

The *Friar's hole* reserved a particular place in Boldori's memory. In the 1920s, the speleologist had a primary role in some of the biological discoveries that took place there:

> In 1923, when I entered the Friar's hole (…) for the first time, I certainly did not think that the cave would provide me with so many fascinating questions, nor that it would excite me so much, that I would come back, at least eighty times in the following years[9].

To Boldori, a trained entomologist, the main fascinating questions were linked to the finding of some still unknown species of coleoptera which turned out to be very rare, if not unique. But the campaign of scientific enquiry of the twenties paid did not only pay attention to the insects. During the same period, the international research project defined by Emil G. Racoviță (1868-1947) in 1904, wanted to homologate studies on the Karstic phenomena around Europe, especially focused on Italy. "...and of course Brescia's province is present with Paitone and its *Friar's hole*", wrote Boldori, seemingly proud[10].

This claim of pride was not only personal, or local. It was about politics, it included an explicit request for environmental protection. In the 1960s, Italian legislation for the environment was regulated by the law 1497 issued in 1939, *Protection of natural beauties*. According to that law, the State should safeguard immovable real estate with a "conspicuous character of natural beauty or geological singularity"[11], through lists compiled by the provincial districts[12]. Since it seemed

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7 Boldori 1967: 26.

8 Boldori 1963: 181 "Ma in quest'ultimi due anni il male si è infittito: altre strade hanno solcato le pendici su cui si tentava un debole rimboschimento di cipressi tesi a dar forza alla boscaglia di quercioli (…) Dopo le strade son venute le cave e l'esplosivo (…) Esse cave stanno estendendosi e si avvicinano con ritmo paurosamente veloce ad una grotta che (…) si chiama "Buco del Frate" (…) È di somma importanza invece far sì che la grotta venga salvata, cioè non venga distrutta dall'avanzare delle cavem né riempita dai detriti e vorremmo aggiungere (…) nemmeno scossa dagli scoppi delle mine".

9 Boldori 1967: 24 "Quando nel lontano 1923 entrai per la prima volta nel *Buco del Frate* (…) certo non pensavo né che la grotta mi riservasse tante fascinose questioni, né mi appassionasse quindi al punto da farmici ritornare, negli anni che seguirono, per un'ottantina di volte".

10 Boldori 1967: 27 "…e la provincia di Brescia è naturalmente presente con Paitone ed il suo *Buco del Frate*". Results of the Italian researches appeared on the seventh series of "*Biospeleologica*" from 1918 to 1927.

difficult to persuade the provincial committee of the beauty of the site, to be more successful it was instead stated that its "geological singularity" was certified by international projects.

> Let this be clear from the very beginning : the Friar's hole (no. 1 Lo of the national speleologic register) is not a Postumia, nor a Castellana ; it is not a sequence of spaces embellished with limestone collars and rocks lace, though it has an unmistakable wild beauty. Anyway it is a cave of great interest for the scholar (...) Many other things could be said, but (...) what is important is the defence, the protection of the Friar's hole, which today is a classical place for research, still rich in unknown matters and in study possibilities[13].

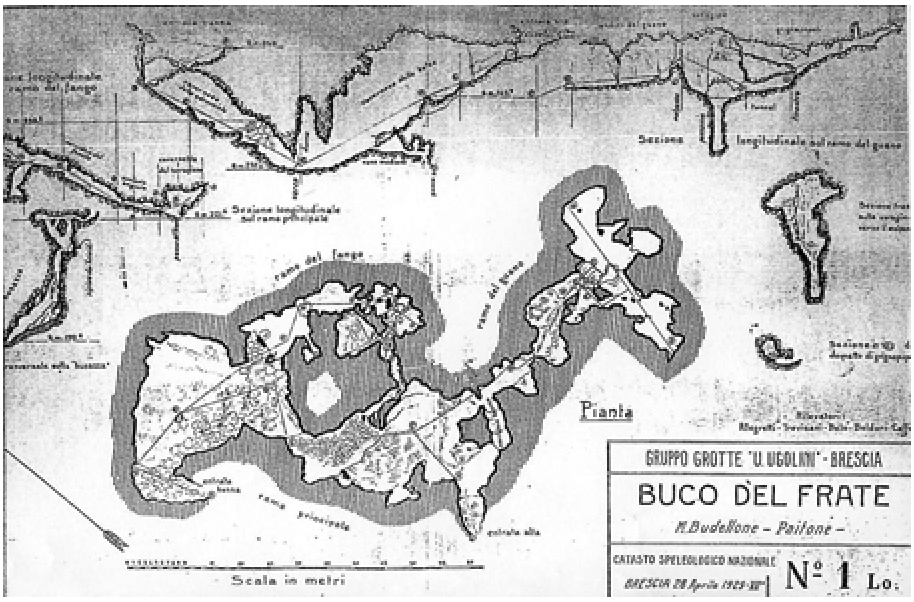

Figure 2: Relief of the *Friar's hole* for the national speleologic register, April 28, 1929. The number "1 Lo" has been often used to underline symbolically the historical and scientific significance of the site.

In a way, Boldori did not renounce to consider the cave "beautiful". But he knew the wild beauty he referred to was a concept missing in the Italian legislation[14]. It was not recognized by the common people, nor by naturalists[15]. This wild beauty was not pictorial. It was not humanistic. It was not even *rocaille*. It did not relate to an aesthetic of measures and/or decorations[16]. Probably,

11 L 1497/1939 (June, 29): art. 1.
12 L 1497/1939 (June, 29): art. 2.
13 Boldori 1963: 181-82 "Intendiamoci subito: il Buco del Frate (n. 1 Lo del catasto speleologico nazionale) non è una Postumia, non è una Castellana; non è un succedersi di vani adorni di trine calcaree e di merletti di roccia, pur avendo una sua inconfondibile selvaggia bellezza, ma è una grotta di grande interesse per lo studioso (…) Molte altre cose si potrebbero dire, ma (…) quel che conta è la difesa , la tutela del Buco del frate ormai località classica di ricerche, ricca tuttora di incognite e di possibilità di studio".
14 Seemingly, the concept of "wild beauty" is on loan from the concept of "wilderness", central in Henry David Thoreau's vision of ecology and in the making of the American environmental culture: Worster 19942: 57-112. Today the concept of "wilderness" is opposed by some environmental historians such as William Cronon, since it would set man outside of nature, and either refers to a limitative romantic aesthetic: Dann-Mittman 1997.

this was the reason why Boldori described the cave as a *classical* place for research. He was shifting into the field of scientific knowledge (I would say normative knowledge)[17] a concept considered necessary, but actually inapplicable in its formal meaning. In the passage above, the label of "classicism" is gained by a double reference to the time scale that intends to delete the ending of an historical trajectory[18].

Figure 3: External view of the *Friar's hole* as it appeared in the 1920s. The absence of "beautiful" features has been a problem in for preservation efforts. From the beginning, environmental tutelage problematically confronted aesthetical questions.

On one side, the cave was the very place where things were started. The mention between brackets of the number "1 Lo" that the *Friar's hole* gained in the national speleologic register of at least 1500 caves in Lombardy ("Lo"), seems not at all casual. The national speleologic register, published by the Italian Intitute of Speleology since its birth in 1927[19] wanted to follow international standards in speleology. It wanted to create an homogeneous database to which could be referred, in order to avoid repetitions while illustrating new results in caves that had already been described[20]. So

15 Boldori refers to the two mountains that surround the cave as to mountains "not beautiful, to say the truth" and as "nothing spectacular" (Boldori 1963: 180-81). Maybe for a particular taste for contrasts, the naturalist Valerio Giacomini (1914-1981) was even more drastic: "Anyone also poorly supplied with naturalistic sensibility who would like to face the short but *not so much attractive* slope that leads from the green plane of Prevalle to these *dreary, grey, sun-hit* rises, would astonish of grateful wonder by approaching so curious and characteristic forms of superficial and subterranean karstsism" (Giacomini 1937: 227. Italics mine).

16 I find quite meaningful that Boldori himself, while describing the beauty of the main Italian caves, avoids completely a gothic glossary. About "pictorialism" of natural beauties in Italian legislation, consider that one of the four classes of "natural beauties" (L 1497/1939 (June, 29), art. 1) is constituted by the "panoramic beauties, regarded as natural paintings" ("le bellezze panoramiche considerate come quadri naturali"). The class is registered in the 2004 "Code for cultural and natural goods" (*Codice dei beni culturali e ambientali*, DLgs 42/2004 (January, 22), art. 136) and consequently still operating.

17 Gombrich 1963 is in fact very useful for the relationship between naming, aesthetics of science and visual reception.

18 On different meanings of the word "classic": Tatarkiewicz 1958.

19 The Italian Institute of Speleology reached its final setting in 1929, but publications of the register date back to 1927, year of birth of the Institute's journal: *Le grotte d'Italia.*

20 Gortani 1930.

Boldori's research in the late twenties was inscribed in a lively context of disciplinary settlement. And the relevance of his (and Corrado Allegretti, or Gustvo Laeng) research in east Lombardy probably had its importance both in leading the territorial division for the register to assume an unusual east to west direction, and in giving the *Friar's hole* the symbolically meaningful "number one"[21].

On the other side, Boldori was not simply thinking of a memorial. The cave was still rich in unknown material to study. Just the year before Boldori's plea, the *Annals* of a recently opened little museum started their publications with a dossier on the excavation campaign of 1954-56 that resulted in impressive paleontologic findings[22].

In fact, Boldori thought that the place was perfect to establish an Italian centre for biospeleological research[23]. The reason for "classicism" was not only because it was able to overcome the timescale, it dealt with an ontological status. As an object of enquiry, the cave was classical because it was *complete*.

> The Friar's hole is, in certain way, a complete cave since it offers great abundance in fauna in a place where flora is already interesting. And everything in a little "Karst" that condenses nearly the whole of speleologic phenomena. The cave offers branches almost horizontal, branches with remarkable deposits of guano, branches in which big blocks create little biotopes protected by minimal alterations. There are different kinds of wells, narrow passages and very high domes, while the entrance offers a series of areas submitted to slight changes in light investment. The covering of the cave changes from a thin cover maybe a couple of meters to imposing strata of limestone placed upon each other. In short, it is a cave with an near completeness of most aspects, that should be considered a rare example of a natural, subterranean laboratory. These laboratories are rare.[24]

The marriage of classicism and scientific enquiry can be seen as a mediating strategy between a demand for ecological preservation and a 1930s legislation mainly about landscapes, and formal aesthetics. In any case, it was not sufficient to get the *Friar's hole* in a protection program. Even the huge *bibliographical curriculum* of the cave presented by Boldori was not useful. But at least it

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21 Scheme of the territorial division of Lombardy into three east to west-speleological areas is reproduced in Pavan-Pavan 1955: 5. The official mapping that assumes the *Friar's hole* as no 1Lo of the national speleologic register is dated April 28, 1929. The related description was published next year in the journal *Le grotte d'Italia*: Boldori 1930. During the Wandering Seminar we also met another "lucky number": Marconi's licence no 7777/00. See the object in the Wandering Seminar Website (http://scientificobjects.mpiwg-berlin.mpg.de: "Wandering Seminar").

22 Mazza 1962. Studies and communications about the 1954-56 campaign, that brought into light rests of *Ursus spaeleus, Canis lupus* and *Hyaena spaelea* in Allegretti 1956, Pasa 1956, Marzollo 1962.

23 Boldori 1963: 183.

24 Boldori 1963: 182-83 "Il "Buco del Frate" è una grotta in un certo senso completa perché offre gran dovizia di fauna in una zona con una flora certo interessante. Il tutto in un piccolo "carso" che condensa la quasi totalità dei fenomeni speleologi. La grotta in parola offre rami pressoché orizzontali, rami con depositi notevoli di guano, rami in cui grandi massi creano piccoli biotopi difesi da facili alterazioni. Vi sono pozzi di vario impegno, strettoie e duomi altissimi, mentre l'entrata inferiore offre un susseguirsi di zone sottoposte al lento variare dell'investimento luminoso. La copertura della grotta varia da un tenue copertura forse di uno o pochi metri ad un imponente sovrapporsi di strati calcarei. In una parola è una grotta con una quasi completezza dei più vari aspetti, da potersi considerare come un raro esempio di naturale laboratorio sotterraneo. Rari sono questi laboratori."

increased a civic and political sense of shame about the inability of a legislatively motionless Italy to protect sites of scientific interests[25].

In fact, requests for a renewed and more efficient legislation on environmental protection were growing[26]. They were made more urgent by the swiftness of the industrial development, and by the lively European context[27], but they were not answered properly yet. It was only after 1977, when a large part of the legislative powers in environmental protection moved from the State to the Regions that things started to change. In the same year, the *Friar's hole* finally entered a list of protected sites. In a way, it was too late: the "classical space" for scientific knowledge had turned into a place of scientific memory.

What a simple word allows to say

In the "Authority greetings" of a little book dedicated to the *Friar's hole* that appeared in 2003, the councillor for the environment of Lombardy pointed out the reasons why the Region included the site in a list of protected areas:

> The Friar's hole has since 1977 been recognized as a geotope of particular regional interest. Law 83 of 1986[28] has classified it as a "natural monument", since it was an element of particular naturalistic and scientific significance.
> The unquestionable scientific interest that characterizes the cave under the different aspects of speleology, geo-morphology, paleontology and fauna is proven by the fact that the cave has been the object of numerous studies since the beginning of the Twentieth century. (…)
> Natural monuments often assume this double value: on one side, they give testimony of the natural phenomena by which they are originated. On the other side, they remember the cultural and scientific activities by which they were surrounded while time was passing by[29].

In spite, or maybe because of its political rhetorical tone, the short speech was very able in catching what the word "monument" allowed to say. It referred both to nature and to history, making the most of the "reminder" radix of the word. It avoided aesthetics, but not humanities. The use of the verb *circondare* ("surround") underlined with a visual metaphor both a humanistic way to

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25 The bibliographical lists of 120 works dedicated to the cave from 1882 to 1954 appears in Boldori 1967: 27 and refers to the bibliography on Lombardy speleology appeared in Pavan-Pavan 1955. The "sense of shame" is highlightened, in Boldori's words, by a specific comparison with other countries: "It is not less true then scholars of other countries will get more irritated than us, complaining that in Italy there is no respect for the things of nature" (Boldori 1967: 26 "Non è men vero che studiosi d'altri paesi si sdegneranno più di noi lamentando che in Italia non si ha il rispetto per le cose della natura").

26 For a first overlook: Di Fidio 1991, Ceruti ed. 1996, Signorino ed. 1996.

27 A *European committee for the conservation of Nature and its resources* was created in 1963; in 1966 the European Council decided to declare the 1970 as "Year of the safeguard of nature".

28 To say the truth, the regional law that the text refers to is the number 86 of 1983. Quite an embarrassing mistake for the regional assessor at the environment!

29 F. Nicoli Cristiani in Vailati 2003: 5 "Il Buco del Frate è stato riconosciuto come geotopo di particolare interesse regionale fin dal 1977. La legge n. 83 del 1986 (*sic*, see note 17) l'ha succesivamente classificato come "monumento naturale", in quanto elemento di particolare pregio naturalistico e scientifico. L'indubbio interesse scientifico che effettivamente caratterizza la Grotta sotto i diversi profili speleologico, geomorfologico, paleontologico e faunistico, è testimoniato peraltro dai numerosi studi di cui è stato oggetto dagli inizi del '900 ad oggi. (…) I Monumenti naturali assumono spesso questo duplice valore: testimoniano da un lato i fenomeni naturali da cui hanno avuto origine, dall'altro ricordano l'attività culturale e scientifica che nel tempo li ha circondati".

consider monuments as objects of interest, and a harmonic shape of the relationships between men and environment.

The word *monument* refers to broader lexical practices than *geotope*, and consequently has the ability to persuade wider audiences than just the scientific ones to the fact that the object it designates is something one should care about. It is typically connected to a culture of massive preservation, since the object it indicates is usually meaningful as a memory to be kept alive. By coincidence, the memorial meaning of the word *monument* combined perfectly with the fact that from the late 1970s the *Friars' hole* was confirmed as a classical place of the birth of speleology in Lombardy, but was not longer considered a site of active research[30]. The grown-up discipline had turned its eyes elsewhere, because palaeontological samples were no longer available and because the intrusive presence of quarries nearby compromised the biological environment.

The law that introduced the concept of *natural monument* in Lombardy in 1983, was the result of a long process that started about ten years before[31]. Right after some important competences in environmental protection and preservation of "natural goods" were moved from State to Regions in 1977[32], the Region published a law concerning *Measures in the field of environmental and ecological tutelage*[33]. That same year, the Region committed to the creation of a catalogue to make a complete map of the areas in Lombardy that were being preserved by the national law 1497/1939 on natural beauties. The catalogue showed clearly the necessity to overcome an episodic tutelage, expressed through aesthetic values[34]. As pointed out by a conference initiated by the Region of Lombardy in that same year 1977[35], it was necessary to move towards an "ecosystem" perspective where not only "landscape paintings" needed protection, but more importantly the relationships between men and their environment. That perspective, ratified by the UN *Declaration on the human environment* (Stockholm 1972), made tutelage even more necessary in areas with very low aesthetic appeal, such as industrialized districts, or densely populated regions. The memory of the ecological disaster of Seveso, where on July 10, 1976 a toxic cloud of dioxin generated by an accident in a chemical factory caused harm to a highly urbanized area twenty kilometres north of Milan, was still fresh and painful as were the memories of the difficulties and delays during the management of the emergency.

Though published right after the move of powers in environmental safeguarding from the State to the Regions, the 1977 regional law *Measures in the field of environmental and ecological*

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30 After 1967, another paleo-speleological expedition was organized in 1970, but with not satisfactory results. See Simoni 1971. On the other side, archive researches traced back to 1872 the first "scientific visit" to the cave. The visitor, Giuseppe Ragazzoni (1824-1898) was one of the most important actor in the establishment of a speleological tradition in the area of Brescia, which became in the late nineteenth century the Italian area better known from a speleological point of view after the Karst. See Vailati 2003: 52-60.

31 Furlanetto 1984 remembers the Council of the Region undertook to elaborate a plan for protected areas since November 8, 1973.

32 DPR 616/1977 (July, 24): mainly articles 80-83.

33 LR Lombardia 33/1977 (July, 27):*Misure nel campo della tutela ambientale ed ecologica.*

34 Regione Lombardia 1981. In the "Authorities greetings" Luigi Vertemati, councillor for territorial politics of the Region wrote: "The publication (…) show(s) the substantial episodic nature with which, in back times, on proceeded in the field and clearly denounce(s) that an environmental policy that only confides on a binding policy can not be longer proposed" ("La pubblicazione (…) evidenzia(...) la sostanziale episodicità con cui si è proceduto in passato nella materia e denuncia(…) l'improponibilità di proseguire sulla strada di una politica ambientale affidata alla sola politica vincolistica").

35 Consiglio Regione Lombardia ed. 1978.

tutelage did not acknowledge yet the new competences involved with this change. The law should be considered rather as a result of the conflicts between the State to the Regions, since the institution of the Regions in 1970[36].

The regional government was not satisfied with the definition of *natural beauties*, and the concept of *environmental goods*, used by the new Ministry for cultural and environmental goods (1974). The 1977 law decided to use the concepts of *biotope* and *geotope* to define some particular "local places of specific naturalistic interest" that asked for safeguarding[37]:

> For the purpose of the present law biotopes and geotopes to be protected are considered to be environments, not heavily altered by anthropic interventions, that are of particular natural and scientific interest for the presence of vegetal, zoological, geo-morphological, paleontological, mineralogical or hydrological displays (…)[38].

Differing from *natural beauty* and *environmental good*, *biotope* and *geotope* were explicitly scientific terms. They broke with an aesthetical tradition in naming, but also with a circular idea of complementation between humanistic and scientific cultures (or: between "culture" and "science", as often described in nomenclature documents in the 70s).

Not much used at a legislative level, the terms were frequently employed by natural scientists to describe particular areas. The term *biotope* was introduced in Germany at the beginning of the twentieth century. According to Haeckel's ideas on habitat, it was used to indicate an area of similar environmental conditions providing living space for a specific assemblage of plants and/or animals. As a consequence, *geotope* (from the German *geotop*) was introduced to indicate a small spatial unit, geographically homogeneous, recognizable from the surroundings because of the geological and geo-morphological processes that characterize it[39].

By using these terms, the Region of Lombardy seemed to recognize the first importance of scientific reasons for tutelage. To elaborate on "compromise-formulas" like the one used by Boldori in his 1960s pleas was not longer necessary. A biotope should be preserved as a biotope, a geotope as a geotope. The *Friar's hole*, which entered the list of preserved areas attached to this law, did not need its "wild beauty", nor its "classicity" anymore.

Although the discussion of the law does not provide particular information about the decision to introduce these terms[40], we can attempt an interpretation by looking at some of its current uses. We know, for instance, that the term *biotope* has been used in territorial planning documents at least since 1971. During that year the Italian National Research Council presented a *map of Italian biotopes* as a result of a more general program intended to locate areas liable for preservation[41]. In

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36 On these conflicts see Ceruti ed. 1996: 16-21. Concerning Lombardy, we should remember the long, pioneering and often opposed process of institution of the first regional park in Italy along the Ticino river (1971-74), and an official petition against restrictive interpretations on territorial planning agreed by the State (1972).

37 LR Lombardy 33/1977 (July, 27) : art. 1 "luoghi di particolare interesse naturalistico locale".

38 LR Lombardy 33/1977 (July, 27): art. 2 "Agli effetti della presente legge sono considerati biotopi e geotopi da tutelare gli ambienti, non gravemente alterati da interventi antropici, che siano di particolare interesse naturalistico e scientifico per la presenza di manifestazioni vegetali, zoologiche, geomorfologiche, paleontologiche, mineralogiche o idrologiche (…)".

39 The first occurrence of the term *biotope* is in Dahl 1908. Definition of *geotope* according to Sturm 1994.

40 Regione Lombardia 1975-80: 1813-27.

41 Pratesi 1973 : 25.

1972, the Italian botanical society presented a "census of remarkable biotopes that deserved protection"[42]. In 1973, the European Council circulated a "classificatory essay" on the terms used for protected areas in Europe, in which "biotope preservation" was the expression used to describe purely scientific interests in the tutelage[43].

The use of *biotope* answered a demand for protection clearly expressed by scientific *milieus* both in Italian and European contexts, but the use of *geotope* seemed more problematic. Possibly this term was introduced for a simple choice of symmetry. But it could also be that the reference to an explicit German nomenclature – not much used elsewhere[44] – was chosen as an implicit critique to the national policy. Just one year earlier, Germany ratified its *Bundesnaturschutzgesetz* (Federal Nature Conservation Act): this general policy law did not only consider the scientific motivations as essential, but also delegated almost all the competences in territorial and eco-systematic planning to the *Länder*.

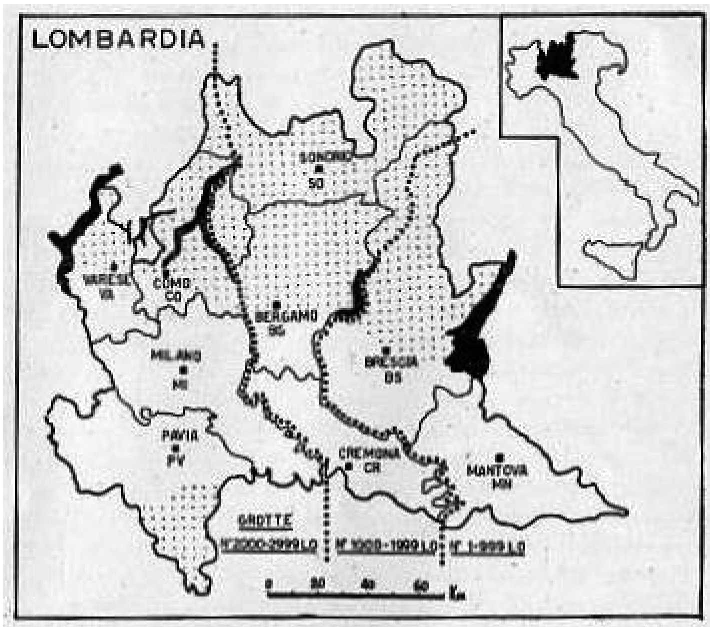

Figure 4: Map of Lombardy for the usage of the national speleologic register. The division into three areas assumes an unusual east to west direction, probably due to the intensity of research in East Lombardy at the same period that the register was established.

Flying high and coming back to sentimentalism

When, in the afternoon of July 28, 1983 the regional counsellors of Lombardy met to pass the law – later known as *General plan for the protected regional areas*[45] – the sensation of pride was in the air. It didn't matter that in front of the Regional office some environmental groups were protesting

42 Pratesi 1973 : 25.
43 Conseil de L'europe 1973: 102, 104.
44 On the german origins of the term see Wiedenbein 1994.
45 LR Lombardy 86/1983 (November, 30). *General plan for the regional protected areas. Rules for the institution and the managing of the reserves, the parks and the natural monuments, as well as areas of particular natural and environmental relevance.* Information behind are mainly taken from the discussion on the law in Regione Lombardia 1980-85: 2669-2746.

against the "low compromises at the last moment" by waving posters saying "From Seveso to the fraud-law on the parks"[46]. Of course, that was irritating. But at the same time, it was the evidence of the existence of at least two cultures of landscape preservation, and of the difficulties implied in a long process of mediation aimed at representing the whole society.

Actually, the law aspired to place the 40% of the regional territory under tutelage (a percentage never seen, or imagined in a country with a miserable 0.63% of protected territory)[47] and with this it involved a large part of the population. As a consequence, it was necessary to definitely separate from the association "park"-"system of hard control" in order to avoid refusal or a "park-fear". It was important to present the tutelage program not as an unpopular "top-down" coercive process. It was rather necessary to engage as more as possible citizens' sensibility and awareness, in order to obtain consent.

In short, the law had to find out a good conciliation between anthropocentric and eco-centric points of view, in order to translate a theoretical eco-systemic framework into a general practice. Since this program was completely new in the national scene, and ambitious, it was predictably difficult. The bill was the result of a long process, sometimes encounting difficulties and criticisms of opposite sides[48]. But the final compromise between the naturalists' claims and the necessity of an industrialized population was felt as so "reasonable" that the political consent on the law was unusually unanimous[49]. In many counsellors' opinion, this was a big merit. For instance, the socialist counsellor Maurizio Ricotti though that:

> We know we are trying to fly high, to fly very high and the Region of Lombardy can truly give, on this subject, I am not saying a lesson, but an indication of direction to other boats, bigger sailing ships: to the national legislator for its general law[50].

If then "flying high" would mean "coming back to sentimentalism" in terms of environmental culture, that was a risk worth taking.

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46 "Da Seveso alla legge truffa sui parchi". Protests were mainly concerned with hunting in some particular protected areas and with some mechanism of choice of environmental committeemen. "Seveso" refers to the chemical accident of 1976 mentioned above, "legge truffa" to the national law 148/1953 that introduced a mechanism of majority prize for the parties that obtained more than the 50% of votes. The law, hardly contested, failed in giving expected results while implied a huge loss of votes for its main sponsor (Christian Democracy party) in the next elections. It was abrogated in 1954. The information about the poster in Regione Lombardia 1980-85: 2693. The day before the discussion, a press release with critical remarks on the "low compromises of the last moment" was diffused by an alliance of environmental associations. See: Corriere della Sera 1983a: 14; ARL III.419, prot. 2053/1983 (June, 2).

47 Information from: Regione Lombardia 1980-85: 2681; Pratesi 1971: 14.

48 As seen above, first attempts to create a regional legislation in the field were figured out in 1973 and took back after the delegation of powers in territorial planning from the State to the Regions (1977). The bill that finally turned into the regional law 86/1983 was presented in 1980 by some counsellors of the communist party and adopted by the Regional Council in march 1981. Since then, the law proposal was discussed several times with a great number of associations representing environmental groups as well as productive activities and other groups. During the process critiques were expressed by hunters, environmental groups, agricultural and industrial associations. See ARL III.419, letter ANLC to the President of the seventh commission, June 21, 1983 and protocols: 2569/1981 (July, 6) 2669/1982 (June, 20) 3320/1982 (August, 31). See also Furlanetto 1982.

49 Corriere della Sera 1982b: 15. The unanimous consensus was possible even because many critical amendments were retired just before the approval. "Italia nostra", at the time the main Italian association for preservation and the mostly engaged with a general policy for environmental tutelage expressed a positive judgement of the final version: see Furlanetto 1984.

> One thing that you" says Ricotti to a colleague "regained this evening (…) was to sail, or to fly a little bit higher over law projects that, despite the good frameworks risk to be – how to say – "technicians' property". And I'm saying without polemizing, since I (…) realized that actually this is not the street (…) that should be followed, if we want this operation to be successful in our Region. (…) Since I realized that for me, as maybe for others, when talking of ecology, it is based on a feeling, a sensation, but not yet based on a "culture" which is necessary to support a successful framework: the kind of wind that allow the ship, once departed, to be able to navigate for a long time. So excuse me, if I am tiring you by sharing with you the fruit of this experience in a kind of cultural tone. But please realize that neither the politicians, nor the territory-planners can be instrumental to let this boat navigate and go on, if we do not create the conditions, also by means of this law, to make the birth of an environmental culture possible. We are now only still on a level of sensations and feelings.[51]

Maybe it is because of this "coming back to sentimentalism" that the "good framework" deleted technical definitions as *biotope* and *geotope* and replaced them with a more sentimental *natural monument.*

Not much used in the national legislation, the term was anyway a sort of "back to the roots". Regarded as not conceptually far from *natural beauty*[52], *natural monument* was definitely easier to understand than *biotope* or *geotope.* Of course it did not necessarily refer to an aesthetic dimension, but it had to refer to something more intimate than an "objectivistic" connotation. Something about the history of men and their knowledge, or at least about that humanistic tradition of *exempla* useful for the rhetorical *movere.* In this sense, the definition underlined that complex dialectic between nature and culture which was recognised as fundamental to both the environmental attitudes, and studies. This recognition was probably considered more needed than ever, in a moment in which environmentalism had to "go public" [53].

Going public, *natural monument* derived from *geotope* and *biotope* a less exoteric connotation of hard conservation. As meta-cultural, the definition was helpful in reminding of a dimension less ephemeral than those drawn by specific fields of knowledge. At the same time the new definition was helpful in better justifying conservative preservation: the idea that a monument

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50 Regione Lombardia 1980-85: 2683 "Sappiamo che stiamo cercando di volare alto, di volare molto alto e la Regione Lombardia può dare veramente un'indicazione di marcia e di rotta per altre barche, per velieri più grossi: al legislatore nazionale sulla legge quadro".

51 Regione Lombardia 1980-85: 2677-78 "Una cosa che tu (…) hai recuperato stasera nel tuo intervento (…) è stata quella di veleggiare o di volare un po' alto rispetto a progetti di legge che, nonostante gli impianti validi, rischiano di essere un pochino troppo, come dire?, di proprietà dei tecnici. E lo dico senza polemica, perché io (…) mi sono reso conto che in verità non era questa e non è questa la strada (…) che può essere battuta, perché nella nostra Regione questa operazione riesca. (…) Perché mi sono accorto che in me stesso, come forse negli altri, quando si parla di ecologia forse c'è dietro un sentimento, una sensazione, ma non c'è ancora dietro la cultura che è necessaria a supportare un'operazione valida: quel vento che permette poi alla barca, una volta varata, di poter navigare a lungo. E allora io mi scuso con i presenti, anche perché può sembrare un po' tedioso dare o cercare di dare al mio intervento il frutto di questa mia esperienza, cioè un taglio prevalentemente culturale. Ma guardate bene che non saranno i politici, e tanto meno gli urbanisti come strumento, in grado di far navigare questa barca e di farla andare avanti se non si creano le condizioni, anche attraverso questa legge, di far nascere una cultura ecologica, che non c'è ancora se non a livello di sensazione o di sentimento."

52 The association of farmers observed that, since the definition *natural monument* was unique in the legislative context but at the same time very similar to the definition of *natural beauty*, Region Lombardy probably wanted to arrogate to itself competences up to the central government. See ARL, III.419, prot. 3751/1981 (October, 15).

should be preserved integrally was generally accepted, since it has been turned into action by centuries of tutelage practices of cultural goods.

Since the infancy of the unitary state, protection of architectural groups as *National Monuments* made Italian legislation confident with the "cultural" declination of the word[54]. At the beginning of the twentieth century, the legislative use of the word *monument* was able to indicate a "specific thing" (mainly an architectural group) appearing in a list of national places posed under tutelage, or a "generally remarkable thing" reminding of an important aspect of the history, the art or the literature of the nation.

This is why, when in 1905 Giovanni Rosadi invited the Italian government to pledge for a natural beauties preservation bill, the word *monument*, even if not written, was clearly signified: "The House of Parliament invite the government to present a bill for the safeguard of those natural beauties that are connected to the literature, the art, and the history of Italy"[55]. Nature was not valuable for itself, but was a reminder of a cultural tradition intended mainly as humanistic heritage.

This meaning was even more evident when, in 1911, Rosadi tried to appease the opponents by saying that "a law that would defend natural beauties not necessarily has to include them all (…) but only the ones that have an extraordinary value related to nature or to memory"[56]. It was quite understandable that the Italian Botanical Society (in its general assembly in Rome, October 12, 1911) made an appeal the way it did it: "so that the law for the tutelage of the landscape proposed by Mr. Rosadi could have wider meaning, and he could consider the *natural monuments under their scientific value*, so that also flora could gain protection"[57]. It was encouraging also, that *monument* and *scientific value* were considered not contradictory, but actually mutually qualifying.

Any reference to the word *monument* was deleted by the time of the final approval of the law, something pursued by Benedetto Croce only in the late 1922. In the meanwhile the same expression, though dangerously connected to formal aesthetics, was living a more promising life in nearby France.

The beginning of an Arcadian environmentalism in France is usually associated to the establishment of a *Ligue pour la conservation des sites pittoresques*, in the late nineteenth century. Mainly composed by artists and literary men, the *Ligue* was influential in posing the issues that

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53 On the nature/culture dialectics through history: Worster 1985, Evans 1992. "Going public" is an expression used by Evans 1992: 121 to characterize the political nature of British environmentalism from the 1970s. Nature/culture dialectics of this period, with a closer look to Italy, are analyzed by Certomà 2003. Dann-Mittman 1997 report on debates over these dialectics in the 1990s and on attempts of refreshing the definition by introducing opposites such as "real"/"virtual".

54 A first list of (ecclesiastic) places named as *national monuments* and required for protection appeared in the law 3096/1866 (July 7) on the suppression of religious corporations. During the 1870s the term was used to qualify the peripheral offices dedicated to the preservation of cultural goods (*Prefetture delle commissioni conservatrici di monumenti e oggetti d'arte e d'antichità*, 1874-76; *Ispettorati agli scavi e ai monumenti*, 1875-80). In 1884 a ministerial decree (November 27) nominated *Regional Committees for the National Monuments* to refresh the list of cultural spots protected by means of the State. Condemi 1997: 23-31.

55 Ceruti ed. 1996: 11.

56 Ceruti ed. 1996: 12.

57 Ceruti ed. 1996: 14 Italics mine.

lead, in 1906, to the approval of the law *Protection des sites et des monuments naturels de caractère artistique*.

As far as I know, this was the very first appearance of the expression into legislation, and the one that enhanced its subsequent spread, most. As a matter of fact, the persistence of the term in the French legislation allowed Edouard Bourdelle to use the category of *natural monument* while proposing a "unified system for the nomenclature in the field of nature protection" (1948) adopted by the IUCN (*World conservation union*, former *International Union for the Conservation of Nature and Natural Resources*) in 1956[58].

All of the following summaries of categories edited by IUCN (1967, 1978, 1994) included the class: *natural monuments*. Since these summaries were used to register the worldwide environmental patrimony and since they explicitly aimed to standardize nomenclature in the field, their normative power should be considered.

Since 1962, Italian environmental associations and member of Parliament who had been asking for a new general law on environmental tutelage, looked at the IUCN categories as a model[59]. At Lombardy law arrived earlier and aspired to be exemplar for the national legislator, we can assume that the formal acceptance of the IUCN categories were also tied to the Italian history for environmental protection.

Nevertheless, behind the same name we can find objects defined in very different ways. The definition of *natural monument* according to Lombardy is "single elements or little areas of natural environment of particular naturalistic and scientific significance, that should be preserved in their integrity"[60], and according to the IUCN is "a natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative of aesthetic qualities or cultural significance"[61].

As we have seen, the Lombard *natural monument* reflects a 1970s-onwards necessity of environmentalism to go public. It is a compromise between scientific knowledge and social feeling that only keeps hard-conservative and ambiguously referential connotations. On the other side, the IUCN *natural monument* still reflects its early twentieth-century *pictoresque* birth, and a history where scientific and aesthetic reasons for tutelage were considered opposites[62]. Though slight changes in definition were made were different IUCN summaries of categories came out, these often have been considered insufficient by many scientific and enivronmental communities: aestheticism remains a problematic primacy[63].

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58 Bagatti Valsecchi 1964; Signorino ed. 1996: 693-96.
59 Camera dei deputati 1963-68; Italia Nostra 1965.
60 LR Lombardy 86/1983 (November, 30): art. 1.
61 IUCN categories 1994: category III.
62 An astonishing example of this history is the already quoted *Essai de classification* edited by Conseil d'Europe 1973. Inspired by the IUCN categories, the European Council proposes four categories from the most scientific one (A) to the most recreational one (D). The only admissible element that characterizes (A) is the scientific interest. In these areas no other people than scientists are allowed to enter and every kind of human intervention is strictly forbidden. (D) are defined by a mostly recreational destination, considered by evaluating "cultural, aesthetic and naturalistic" interests. Mostly every kind of human activities as well as "motorized circulation" are generally allowed. In the *Essai*, the expression *biotope protection* appears only to define a possible (A) activity, while *natural monument* appears only to define a possible (D) feature.
63 Signorino ed. 1996: 697-704.

The problem seems sensible between geologists. Since *natural monument* started to indicate areas of relatively little dimensions[64], because of a translational habit that considers *monument* as equivalent to a visible and easily noticeable tangible object, the definition turned out to be more suitable for geological than biological displays[65]. Geologists fear that, as a consequence, communities will consider geological features only relevant when they are "monumental"; motionless, distinguishable from wider contexts, and mostly aesthetically remarkable[66].

From the 1990s, some possible solutions were suggested. On one side, the participants of the first international symposium on the protection of geological heritage (Digne, France: 1991) wrote an *International declaration on the rights of the memory of the Earth*, underlining the importance of geological features in an historical-sentimental perspective[67]. On the other side, the IUGN (International Union of Geological Sciences) started in 1995 an international program to make an inventory of geological and geo-morphological sites. To name these, IUGN choose a refreshed (and extended) version of *geotope*: namely *geosite*[68].

Both the solutions described above avoided aesthetical formulas. Both showed sensibility to those compromises between scientific knowledge and social feelings that characterize an environmental culture aspiring to go public.

While echoing Lovelock's *Gaia hypothesis*[69], the *Declaration on the memory of the Earth* assumes that, apart from beauty, geological features always can aspire to move feelings since they are intrinsically "monuments". By substituting the Greek with the Latin suffix, *geosite* echoes the British tradition of preservation of the so-called *Sites of special scientific interests*[70]. It is neutral, easily understandable, and avoids any qualitative aspect but Earth.

Seemingly, geological programs reject a monumental concept of preservation because it is associated with a "still life" sense of beauty. On the other hand, a strictly hierarchical concept of preservation, concerned with a vision of scientific sites as *Sancta Sanctorum*, risked to turn geology into a Cindarella: she may be the most capable girl, but she is banished into a kitchen[71]:

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64 The already quoted *Bundesnaturschutzgesetz*, for instance, foresee for natural monuments a maximum extension of five hectares.

65 According to Di Fidio 1991: 155, "to say the truth, natural monuments are essentially objects, or group of objects that can be connected in inseparable ways with definite areas. This characterization as objects (…) implies that the concept of natural monument is easier applicable to geological displays then to biological ones, with the exception of trees".

66 The problem is described, in a *Geosites* program presentation, as follows: "In the field of preservation of nature and its resources, the delay accumulated by the earth sciences towards other disciplines depends on deep social and cultural reasons, connected to scarcity in the systems of divulgation and information of arguments as fascinating as complex . This gap of knowledge brings to consider wrongly the geological context not as a dynamic component of the landscape, but as something motionless. The geological context is so perceived and appreciated only when representing a natural monument, a landscape singularity, or, to synthesize, a scenic element, static and uprooted from the territory and its evolution. As a consequence, it is a common opinion that we should consider as geological goods liable to tutelage, those "natural beauties" that attract crowds of tourists". Torino 2006: 2.

67 The fourth point, for instance, statues: "Our history and the history of the Earth are closely linked. Its origins are our origins, its history is our history and its future will be our future".

68 Poli ed. 1999; Amorfini ed. 2005.

69 Lovelock 1979.

70 The category was introduced in 1949 by the *National Parks and Access to the Countryside Act*. See Evans 1992: 75-78.

> Any 'geological object' becomes world heritage, and consequently 'cultural good' the moment its knowledge is shared and the object can be benefited. Otherwise it remains just a finding, an insignificant piece of catalogue[72].

Figure 5: Quarries near the *Friar's hole*, as they appear today. From the 1960s, the opening of new quarries and the use of mine explosions claims for environmental protection were raised. The limited area of monitoring accorded to a "natural monument" is however problematic, since it implies that the monument is independent and distinguishable from wider contexts. This is one of the reasons why today geologists prefer to use the term "geosite" to indicate areas geologically remarkable.

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Today the *Friar's hole* is still there, still surrounded by expanding quarries. Not far from warnings of mine explosion, a wooden panel marks the presence of the cave, and the fact that it is a natural monument. Naturalists and amateurs won obtaining tutelage from the region, but for a long time

71 The expression *Sancta Sanctorum* was used by G. H. Lestelle, *Inspecteur général des monuments historiques chargé des sites de France*, while commenting the law 60-708/1960 (July, 22) on *Object du classement en parc national*: "As a line of conduct, aFrench national park will be made up, in its centre, by a strict nature reserve. This will be, in a sort of way, its *Sancta Sanctorum*, forbidden to anyone but scientist", quoted in Camera dei Deputati 1963-68: 45. This expression reflects vividly a hierarchical (and religious) concept of environmental preservation dominating before the 1970s but still problematic when compared with the human context of landscapes : "This is a point that ought to be further assimilated especially by scientists and environmentalists, so to make their suggestions understandable, and welcomed by governors" (P. F. Federici in Amorfini ed. 2005: 8). The expression *Cindarella* is a quotation from W. A. Wimbledon, in Poli ed. 1999: 65.

72 "Un qualsiasi 'oggetto geologico' diventa infatti patrimonio comune dell'umanità, e quindi 'Bene culturale', solo nel momento in cui la conoscenza viene condivisa e l'oggetto può essere fruito, altrimenti rimane solo un reperto, insignificante parte di un catalogo" G. Poli in Poli ed. 1999:9; Similarly, P. F. Federici (Amorfini ed. 2005: 9) points out: "An object come into being a geosite right in the moment when its knowledge is shared and both the knowlegde and the object can be benefited" ("Ma un oggetto diventa geosito nel momento in cui la conoscenza viene condivisa ed essa e l'oggetto vengano fruiti")

they had to deal with the delays of the municipal district in activating measures of protection. Some of their requests were finally granted. Today the two entrances are protected by gates, a limited area of respect has been acquired. Adjustments have been made to the street connecting the area to the quarries, to prevent discarded material from filling the cave[73]. Anyway, the contrast between a regime of preservation that is pretending to be "integral", operates only in the limited monitoring area, and the plan for excavation licences is in the terminology, and remains unsolved.

The cave has been defined as a classical place for research, a geotope, a biotope, a natural monument. Today it would probably be considered a also as a geosite. Through history, sometimes these definitions seem to elide one another, but they not necessarily need to. They delineate histories, movements of ideas. The definitions are connected with the cultures they express, and with the way they got into practice. If a place of research looks for "classicism", it should be because we want to find a way to consider its humanistic beauty. If a natural monument is considered "static", that should be because we have been used to consider monuments as tangible objects, often referring to events that frequently passed away. If the importance of a "geosite" is described by referring to the history of the Earth, that should be because "natural monument" got the meaning of "naturally monumental".

Differently from scientific objects in a science museum hall, geological features can not be removed or archived. But like eyes, terms can see different things, or ask for different things to be seen. Attempting depictions can maybe help in considering in which way cultures reflect on themselves, and on their objects.

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73 Still in 1989, the local seat of WWF and members of the political opposition in the municipal district were denouncing the administrators' incapability either to protect the area and to oppose the economical interests of the societies excavating nearby. Though regional funds were available since 1981, at that date the area of respect has been reduced and was not acquired yet. See: Vitali 1989, Ondei 1989. The majority of tutelage operations were done from the 1995 onwards by a different administration. This last is today trying to enlarge the area of respect and, by those means, to contrast the opening of new quarries foreseen by provincial plans.

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Reconstruction of Scientific Instruments and Experimental History of Science

Stefano Salvia

Between "rêverie" and method: the magic of reconstructions

The aim of our discussion is to outline a general overview of the main questions that could arise when we consider a reconstructive approach to the history of science and technology as part of its current practice. It is a very first attempt for us to consider this topic in a systematic way, starting from a private "notebook" of different and isolated reflections about, and also from our personal experience on reconstruction of early seventeenth-century devices used by Galileo to perform his measures and experiments of "mechanics". This particular field of research will afterwards provide us most of the material for a brief survey on the theoretical and technical problems that such an "applied" method may encounter on its own way.

The use of reconstructions has become quite widespread in recent years, not only strictu sensu as *material* but also as *virtual* 3D and animated "objects", challenging our traditional notions of *objectivity* (both as "Gegenständlichkeit" and "Objektivität"), *de-/re-materialization*, *presence/presentification*, *re-production*, even our common sense and our implicit "ontology" about the meaning of being *in contact* with a "thing". One could say that the technoscientific and post-industrial society in which we live nowadays is making Heidegger's classical distinction between "Dinge" and "Sachen" more and more problematic.

Maybe these increasing ontological co-implications have lead many historians, philosophers, and sociologists to focus their attention on the so called *material culture/context* of (shared) knowledge, ranging from history and philosophy of science to history of art and design, from history of music to the relationship between science and literature, technology and markets, just to give some examples of how broad such a transdisciplinary area can be. Therefore, the question "what makes an object scientific?" does not seem to be in opposition or even in contradiction with another fundamental question, "why is our scientific culture so object-oriented?". They could be seen as two different perspectives from which to consider the same problem, the question both of *scientific objectivity* and of *objectivation in science*.

Of course, the availability of new materials and techniques of *materialization* and *visualization* is at the same time part, cause, and effect of this complex cultural phenomenon. This could explain why we are so interested in trying to reconstruct e.g. a musical instrument of antiquity starting from its representation on a Greek vase or on a Roman mosaic in Pompei, to bring its "voice" back from oblivion, even if we do not actually have anything but a few conjectures about how and by whom it was played, in which context it was used, and more generally how ancient music was really performed. All the available information about the theoretical and technical "know-how", so to speak, comes from the extant *verbal* sources of classic and late antiquity, mainly from Augustine's *De musica*, thanks to its nature both as philosophical treatise and as disciplinary compendium.

Figure 1: A Roman mosaic representing two musicians and their instruments.

Nevertheless, no verbal documentation, even if relatively complete, is truly able to give us back the *non-coded* and *informal* knowledge, the specific skills that were involved and embodied in the artisanal construction of an ancient instrument. Moreover, we have to be very careful when we use a picture as a starting model for a reconstruction. Images have their own *visual* "grammar", their own modalities of *non-verbal* communication, let us say their own "language". They could instantiate very different kinds of *re-presentation*: a schematic and simplified stylization, a "purified" and archetypical idealization, an "objective" and analytical description, rhetorical or symbolic depiction, and so on. We can only suppose – and hope, at most – that the "alltäglich" scenes represented in many Roman villas are really "snapshots" of everyday life directly coming from the past, but we could be wrong.

Would it be possible not to mention one of the biggest and most important projects of virtual reconstruction ever carried out regarding the history of ancient Rome? This is the 3D high-resolution, dynamic, and interactive reproduction of the "caput mundi", from the early Republican Age to Constantine's empire, with the possibility of a real-time comparison between past and present, what "was there" at that time and what remains today. The project involves the cooperation of many European and American institutions, and of course the three main Universities of Rome. Once more, one could ask: does it make sense, even if such a reconstructive model is based on the most accurate philological and historical knowledge at our disposal on the urban history of the Roman capital? At what level of resolution should we stop? Is the objection that we are not able to reproduce each detail – let us say the bakery owned by "Titius Caius Sempronius" close to the Senate – a good argument against such a big enterprise?

Figure 2: A virtual reconstruction of the Amphitheatrum Flavium in ancient Rome.

The examples of "reconstruction-philia" we have just discussed pertain to ancient history, because of the amount of interest and money invested in reconstructions and exhibitions on this subject, especially since the techniques of digital imaging and virtual reality have become very common and easy to employ on the Web. But we could do the same with so many attempts of reconstructing Leonardo's machines from his manuscripts, or with the "dream" for a musician of playing Bach's sonatas with a reconstructed clavichord that Bach himself must have used at his time. A reconstruction, a replica of something that does not exist any more, seems to have a sort of magic or even religious aura. Its fascinating power goes beyond any methodological criticism that could be raised against it. Reconstructions have something to do with "resurrection" from death. They embed the aim of "saving what is lost", preserving "memory" and "identity", re-writing our narratives about history.

Many historians of science display a positive (if not enthusiastic) attitude concerning the use of reconstructions in their own discipline, while others are very sceptical (if not suspicious) about it, accusing the former of being victims of this "enchantment". They could say, "One cannot 're-build' the past or looking really at the 're-birth' of a remain, as H. G. Well's time-traveller could do with his famous machine, simply by pulling back a lever!"

Science, history, and experiments

Do historians actually need to build reconstructions of instruments, machines, or even experimental environments, for their own work? One could reply that it depends on which kind of historiography we have in mind and how much we want to be inclusive from a methodological point of view. A long (and perhaps old-fashioned) debate has made a strong opposition between an "epistemological" and a "purely historical" approach. It is not difficult to recognize here an echo of the often very complicated relationship between history and philosophy of science in the last century, across different cultural traditions and contexts in which these two disciplines built up their own identity and academic status. More recently, the development of the so-called *Sociology of Scientific Knowledge* (SSK) has refreshed this debate, showing how fluid and arbitrary the boundaries among history, philosophy, and sociology of science and technology can be.

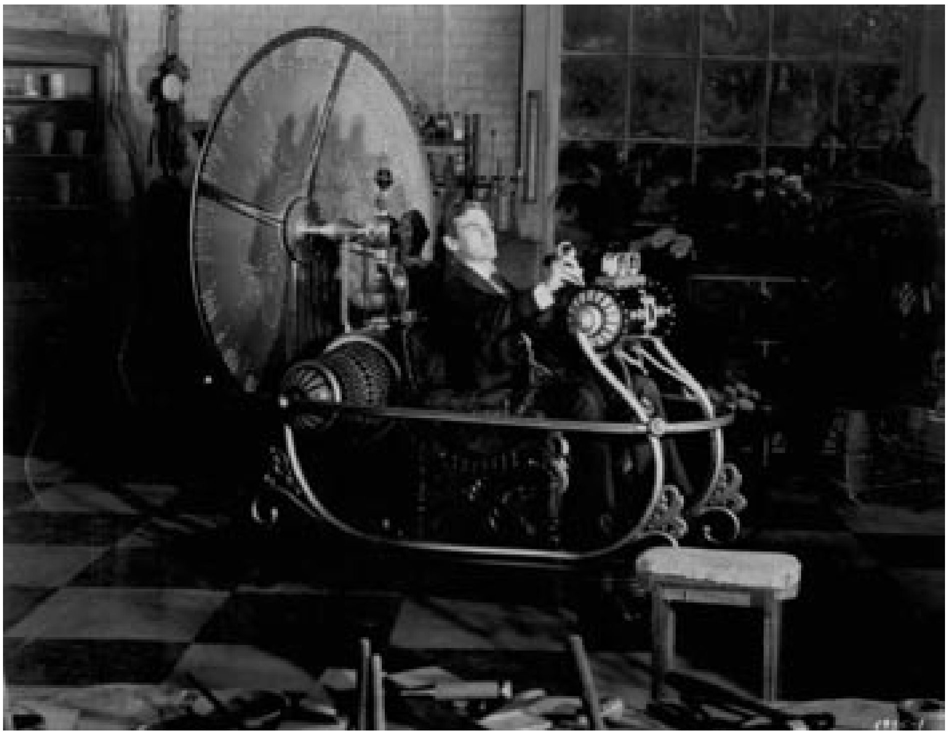

Figure 3: George Pal's *The Time Machine* (1960), inspired by H. G. Well's novel (1895).

Of course, this is not the right place to discuss more in detail such a complicated and delicate matter, but sometimes this opposition crossed over with another order of questions. Does history have only a merely *descriptive* task, or should it have also an *explanatory* goal, like many other sciences? Does this distinction between *description* and *explanation* really make sense, if we consider also the most recent developments in the philosophy of natural and social sciences?

Different solutions and intermediate positions are possible. If we assume a too rigid and exclusive perspective, according to which an historian should work only with extant and original testimonies of the past, we move toward a form of radical "historicism" that looks with suspicion at any search for strong causal relationships among historical events. Any theoretical framework that aims at providing an explanatory account without being as much adherent as possible to what we "positively" have as historical sources, has to be regarded with scepticism as speculative or even spurious, including the attempt to "rebuild" what did not survive through time and so cannot be available anymore.

One could argue, on the other hand, that historiography – if not philology itself, at a very basic level – is always concerned with "reconstructing" the past from what is accessible to the present state of our knowledge. When a historian works on his documents and formulates a historiographical hypothesis, he wants to provide also a reliable account, a sort of *heuristic* model, whose key categories and concepts are in any case theoretical "filters" through which facts, events, and contexts can be selected, interpreted, and explained. The non-neutral nature of the observer's "eye" is something that does not need to be discussed here. Anyway, many of the objections that can be raised against a reconstructive approach in the history of science and technology move actually from an attitude we have just referred to.

The risk of what we have called "radical historicism" is a lack of awareness about this non-neutrality, the illusion of "letting the past speak for itself". It could be regarded as a myth of the historical datum, not different from some extreme versions of empiricism and foundationalism in the philosophy of natural sciences. An excessively cautious and sceptic habit against any possible form of "presentism" can turn itself into this sort of self-deception. On the contrary, the risk of the exactly opposite attitude is a specular lack of consciousness about the historicity and incompleteness of any perspective of analysis (even the most aprioristic one) that moves from our present time, something that Wilhelm Dilthey could ironically call "Geistesphilosophie".

A historico-critical attitude that tries to balance these two possible risks, being aware of both the theoretical and the historical nature of any account of the past, seems to be the only reasonable solution, at least from a "regulative" point of view. It is a sort of paradoxical dilemma, with what seems to be a basic and necessary co-implication between *history* and *theory*. The challenge is to look at it not as a limitation, but as the *a priori* and productive condition for any sort of investigation, at most if we consider such an open and interdisciplinary field of research like the *Science and Technology Studies* (STS), i.e. the convergence among history, philosophy, and sociology of scientific knowledge and practices, with all their possible interactions and crossing links.

Considering this emerging new perspective, the oppositions we mentioned above seem to lose most of their previous relevance, including the question whether a historian, a philosopher, or even a sociologist of the STS should prefer a "top-down" or a "bottom-up" perspective, a "low resolution" (macro) or a "high resolution" (micro) level of analysis, a big picture- or a case study-oriented research, and so on. Each methodological choice has its own advantages and limits, as well as each disciplinary area has its own more or less established traditions, interests, and potential developments. In any case they could be seen as different windows that give access to the complex phenomenon of *technoscience*, as it should be nowadays conceived in our post-industrial *society of knowledge*. It is the explicit or implicit starting point for every question concerning what we usually call "science" (still looking at it as something different from "technology"), its origins and history, its theoretical features, the influence from and the impact on its social, economic, political, and cultural milieu.

From this point of view, a reconstructive approach to the material culture of scientific discovery and practice can be considered as an important contribute to an integrated *experimental history of science* that regards both the extant historical instruments and their present reconstructions from different kinds of sources as its own objects of inquiry. We have just recalled how much the *non-verbal* documentation has become as important as *verbal* in the last decades. This is true in particular for an "applied" historiography whose task is to give an account of the deep entanglement between ideas and things, theories and experiments, methods and results, concepts and their embodied expression as devices and workspaces. Graphs, diagrams, schemata, drawings, plans, all we could classify as *iconic/iconographic* material, play a key role as well as data, measures, reports, and descriptions, if our goal is to reproduce a working instrument or a machine and its context of use, in order to explain how it worked, why it was built and by whom, its original functions, the conceptual framework that made it possible and useful for a certain purpose. On one hand the shift among different modalities of visual representation we referred to may affect the "reliability" of an image used for a reconstruction, but on the other hand it could be regarded as a sort of prismatic lens through which an object can be observed from many angles.

These attempts of integration lead however to some epistemological and methodological problems and objections that we cannot simply avoid, even if we want to be as "tolerant" as possible looking at what we have just referred to as *experimental history* as a more specific branch of the STS. One can say that every *syncretic* and *unifying* attitude has to deal with a possible mismatch or contradiction among different approaches, methods, and epistemic values, coming from different disciplinary areas. As we said before, the main challenge is to make this "essential tension" a critical and productive factor for a more general and comprehensive point of view, instead of perceiving it only as a sign of confusion, weakness, and incoherence, or even a clue of superficial eclectism.

Just to give an example, the literature in and on *actor network theory* has already become enormous in less than two decades and it is still growing. Beyond any discussion about its epistemological and methodological status, its "successes" and "failures", this particular approach in the SSK has led to a deep reconsideration of the traditionally dualistic relationship between subject and object of inquiry, actor and instrument, theory and practice, knowledge and communication, thought and expression, and so on. Bruno Latour's fascinating and problematic notion of *actant* – also because of its wide range of applicability – plays a powerful deconstructing and reconstructing role in his model, something that we could see as an interesting starting point toward a *trans-humanistic* perspective, in which "things" and "artefacts" are *performative actors/agents* and the "non-human" (or better "trans-human") has a primary causal and relational relevance, as well as the human nodes of a functional and knowledge-based network.[1] "Performative" is here used precisely in the sense that the actors/agents are objectivations or *inscriptions* which both instantiate a network of functional relationships and can actively establish new relations and functions at the same time. A possible outcome that cannot be neglected if we want to be aware of the background assumptions we make each time we deal with *scientific objects* and their possible *contexts*, especially when this implies a reconstructive method that has to answer to the questions we mentioned at the beginning.

Reconstruction and simulation: two faces of the same medal?

At this point, one could ask if it is correct to use reconstructions as *performing experiments* in history of science and technology, where "performing" should not only mean "working" but also *explaining* themselves and their historical, theoretical, and experimental meaning through their own contextualized performance, so that we could overlap the semantic areas of the terms

1 B. Latour – S. Woolgar, *Laboratory Life. The Construction of Scientific Facts*, Princeton 1986. B. Latour, *Science in Action. How to follow Scientists and Engineers through Society*, Cambridge (Mass.) 1987.

performing and *performative*. “Wortspiel” apart, the question concerns directly the problem of the epistemological status of a historiography that aims at bringing an object “back to life”, from a perspective that should of course avoid any sort of naive “self-deception”, as we pointed out before. This sort of *re-presentification* of the past seems to be based on the implicit assumption that reconstructions could be crucial for accepting or refusing an *explanatory hypothesis/model* in history, as experiments can be in the natural sciences. Moreover, the extended meaning we have just attributed to the term “performing” goes in the direction of a very particular kind of experimental evidence, which is usually defined *synthetic* or *simulative*, like in the cognitive sciences, AI, and robotics.

Obviously an endless technical literature on the problems related to the use and the implementation of simulations and synthetic models in these fields of research exists, but an incursion into all this matter would lead us too much far from our topic. Anyway, following what could be only a suggestive comparison between two very different concepts of *evidence*, one could feel authorized to conclude that a reconstructed object is able to “implement” or to “interpolate” the information actually available from the extant historical sources that have made its reconstruction possible. One could say that a reconstruction can go beyond the simple historical *analysis* by means of its own *synthetic* nature and its working performance, saying something more about itself through its own active (re)presentification. The difference between *simulation* and *reconstruction* would become in this case only a difference in orientation of the “time-arrow”: the former being *forward-oriented* (explanation as *productive construction* and *prediction*) and the latter being *backward-oriented* (explanation as *re-productive construction* and *retrodiction*). This seems to us quite problematic, even if very stimulating. No “user-friendly” solution seems to be behind the corner. Maybe it is better to leave the problem open, exploring some possible implications.

Furthermore, the word *implementation* could besides be regarded as the key term of such a parallel, both concerning what we have called the “performativity” of a reconstruction and the more general question if we are allowed to consider the work of a historian as similar to the kind of research carried on by a natural or a cognitive scientist, at least from a very basic methodological level. Starting from this last point, we should assume, as we just said above, that there is neither a radical nor an essential difference between the historiographical and the scientific use of the word *evidence*, in order to claim that *experimentation* – and *simulation/reconstruction* as a special form of experimentation – makes sense also in historiography, and in particular in history of science. It sounds of course like a very strong assumption, if not too reductive, at least because we are normally not used to consider the “Kulturwissenschaften” as based on an “experimental method”. However, also a too strong opposition between *history* and *science* seems to be artificial, even “ideological”, just because of the mutual interplay between historical and scientific knowledge in such a multidisciplinary field like the STS.

Let us consider, as a counter-example, the use of modern technologies coming from nuclear and particle physics to date documents and artefacts of the past, e.g. in the PIXE scanning. They are becoming a common research tool for archaeology and therefore, more or less directly, for historiography. Does not this entanglement between historical research and contemporary physics have anything to do with preparation, measurement, experimentation, production and circulation of “inscriptions”, as well as verification/falsification of certain working-hypotheses?

How much can we legitimately distinguish between "historical" and "scientific" explanation or evidence, in this case?

Carl Gustav Hempel, on the contrary, would not have any problem to accept this view.[2] As a logical empiricist, he looked at the "Naturwissenschaften" (mainly the physico-mathematical sciences) as the epistemological framework and paradigm on which to found the notions of "Wissenschaft" and "Wissenschaftlichkeit" themselves. We are supposed not to be "neo-positivists", so we do not necessarily need to support such a heavy form of reductionism. What is rather interesting here is Hempel's comparison between "historical explanation" and the explanatory accounts produced in biology and the life sciences, especially in evolutionary-developmental biology and palaeontology, all disciplines we are used to classify as "experimental", beyond any old-fashioned opposition between "nomological" and "ideographic", observational/ descriptive ("soft") and explanatory/exact ("hard") sciences. We do not want to engage with the details of his arguments, but they seem to go precisely in the direction of conceiving both kinds of account as based on a *retrospective explanation* that implies the uniqueness and irreversibility of its *explananda*.

So we come back to the specular relationship that could be established between *simulation* and *reconstruction*, as we have outlined it before. The main epistemic problem traditionally related to what is called "implementation" in AI and in the cognitive sciences is the *functional equivalence* of different simulative/reconstructive models. In other words, it is the "black box" dilemma, the problem of the degree of *functional abstraction* and *descriptive/explanatory resolution* of the model: similar or even identical constructions, with similar or even identical "performances", at a low resolution, can be very different in details. Focusing more on our topic, we could face an analogous problem when we "rebuild" something that does not exist any more, basing our reconstruction on the actually available sources (both verbal and non-verbal), which can often give only partial information about the original context of production and use of an object, as well as about its detailed features.

This last remark may appear quite trivial, but one could ask whether the supposed performative "surplus" that a reconstruction should display, by means of its own being "working", "in action", "in (a new) context", has anything to do with the degree of functional resolution obtained by implementing the available historical information. To reformulate the question, how much of our *present time* are we allowed to put in this *historical experiment*, both conceptually and materially, in order to implement/interpolate the possible lack of information/knowledge at a higher level of resolution? Should we therefore come back to the previous questions about the risks of "presentism" and "presentification" in history of science that we had already considered when we started our discussion? Another question is implied, perhaps more philosophical but strongly related with the previous one: does an extant document of the past have a *privileged* epistemic status, a lower degree of *mediation*, compared with that of a reconstructed object? The "common sense" would answer, "Yes, of course!" Is it the same kind of common sense according to which "data" are in some way given to us, while "ideas" should be based on their posterior (re)elaboration?

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2 C. G. Hempel, *Philosophy of Natural Sciences*, Englewood Cliffs (N.J.) 1966.

Reconstruction vs restoration: implementation and "reverse engineering"

On the other hand, one cannot deny that there is a sort of "knowledge gap" between the information achievable from the documentation and the (re)contextualized performativity of a reconstructed device "in action". Many technicians who work professionally at reconstructing instruments, machines, and experiments devote themselves to the "routine" of providing building materials, techniques, artisanal skills, and step-by-step solutions for the problems they confront every day. They usually *feel* this implementative "surplus" through their own procedures and activities, as something that has much more things to say than a written text, an oral description, or an image, even if they are often the only available source from which to start. Something "more" that should justify and support the use of reconstructions within the framework of an experimental history of science and technology.

Following Michael Polanyi's "post-critical" account, one could render this particular *feeling* in terms of *tacit knowledge*, both personal and shared (inter-personal) at the same time, embodied by "non-conceptual" or "non-propositional" practices, standardized gestures, trained actions, more or less stereotyped patterns of kinaesthetic coordination that we could call *habits*, or even "rituals".[3]

One could argue, however, that this use of *tacit* or *implicit* is somehow ambiguous, if not suspect. Are we sure that what we regard as "unexpressed" is really independent from what we *want* to see as "objectively" instantiated? Of course we do not want to enter a (definitely not new) digression on "hermeneutic circles". What we would like to point out here is only the risk of abusing such a heuristic strategy like a "passe-par-tout", assuming in advance what should be demonstrated at the end, "discovering" a posteriori what was already presupposed a priori. Our suggestion is to replace this strong opposition between *explicit* and *implicit* with a still problematic but maybe less ambiguous distinction between *coded* or *formal* and *non-coded* or *informal* knowledge, starting from the assumption that both these modalities are anyway "explicit", "expressed", "inscribed". If it makes sense to talk about a *corpus of knowledge* shared by some practitioners, including people involved in the practice of reconstruction, replication, or restoration, such a corpus should be regarded as a complex and dynamic field of interactions among different formal and informal "savoirs" and "arts", as well as among different forms and levels both of *conceptualization* and *objectivation*.

Maybe the sensation of being more "lively" and "directly" in contact with the day-by-day job of the instrument-makers of the past we referred to before is partially based on the implicit assumption that the know-how required *today* to make a reconstruction of an instrument should be more or less of the *same* kind as the technical expertise required to do such a job at *that* time. Far from being simplistic or reductive, this claims raises a lot of questions about the relationship between "pure" and "applied" methodology, theoretical and technical implementation, understanding of the extant historical documents and experimental practice, in *reconstructing* as much as in *restoring* scientific objects.

In this last case the task of a historian-technician engaged in restoring experimental equipment might appear simpler than in the previous situation, in which a no longer existing

3 M. Polanyi, *Personal Knowledge. Towards a Post Critical Philosophy*, London 1958, 1998^2. Idem, *The Tacit Dimension*, New York 1967.

object has to be rebuilt completely anew. But restoration is not at all an easier affair than reconstruction, although it might seem at a very first glance a more comfortable and less embarrassing question of "reverse engineering", starting from an incomplete or damaged but still extant instrument or device that is supposed to be a more "reliable" and "objective" historical source than texts and pictures. Restoring it implies nevertheless an implementative problem that is not less delicate than that one involved in the reconstruction of a machine from a plan or of an ancient building from its ruins.

Figure 4: Kristian Birkeland's portrait on the 200 Norwegian crowns banknotes. On the left: his "Terrella".

Just to provide a typical example in which restoring and preserving is not less problematic than reconstructing, let us consider the case of the famous "Terrella" made in 1913 by the Norwegian physicist Kristian Birkeland (1867-1917) to simulate the phenomenon of the aurora borealis. According to Birkeland's hypothesis of explanation, the aurora was the result of the interaction between the flow of charged particles that would be later called "solar wind" (electrons, in his model) and the terrestrial magnetic field. J. J. Thomson's discovery of the electron and experiments with vacuum tubes in the last decade of the nineteenth century had opened the way for this kind of inquiries, in which it is not difficult to recognize a common pattern that ranges from the first research on "cathodic rays" to Roentgen's discovery of the X-rays, all the way to the development of the first thermoionic and then electronic valves between the 1920s and the 1940s. Birkeland's simulation was based on the same principle of the cathodic tube, by means of a vacuum chamber in which air was replaced by a subtle gas. Forced on its way by a magnetic field, the electronic current generated through the ionized gas from the cathode (which represented the Sun) to the anode (a metallic sphere that was a miniature model of the Earth) was expected to reproduce the same electronic currents generated in the terrestrial ionosphere, and which, according to Birkeland's model, generated the atmospheric phenomena known for centuries known as aurora borealis or "northern lights".

In 1995 the Department of Physics of the University of Tromsø in Norway decided to restore Birkeland's apparatus and to reproduce – hence to "reconstruct" – the original experiment performed by Birkeland in 1913. The most straightforward way to do that could simply be to substitute the damaged or missing parts with modern materials and pieces of equipment, similar or at least analogous to the original ones used by Birkeland. From a strong *functionalist* point of view, in fact, the most important thing is the resulting performance of the system, beyond the specific implementative "details" that can make it possible, so that the problem of the functional equivalence we have discussed above turns itself into a sort of methodological freedom.

The most interesting point of the "Terrella affair" is precisely the discussion that arose day by day among the physicists and the staff of the department about the "know-how" that could or could not be put into the restoration process. One of the main technical problems they had to face was the state of conservation of the vacuum chamber, especially of its glasses, that had to be very thick and strong to resist to the difference of pressure between the external atmosphere and the internal space. Also some components of the air pumps used in the experiment had to be replaced.

How to restore the whole machine, how to guarantee its original performance, without going "beyond 1913", so to speak? Should all the possible leaks of the chamber be prevented, according to the present high-quality standards of experimentation in physics? Should the performance of Birkeland's device be "improved" and "standardized", according to the most recent safety rules and procedures that must be followed in a modern laboratory? Last but not least: would it make sense to refer to the restored apparatus still as "Birkeland's Terrella", if the team of technicians in Tromsø had chosen the "easiest" way we tried to suggest through these questions? Fortunately this was not the case. Terje Brundtland, former laboratory technician at the University of Tromsø and now Ph.D. in history of science in Oxford, who was responsible at that time for the restoration of Birkeland's device, provides a clear and detailed account of the main difficulties he had to confront and of the general aim of this enterprise. At each step of the restoring work crucial decisions had to be made, which could affect the whole outcome and, let us say, its *historico-epistemic* status.

> The original chamber and a 24 cm terrella survive to the present day and are now kept in the Auroral Observatory at the University of Tromsø, Norway. Over the years the chamber had fallen into a poor state of repair. The glass windows were partly broken and the original sealing agent had been removed. Pump connections and electrodes were missing, and electric insulators had crumbled away.
> In 1995 it was decided to restore the whole of Birkeland's experimental apparatus to working order. Although several missing parts would necessarily have to be replaced, the chamber and the terrellas are so important as objects in the history of Norwegian science that it was decided that no changes to the original components could be allowed during the restoration work.
> With such constrictions, a range of questions and considerations had to be taken into account in planning the programme of restoration. Compromises had to be made based on safety, budget, maintenance possibilities, and the strong desire to restore the apparatus to its original appearance as closely as possible.
> One of the most important considerations was that of the force of atmospheric pressure on the walls of the chamber. [...] If a window should break during a demonstration due to the external pressure of 7 tonnes, the implosion could throw pieces of glass into the room, causing serious injury to onlookers.
> The new windows had to be absolutely safe. They were made of laminated glass, a little thicker than the original, but mounted in such a way that their outside surfaces were flush with the frame of the chamber. [...] As part of the reconstruction process, calculations were made of the loads on the windows, the plates, the beams and the rivets, to confirm that dangerous implosions could not occur. [...]
> To deal with the potential leak issue, it was decided to make a compromise and to use rubber gaskets as seals around the oval inspection hatch and between the windows, while a sealing agent close to the original type was used to cover the rivets and all other gaps. The use of this

> sealing strategy made maintenance feasible as well as giving the chamber the feel of the original in both look and operation. [...]
> Many of the records of Birkeland's vacuum and other laboratory methods have disappeared and he left few technical details of how the chamber should be operated. The actual process of restoring the experiment using the old components revealed much that could not be inferred from the published documentation and shed light on sources well known but not fully understood. Practical skills and laboratory techniques taken for granted at the beginning of the century had to be learnt again from scratch. More than anything else, the restoration work showed that the strength of the glass and the leakage problems must have been some of the main problems more than eighty years ago.[4]

The problem of methodological and technical implementation is therefore the real hardcore of any *synthetic experiment*, also in history of science and technology. It is the problem of how much *our* conceptual frameworks, *our* (coded or non-coded) knowledge, and *our* practical skills are involved in the process of mediation that necessarily occurs during such a "re-making". It shows at the same time the great potentialities and the intrinsic limitations of a simulative/reconstructive methodology.

Furthermore, assuming that we have all the structural and functional information we need from the analysis of the historical sources at our disposal, the question of the degree of implementation of a reconstructed device could be raised also at a "meta-level" of research. Even the (re)construction *techniques* themselves should in fact be reconstructed, in order to give back "performatively" the original context in which an object had come into being in the past. If we rebuild an instrument or even a whole experimental environment of more than a century ago, is it correct to use the most recent precision techniques, for example an industrial machine nowadays used to produce laboratory objects and pieces of equipment, like chemical glassware or metal components? Such a choice, many times the only and inevitable solution, might lead to anachronisms that could in some cases compromise the "performance" of the reconstruction even at a relatively low level of functional resolution. Any historiographical hypothesis or claim that is based not only on the already available sources, but also on the actual features of the so obtained reconstruction, might be affected by the same anachronisms that were more or less consciously embedded in it. In this case, its status of reliable "historical experiment" could become dubious and questionable.

Anyway, we have to consider that reconstructions are not always intended to have such a strong epistemic value. Many of them are often built "only" to embody and display some particular narratives for museum or teaching purposes, so that they should be regarded more as *demonstrative* devices than synthetic "Experimentalsysteme" in history of science. In other contexts, their *educational* function is so predominant that we could look at them as a sort of *meta-historical (re)presentifications*, that is to say *modern translations* of objects that originally belonged to another time. In this last case, they are regarded as "archetypical", assuming a symbolic significance that goes beyond their specific historical meaning. We might say that their *diachronic* dimension "collapses" into an a-temporal idealization and "condensation" that establishes a

4 Terje Brundtland, *The Birkeland Terrella*, «Sphaera» [newsletter of the Museum of History of Science in Oxford], issue n. 7 (Spring 1998); http://www.mhs.ox.ac.uk/sphaera

direct connection with the *synchronicity* of current scientific knowledge, both theoretically and experimentally.

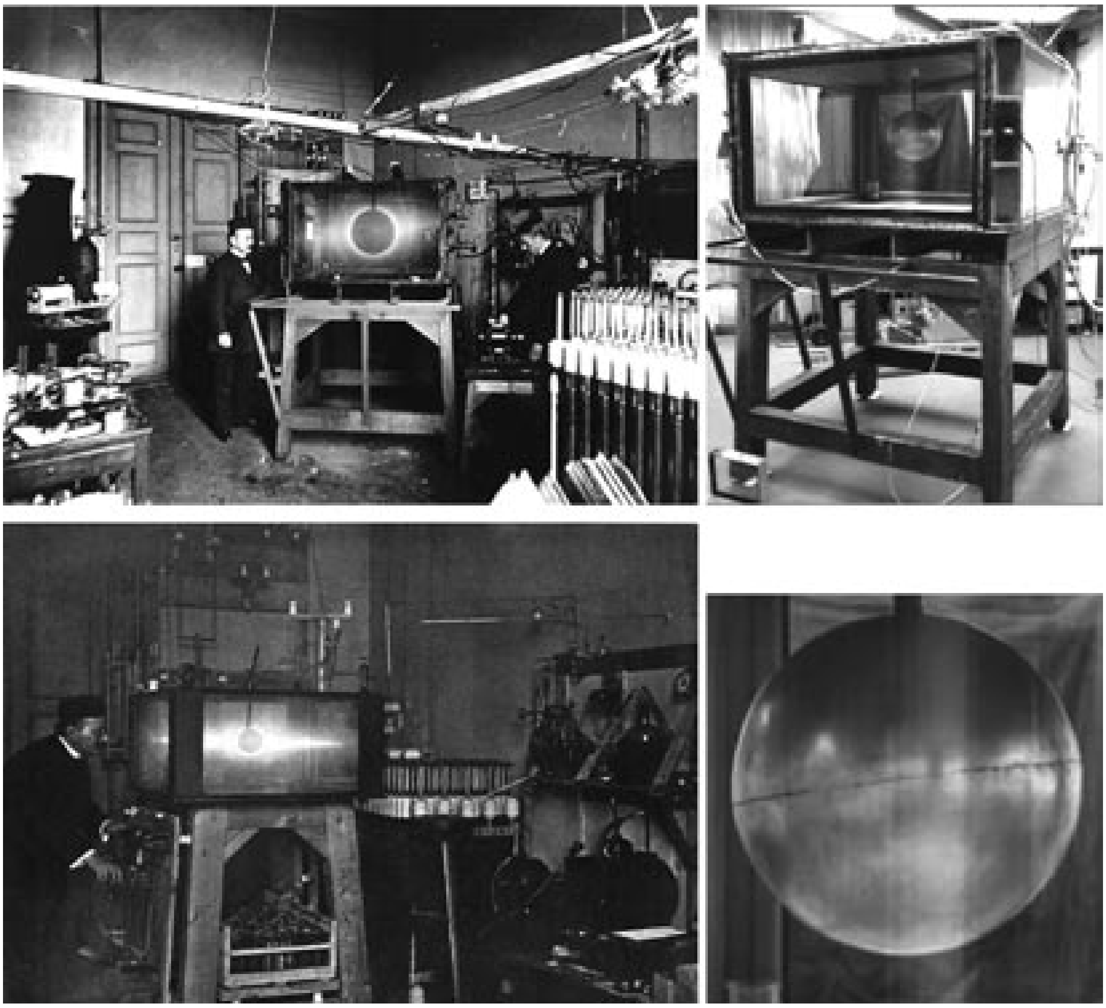

Figure 5: Kristian Birkeland's "Terrella" in Tromsø. On the left: Birkeland at work in his laboratory in 1913. On the right: the "Terella" after its restoration in 1995.

"Galileo's waterclock": a case study?

This is often the case of many classical instruments used at university departments or in didactic laboratories/cabinets of physics, like *the* pendulum or *the* inclined plane, as well as of particular devices that are (re)constructed not only for their (meta)historical value but also because they are *new* or rather *re-considered* objects of inquiry for contemporary fields of research, so that they might have "still something/new things to say".

Let us consider by the way one concrete example of reconstruction we had the occasion to deal with in the last two years, during the making of the permanent exhibition *Il Laboratorio di Galileo Galilei* at the Museum of the Department of Physics at the University of Pisa. It is the reconstruction of the "waterclock" that Galileo used to measure continuous time intervals during his experiments with the inclined plane, probably performed in Padua between 1592 and 1604.

Our primary historical source, the description of what could be seen as a first prototype of "recording chronograph", is in the Third Day of the *Discorsi e dimostrazioni matematiche intorno a due nuove scienze* (1639). There are neither detailed drawings nor schematic pictures of it. Galileo's words are all we have both as extant document and basic starting point for any attempt to "re-build" his device. Here is the original description of this instrument:

> Quanto poi alla misura del tempo, si teneva una gran secchia piena d'acqua, attaccata in alto, la quale per un sottil cannellino, saldatogli nel fondo, versava un sottil filo d'acqua, che s'andava ricevendo con un piccol bicchiero per tutto 'l tempo che la palla scendeva nel canale o nelle sue parti: le particelle poi d'acqua, in tal guisa raccolte, s'andavano di volta in volta con esattissima bilancia pesando, dandoci le differenze e proporzioni de i pesi loro le differenze e proporzioni de i tempi; e questo con tal giustezza, che, come ho detto, tali operazioni, molte e molte volte replicate, già mai non differivano d'un notabil momento.[5]

> For the measurement of time, we employed a large vessel of water placed in an elevated position; to the bottom of this vessel was soldered a pipe of small diameter giving a thin jet of water, which we collected in a small glass during the time of each descent, whether for the whole length of the channel or for a part of its length; the water thus collected was weighed, after each descent, on a very accurate balance; the differences and ratios of these weights gave us the differences and ratios of the times, and this with such accuracy that although the operation was repeated many, many times, there was no appreciable discrepancy in the results.[6]

The text is quite vague and of course this "vagueness" is the first obstacle our *experimental historian of science* has to confront. The problem of the methodological and technological *implementation strategies* used for a reconstruction plays a crucial role precisely at this point, as well as the problematic gap and negotiation between two different modalities of "presence", or better "(re)presentification": our only *verbal* access to a no longer existing but historically documented object, on one hand, and our desire of being "in touch" with its re-materialized and objectivated surrogate, on the other one. We have already seen how powerful and fascinating such a "fetishist" and "religious" desire can be, because of its strong relationship with "life", "death", "survival" through time and space, with the (re)construction of a narrative identity by means of an established tradition, and, vice versa, of an identifying tradition by means of established narratives. As we have said before, this co-implication has much to do with space-time "contraction" and historico-cultural symbolization. We will see below how demonstrative and didactic reconstructions in particular can also play a fundamental role in the "fabrica consensus" and in the so-called "public understanding" of science and technology.

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5 G. Galilei, *Discorsi e dimostrazioni matematiche intorno a due nuove scienze attenenti la meccanica e i movimenti locali*, in *Le opere di Galileo Galilei. Edizione Nazionale sotto gli auspici di Sua Maestà il Re d'Italia*, 20 vols., E. Alberi, I. Del Lungo, and A. Favaro (eds.), Giunti Barbera, Florence 1890-1909, vol. VIII, p. 213.

6 Idem, *Dialogues Concerning Two New Sciences*, H. Crew and A. de Salvio (trans.), Northwestern University, Evanston and Chicago 1946, pp. 171-172.

Figure 6: The Museum of the Department of Physics, University of Pisa.

The waterclock at Pisa is a sort of remake of a previous one built and described by Thomas Settle in his famous article 'An Experiment in the History of Science'[7], in order to test the degree of precision that Galileo could obtain with his own instrument, probably at most of ± 0.1 seconds. So we are talking about the re-make of a re-built object, something that should immediately warn us about the mediations that can occur during the process, even in the case of a mere copy. But this is not our case, as we will try to show in a few lines. We are rather in front of a museological *re-interpretation* of a reconstruction. This implies a process of *re-contextualization* from an experimental device made to provide evidence for a particular historiographical claim to a museum object whose task is to show and to confirm the "already tested" truth of that claim. In other words, the Pisan waterclock is part of a *reconstructive exhibition*. Its specific role is to embody a narrative that is based on (and supported by) the results obtained by Settle's *reconstructive experiment*. Both the two instruments are working reconstructions, both can actually have the primary function of water chronographs, but the *context-shift* between them involves also a *performance-shift* that seems to make and to mark the main difference between them.

[7] Th. B. Settle, 'An Experiment in the History of Science', «Science», vol. 133, Jan. 1961, pp. 19-23. Idem, 'Galileo and Early Experimentation', in *Springs of Scientific Creativity: Essays on Founders of Modern Science*, R. Aris, H. T. Davis, and R. H. Stuewer (eds.), Minneapolis 1983, pp. 3-20.

Figure 7: "Galileo's waterclock" at the Museum of the Department of Physics, University of Pisa.

Figure 8: Roberto Vergara Caffarelli with the "waterclock" and the inclined plane.

Thomas Settle's target was to get as much direct corroboration as possible against Alexandre Koyré's well known statements about the merely speculative and "mental" nature of most of Galileo's experiments.[8] Like Stillman Drake, and despite Koyré's scepticism even about the empirical data often reported by Galileo in his own works and notes, he was persuaded of the genuine skills of the Pisan scientist as an "applied researcher", if not a "theoretical technician". According to them, Galileo was actually able to achieve the degree of experimental accuracy that seems to fit with his explicit results, also because of his access to the best technical expertise and the most qualified craftsmanship at that time, both in Padua as ordinary professor of mathematics and even more in Florence as "Primary Philosopher and Mathematician of the Grand Duke".[9]

> To get a better appreciation for some of the problems he faced I have tried to reproduce the experiment essentially as Galileo described it. In the process I found that it definitely was technically feasible for him, and I think I gained a good idea of the type of results he probably looked for and of how well they turned out. [...]
> I hope to show that this experiment, once conceived and brought to full maturity, is simple, straightforward, and easy to execute. Thus far I can only reproduce the end product of a process of evolution (in Galileo's own mind) which may have covered 20 years. There is, in addition, a fascinating and vastly important body of knowledge concealed in the "conceiving" and "bringing to maturity" of both the theoretical and empirical aspects of this experimentation, just as in most other significant departure points in the history of experimental science.[10]

Settle's words show a clear example of the methodological attitude a historian of science should regard as a regulative and heuristic framework, if the goal is to build a reconstruction as an *experiment* to test or refuse some historiographical hypotheses. There is no primary involvement here in the narratives that are typically embedded in a *museological reconstruction*, at least at the very beginning of the relatively autonomous life/trajectory that an object like this "waterclock" can have. The original *performative context* in which such an experiment has to work and to produce its results is the "laboratory-workshop" of the historian, which is perhaps not so different from the environment in which an experimental system of our modern times has to perform, a laboratory, an observatory, or a research institute. The choice of the materials and of the techniques of realization, the selection of the tools that can or cannot be used, all the aspects related to the technical implementation must in this case be handled according to the highest degree of *philological* accuracy allowed by the state of our actual historical knowledge. Coming back for a moment to Latour and Woolgar's approach, we might say that even the experimental *environment* in which the reconstructed object operates should reflect the same modality of performance that

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8 A. Koyré, *Études galiléennes*, Paris 1939.
Idem, Études d'histoire de la pensée scientifique, Paris 1966.

9 S. Drake, *Galileo at Work: His Scientific Autobiography*, Chicago 1979.
S. Drake – T. Harvey Levere – W. Shea, *Nature, Experiment, and the Sciences: Essays on Galileo and the History of Science in Honour of Stillman Drake*, Berlin 1990.
S. Drake – T. Harvey Levere – N. M. Swerdlow, *Essays on Galileo and the History and Philosophy of Science*, 2 vols., Toronto 1999.

10 Th. B. Settle, *cit.*, pp. 19-20.
Idem, 'Experimental Research and Galilean Mechanics', in *Galileo Scientist: His Years at Padua and Venice*, Padua-Venice 1992, pp. 39-57.

is requested to it. From this point of view, the historian-technician should be included as an *actor*, a *performer*, a "node" of an experimental *network* that is a (re)construction in itself, in a broader and more functional sense of the term. We might say that in Settle's experiment he should be a "living reconstruction" of Galileo himself! Following the account provided in the article, one has the sensation that "living" refers mainly to the *non-coded/informal* expertise, the "rhythm of the experiment" that the Pisan scientist had achieved by building up and repeating his own measurements many, many times, so that his eyes, ears, hands, his attentive mind and his instrument, all had became different components of an integrated workspace.

Moreover, in this particular case the "waterclock", as described by Galileo, is a compound device, a sort of hybrid between a traditional "clepsydra", a pendulum, and a precision balance. It is part of a more articulated experimental apparatus, in which another instrument is involved, namely an inclined plane, with the specific problems related also to its reconstruction, especially for what concerns the shape of the groove in the middle. Galileo says nothing about this. We have only a quick description of its making, the data he collected, and the calculations he made during his experiments with that plane. Thomas Settle is very cautious about any attempt to "infer" the probable shape of the groove from these material by means of our modern notions of inertial momentum and rotational translation of a sphere along an inclined plane, that were of course not available at the beginning of the seventeenth century. The results Galileo obtained and recorded on his notes and which Settle checked with his own experiment could suggest that the bronze ball should touch the groove in no more than two points, so that it could not be semi-cylindrical, as it was in the exemplars used at the Accademia del Cimento and in the reconstruction held at Institute and Museum of History of Science in Florence. Even if we accept this claim, according to the present state of mechanics, it is not difficult to realize that it is a *negative* claim. It says at most how the groove should *not* be, but a *positive* solution for the implementation is another thing, that has to be justified in some way. The most straightforward and the least "invasive" choice – adopted both by Settle and for the inclined plane reconstructed in Pisa – is to assume a rectangular shape, being aware of the fact that it is only a hypothesis, the simplest approximation but not necessarily the rightest one.

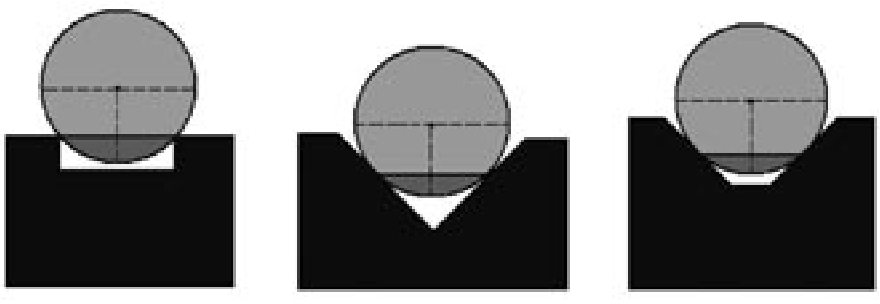

Figure 9: Three possible solutions for the reconstruction of the groove in Galileo's inclined plane.

> The most difficult part of executing the experiment lay in the necessity of choosing equipment and procedures which were available to Galileo or which were inherently no better than those

> he could muster. In making a plane, for instance, I assumed that he would have had excellent craftsmen at his disposal but that the work would have been done essentially by hand. [...]
> Of the three measurements, the measurement of time is the most controversial and the most difficult. With a little thought we find that it has two crucial aspects: we want the flow from the pipe to be uniform for at least the period of our longest readings, and we need to practice so that we can actually release the ball and the water flow at the same time and stop the flow at the strike of the ball without anticipation or delay.
> First, we must remember that the operator is an integral part of the apparatus. He must spend time getting the feel of the equipment, the rhythm of the experiment. He must consciously train his reactions. [...]
> Then we must remember that this is not a water clock; it is what is and no more – a container for water with a pipe of small diameter in its bottom and with no dials, falling weights, or gear trains. All we are interested in, we find, is maintenance of a constant flow in the pipe for a maximum of 8 seconds.[11]

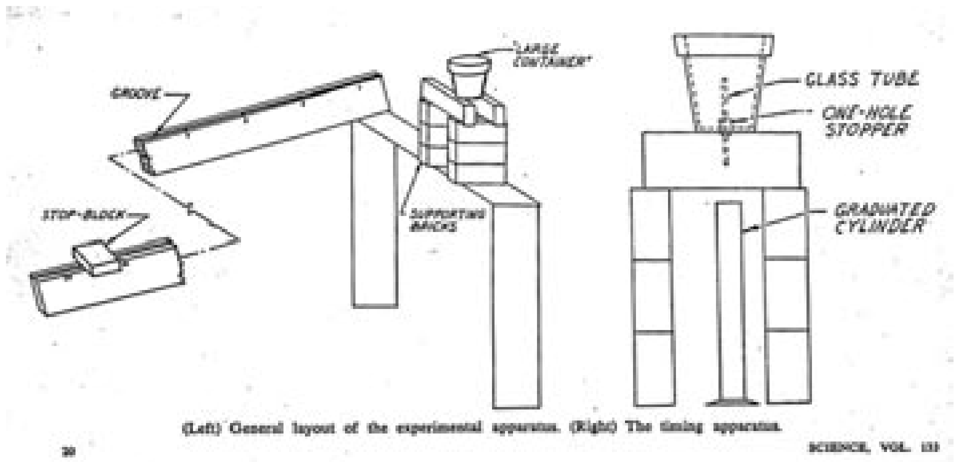

Figure 10: Settle's schematic illustration of his own experiment.

This last statement about what is currently known as "Galileo's waterclock" might appear quite funny, if not provocative. The intention here is precisely to warn the reader about the risk to overload a reconstructive experiment with overly theoretical and "anti-historical" categorizations, like Koyre's *a priori* definition of *scientific instrument* as the historico-theoretical crossing over between science and technique (*techno-logy*), so powerful from an epistemological point of view, but potentially misleading in the methodological and technical implementation of a reconstruction.

> I have tried to emphasize the simplicity and ease with which these results were obtained. [...]
> I am sure, the time measure was not brought to as high a polish as a larger pot, a smaller pipe, and a finer "balance" would have made possible. But with no more precise knowledge of Galileo's tools than what can be learned in the passage cited, I wanted to give "error and inexactitude" every reasonable chance to accumulate.[12]

[11] Idem, *cit.*, pp. 21-22.
[12] Idem, *cit.*, p. 23.

The device that has been (re)built in Pisa could be regarded as an example of a completely different reconstructive attitude, if not opposite to the attitude that Settle declares in the few lines we have just quoted from his article. It does not seem to be made with the explicit aim of giving "error and inexactitude" their "reasonable chance to accumulate". On the contrary, the intention is to remove as much as possible any kind of "error and inexactitude", both systematic and accidental, according to the *current* and *standardized* procedures of realization of a *modern* experimental apparatus. One might say that the "anti-Koyré" and "pro-Galileo" commitment of such a work is so strong that paradoxically it might confirm Koyré's claims themselves, if this were the only reconstruction of the "waterclock" ever made. How would the French historian of science react, in front of a quite "naïf" attempt to refute his statements by means of a reconstruction built with the most recent techniques and with materials currently available in a common ironware shop? Probably he would feel even more sceptical about the experimental character of Galileo's research, especially for what concerns the degree of accuracy he could obtain with the techniques and the materials at his disposal. Furthermore, it is not simply a question of "being more royalist than the king", so to speak. The problem is not so much the precision that a "reconstruction" like this can reach as a performative result – maybe the same precision that has been previously embodied in its implementation by its "modernist" creators. More questionable are specific solutions like the use of a tap to control the uniformity of the water flow, a careless "addition" that, far from being only a question of details, can make the fundamental difference between a reconstruction of *Galileo's* "waterclock" and the construction of a *generic* waterclock, however "well made", interesting, and useful it could be.[13]

Figure 11: The inclined plane and the "great scale" to measure the force of percussion. Museum of the Department of Physics, University of Pisa.

Modern materials, modern techniques of realization, modern solutions to historical problems, were devised for the "waterclock" as well as for many other devices that have been "reconstructed" and put on display at the *Laboratorio*. No wonder that the next step is a comparison between the performance of such a device with that of a *digital chronometer*, in order to show that Galileo – or

13 R. Vergara Caffarelli (ed.), *Galileo e Pisa* [exhibition catalogue], Pisa 2004

rather who has built this "reconstruction" – was "actually" able to achieve a precision of ± 0.01 seconds, even more than what Settle himself could expect! How "modern" was Galileo, *the* father of *the* scientific method, more "contemporary" than his own contemporaries and, why not, even more than many other scientists of the following centuries! It is so "self-evident" that only an "impertinent" historian of science could deny this undeniable fact, just because as a "Geisteswissenschaftler" he understands nothing about how experimental physics really works, no matter if in the seventeenth or in the twentieth century. There is just a secondary "detail", on which all the performance of the Pisan waterclock depends: the calibration of the instrument and the time measurement is performed with a *computer*. *Software* specifically created for the waterclock *automatically* makes the conversion between the weight of the water collected in the glass, obtained with an *electronic* balance, and the time elapsed. Thus the comparison is not between a modern chronometer and a handmade one as well as approximated calculation of the conversion factor weight/time (the only thing Galileo could actually do), but rather between a chronometer and a computer! What does remain of Galileo's original apparatus, at this point? Does such a comparison really support Settle's and Drake's claims about Galileo's experimental practice, by showing that a software is more recent and therefore more "efficient" than a digital chronometer?

Figure 12: A couple of pendulums illustrate Galileo's discoveries on period and amplitude of oscillation. Museum of the Department of Physics, University of Pisa.

If the experimental historian-technician was performer and part of Settle's *reconstructive experiment*, the common visitor of the permanent exhibition *Il Laboratorio di Galileo Galilei* is now actor/spectator and part of an *educational demonstration*. The possibility to have a "direct" and "real-time" comparison between the ciphers displayed on a chronometer and the results displayed on a computer screen seems to give an impressive aura to this device, which, together with its name, refers to Galileo eplicitly as "*the* founder of modern science", "*the* first discoverer of the law of free fall", and so on. This is part of the rhetorics of *scientific authority/authorship*, of the *irrefutable true result*, if not of the *cumulative progress* of scientific knowledge that remind us of the atmosphere that verbal, visual, and even kinaesthetic narratives take when involved in "science centres" or "science museums". Places that have perhaps little to do with a museum of history of science but much to do with the socio-political and cultural dynamics of current "science communication".

Figure 13: Thomas Settle and Roberto Vergara Caffarelli with "Galileo's waterclock" at Pisa.

The Pisan waterclock is in fact conceived as one of the "stations" of a museum itinerary that links together different "reconstructions" of Galilean instruments and experiments. It also includes *the* pendulum and *the* inclined plane, but in a way that seems to lead to a collapse between the diachronic origin and development of the "new science of motion" and the synchronic experimental logic that must be under the spatial and conceptual organization of a modern laboratory of mechanics, exactly what Settle wanted to avoid at any cost. To use a visual metaphor borrowed from the natural sciences, the phylogenetic "bush" seems to be overwhelmed in this case by the systematic “tree”. In other words, referring to Auguste Comte’s introduction to his *Cours de philosophie positive*, the “historical order” seems to be replaced by the “dogmatic order”.

This *fil rouge* is also at work from an ontogenetic point of view, that is to say in defining the “developmental order” in which a visitor should deal with the different reconstructions on display, if we want to extend our metaphor to Ernst Haeckel’s biogenetic theories. All the objects of the exhibition are not only *co-existent* in space, but also ideally *contemporary* in time, so that the historico-critical dimension is mostly suppressed. As a paradoxical outcome of such a narrow attitude, this reinterpretation “Galileo’s waterclock” is not *what it was*, using Settle’s words, but rather *what it should be*, that is to say the application of the isochronism of the pendulum to the ancient clepsydra by means of the precision balance, in order to switch from a discrete to a continuous measurement of time. Something didactically convincing and physically embedded by the three objects themselves, put together to form a single “experimental” system. More than twenty years of reflections, investigations and experiments performed by the *historical* Galileo Galilei since his arrival in Padua are concentrated and “frozen” in a unique apparatus that belongs to a “compact” museological space, where a *mythical* “Galileo” is at work. One might say, ironically, a sort of visual and material instantiation of Koyré’s ideas about the “essence” of a *scientific instrument* and the “nature” of the *scientific revolution*, despite (or even thanks to) the original intentions of its makers!

Figure 14: Other three Galilean objects displayed at the *Laboratorio*. From left to right: the geometric and military compass, the pulsilogium, and the apparatus for demonstrating the “theorem of the cords”.

Nobody wants to deny that a free *reinterpretation* of a historico-experimental system previously (re)built by Thomas Settle has its own right to exist autonomously as a *scientific object*, in the widest sense of this expression. Let it be. Let us consider it part of an ideal and idealized “Galileo’s laboratory” of early modern mechanics, providing that it is not “an experiment in the history of science” and cannot be regarded properly as a *historical reconstruction*. Rather, it is a *didactic* and *museum-oriented* “(re)construction”, that seems to embody a sort of “first glance” rhetorics of immediate and performative “self-evidence”, with the intention of being demonstrative, educative, and spectacular at the same time for the general public. There is nothing “bad” in this. Divulgation is an essential moment in the scientific enterprise. Perhaps this way of conceiving, making, and displaying reconstructions is the best one for the "cognitive economy" of a museum that belongs to a department of physics, and whose ideal visitors are primarily students of the same department. One could regard this collection of "Galilean reconstructions" as a sort of conceptual and material extension of the eighteenth-century ceroplastic anatomical models, of the nineteenth-century didactic cabinet of instruments, of many other objects used for teaching in the same period, like prepared specimens, geological collections, demonstrative sets of glassware for chemical reactions, and so on.

History of scientific experimentation and experimental history of science

However, such forms of (re)presentation cannot be regarded only as signs of a very narrow and "whiggish" attitude toward the history of scientific thought and practice. As we tried to underline before, they play often a fundamental role in the social construction, in the ethical definition, and even in the rhetorical representation of a *meta-historical* body of knowledge that identifies the *scientific community* as a whole, with its own noble "ancestors", "heroes", or even "martyrs", as a long tradition of Galilean iconography, since the very first decades after the death of the Pisan scientist could clearly show. There is a well known relationship between this process of *de-contextualization* (if not *meta-contextualization*) and the complementary phenomenon of *eponymy* – the attribution of the label "Galileo's waterclock" to our instrument, as well as to "his" law of free fall, and so on. It often occurs together with the particular use of *the* "par excellence" we have already encountered in many occasions. They are in fact two aspects of the same *meaning-/status-shift*, from a concrete *historical* object to an idealized *epistemic* one and back again to a different historical *context of action*. This change of context involves a parallel and inseparable change we called the "performative" role of an object, let us say its *action in context*, the narratives it might convey through its being "working", "performing".

One might take this double and dynamic implication between context and action we have already sketched above as a sort of slogan to summarize the very broad use of the term "performance" we have made in these pages. The consequences that this entwinement may have on the different degrees of freedom and resolution according to which such an artefact can be implemented range from a *re-construction* conceived as a *synthetic experiment* in history of science to a *construction* conceived as a *modernizing translation*. In this last situation, in particular, there would be also an identification between backward- and forward-oriented simulation, so that our (re)constructed object could find itself in a very borderline and ambiguous condition. It could be used at the same time to give a superficial impression of "rebirth from the past" and to convey an underlying and not always declared narrative about the present state if not the supposed future development of a "scientific fact", to use Ludwig Fleck's famous expression.[14] Metaphorically speaking, it might be compared with something like a very personal and free reinterpretation of a Renaissance fresco made by a contemporary artist by means of the most recently developed techniques of digital imaging, or even with Marcel Duchamp's provocative remake of *Monna Lisa* to deconstruct the mythology of the "masterpiece" in history of art and to show his personal manifesto.

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[14] L. Fleck, *Entstehung und Entwicklung einer wissenschaftlichen Tatsache*, Basel 1935.

Is this the case for "Galileo's waterclock"? As we said at the beginning, a radical anti-reconstructive approach could argue that it is more or less the same for *any* kind of reconstruction, just because of its belonging to our present time, so that the concept itself of *historical experiment* we have outlined through our discussion would lose most of its consistency. On the other hand, objects like this could be regarded as challenging our individual and social narratives about what is "past" and what is "present", what is "ancient" and what is "modern", how much our cultural heritage has a long-term influence on the *stories* we can tell about *history*, and how much the latter might be affected by the former.

This sort of circular feedback (positive or even negative) seems to be behind any attempt of historiographical "reconstruction", in the widest sense of the term. A fortiori if we consider the interplay between "foreground" and "background" that is constantly at work when we switch from a *history of scientific experimentation* to an *experimental history of science*, as well as from a *historical epistemology* to an *epistemological historiography*. It is clear in fact that when we talk about the possibility of an "Experimentale Wissenschaftsgeschichte" – including a reconstructive approach to scientific practice and its historical contexts – we are swinging between two different but deeply entangled levels of speech, well exemplified by the ambiguity of the title Settle chose for his article. 'An Experiment in the History of Science' could mean both *a scientific experiment of the past* and *a historical experiment of the present*. To distinguish between the two aspects seems to be a hard and maybe useless work.

Perhaps an analogous "spiral" process is underneath the meaning- and status-shift of what could be regarded as a *scientific object* in general, from an object of investigation or an instrument employed for research to an object that is scientific "only because" it is displayed in a science museum or collected by a scientific institution, whatever "scientific" could mean at these different but somehow related patterns of analysis.

It could be more or less the same for a modern reconstruction – even for a reinterpretation like the waterclock in Pisa – that could become a historical document, as scientific object, and vice versa a scientific object, as historical source, across different times, places, and situations. The only point is to be aware, from a *synchronic* point of view, that reconstructions thought as *historical experiments* belong to a completely different and specific *implementative attitude*, if compared with other methodological choices.

On the contrary, the distinction between *non-museological* and *museological* reconstruction does not seem as much relevant as the previous one, since it could be reduced in many cases to a *diachronic* shift in the *performative context* in which exactly the same object does in different ways "what it has to do", so to speak. The *ontological*, *epistemic*, and *historical* trajectories that "an experiment in the history of science" and a demonstrative/didactic device might follow to become museum-(re)oriented objects could in fact be convergent (even physically if they stay in the same showcase or exhibition), although they started their mutually independent "lives" as very divergent modalities of reconstruction.

Therefore, reversing the anti-reconstructive objection we have just mentioned, we might say that the question of the epistemic status of a reconstructed object could be regarded as quite paradigmatic of the inevitable but maybe indispensable ambiguities of history of science itself, if not of any form of historiography at all.

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Bezoars, Necromancers, and Exotic Specimens: Visual Paradoxes in Science Museums

Sophia Vackimes

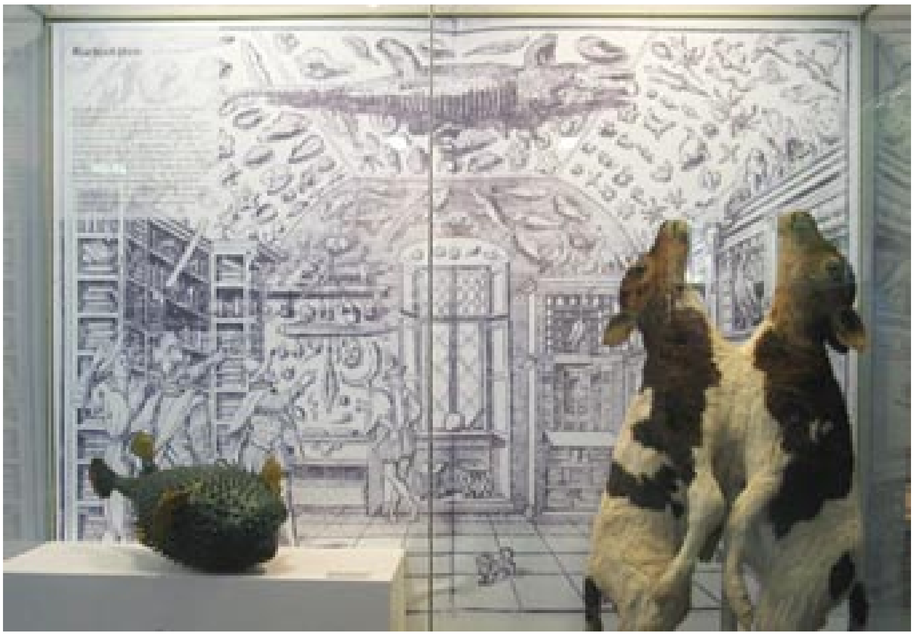

Figure 1: Conjoined twins, petrified dinosaurs, and ancient exhibits with modernity; *Museum of Natural History,* Kassel. Photograph Sophia Vackimes.

What follows is a brief account on the repetitious nature of curatorial history: How bezoars, fetuses, crocodiles, and dusty old books mingle comfortably in museums in modern times, although this is often denied. How modernity, shrouded in historic tradition, presents itself to be the result of time honored scientific legacy totally devoid of superstition.

Science is represented in museums, science centers and other public spaces in three main manners: accumulations of curiosities and natural phenomena, the life and discoveries of distinguished scientists and the wondrous applications of science through technological accomplishments. Each of these modalities has its own merits and purposes, and depending on the venue which hosts an exhibit, their use will vary. These modes do not always appear separately, they are most often found combined into exhibits that best suit the curatorial demands a specific project requires.

Despite a concerted effort to present science as continuous progress, when looking at its museographic representation we find that the narrative spun to weave this continuity is quite arbitrary. In writing the history of museums, many authors take the etymological road in tracing the origins of museums back to ancient Greece and the inspiration given by the wonderful flighty muses of the Olympus. However, linking museums to troves of wonders or to muses is far winded, less grounded in facts and more in a habit, at times poetic and at times political, of tracing all modern marvels back to classical cultures, and is actually a custom rooted in the nineteenth century nationalist practice of seeking ancient origins to legitimize claims to power. Without going as far back as the Greeks or Romans in their ancestry other authors link museums to cabinets of curiosity known as Kunstraritäten, Wunderkammern, or even *gabinetes de hadas*, fairy rooms. These institutions appeared in the late middle ages and housed wonders of the natural world as well as man made objects and were famous for the variety of items amassed within their walls; they were spaces where wonder and amazement at the forms of nature and wonderful human craftsmanship mingled in an ambiance full of accumulations of reptiles, minerals, petrified bones, botanical specimens, works of art and stuffed animals. Varying from the treasure troves of modest individual collectors to those in extravagant principalities such as Burgundian, Italian, Flemish or Spanish royalty, or the estates of religious orders like the Jesuits, they contained at first European and Far East specimens eventually embracing wonders from the New World. Such troves provided nature lovers and academics with such a profusion of objects of study and reflection that they often became primary research centers where the sage, the curious, the philosopher, would scrutinize the finest examples of plants or animals or man-made objects seeking to discover the mysteries of the world. An overview of each of these three alternatives as set in contemporary contexts that try to give scientific exhibits specific continuity seeks to inspire inquiry into the rationales and purposes put into action in the representation of science to present-day society.

Figure 2: Bits and pieces of the famed Tradescant collection on view again; *Oxford Science Museum*, Oxford. Photograph Sophia Vackimes.

Modernity and Its Scientific Proclivities

Musky rooms filled with art canvases, stuffed animals, and jars with botanical specimens from far away lands filled those visually enticing spaces, cabinets of curiosities, or fairy cabinets, gave birth to the science museum as well as to the modern laboratory. The allure that those old collections had, with their haphazard juxtaposition of objects which varying in size, color, and shape provided a stunning visual spectacle for their visiting admirers. Ranging from being troves of marvels to artificial grottoes completely constructed out of pieces of amber "that would look entirely natural, 'holding no appearance neither of form of art, nor of sculpture, nor the labor of the hand of man'" (Palissy 1880 quoted in Daston and Park:286), put together more than three hundred years ago, they contained a varied assortment of objects and artifacts ranging from human bones, unicorn tusks, stuffed crocodiles, bezoars, magical potions, conjoined twins, animal organs either in liquid preparations or stuffed, crocodiles, pelicans, splinters from Christ's cross, owls hanging from walls, arrays of bezoars, or bladder stones etc. This strange mixture did not limit them to a nonsensical or pre-scientific role: "the medieval collection . . . was not a *musaeum* but a *thesaur* in the sense of a repository of economic and spiritual capital" (Daston and Park 2001:74); a capital from whence many drew from and whose puzzles eventually led to the systematization of knowledge we understand today to be modern science.

Figure 3: Seeking to store the universe; *Deutsches Museum*, Munich. Photograph Sophia Vackimes.

Naturalia, Anatomia, Arbitraria?

Even though we might assume these accumulations have been superseded, updated, and improved by modern museographical techniques they can be increasingly seen from the Netherlands to Mexico, from New York to Paris, from Zurich to London. Items such as those can be found in institutions that are heirs to a lengthy research history; however, the great divide between what can be counted as an object that is a valid source of scientific knowledge and what belongs in a conjurer's is less and less apparent today.

The *Mütter Museum* in Philadelphia, for example, holds among its thousands of anatomical items the skeletons of a dwarf and a giant, the saponified body of a woman, a collection of co-joined twins, and more than three hundred objects removed by physicians from peoples' esophagi – all of which were assembled for the teaching of medicine. The *Istituto e Museo di Storia della Scienza* in Florence, exhibits Leonardo da Vinci anatomical drawings, astrolabes and armillary spheres from the Medici collection, as well as Galileo Galilei's finger encased in glass. *The New York Public Library*'s trove is proud of holdings that include among countless marvels of printed medical history Andreas Vesalius' *Anatomia*, American writer Jack Kerouak's crutches – an item the libraries' publications brag about. *The Science Museum* in London recently inaugurated a new exhibition wing in its historical institution – alongside an exhibit of albino animals creatures – mice, a peacock, a cat shown suspended in mid-air – one can find pouches full of blood of different types, objects that arouse phobias in human beings, such as spiders and snakes, plus an euthanasia machine.

Figure 4: Fear of dolls; pedophobia, fear of feathers; pteronophobia; Wellcome Wing, *Science Museum*, London. Photograph Sophia Vackimes.

While Kunstraritäten, with their conceptual juxtapositions, provided occasion for the consideration of either the wonders of divine creation and/or its bizarre boundaries they also paid visual tribute to nature via the copiousness of their overflowing cupboards (Daston and Park 2001:273). Most importantly, they helped their visitors come to grips with nature becoming involved in some way in the creation of knowledge (Baigrie 1996:91). Do strange objects do that for the modern visitor?

Magi, Wizards, and Wise Men

The second most important modality used to represent science concerns its doers. At the mention of the word *scientist* all sorts of images are immediately conjured: white-clad men dedicated to doing research in a laboratory where either bubbling substances or strange equipment with wires hanging everywhere appear as backdrop; as we conjure those images, slowly, with a bit of more definition, personality and charisma will begin to appear the famous men and the experiments or discoveries that rendered them famous: Franklyn and a kite, Einstein and an equation, Bohr and a model of the atom. Luminaries, great discoverers and inventors, geniuses and their colleagues, all of them heirs to a particular type of scientific legacy; none products of exotic or faraway lands, or of indigenous peoples from what are usually considered backwards nations. How modern science's accomplishments are publicly presented usually relies on stereotypes of American/ European self-aggrandizement.

Clad in white garb in an exacerbated state of concentration they are always working for the benefit of mankind – or so we are shown. But, even though this stereotype is obviously extremely simplistic and outdated it is overwhelmingly popular; exhibits constructed around such notions ignore the human element of the adventure of discovery; they warp scientific history caricaturizing it by "holding that science is something that is best done in one's study with pure reason alone" (Baigrie 1996:89), by one group alone and in particular geographies.

Regarding a methodical style of thinking the museum visitor isle to believe that abstract thinking is the general rule in science, and whoever does not practice it is not worthy of induction to the museographic hall of fame. However, this scarcely describes true scientific activity. Even Descartes, the man given credit for the fundamental break between the superstitions of the middle ages and the science of modern times and whose cranium can be seen in Paris, at the *Musee de l' Homme*, as THE example of *Homo sapiens sapiens*, in a largely colonial and condescending illustration of who is who in human rational thought, was not solely an abstract thinker. His activities were quite heterogeneous; he was quite involved in "countless dissections of dogs, cats, rabbits, codfish, and mackerel, and of eyes, livers, and hearts obtained from animals slaughtered in an abattoir" (Baigrie 1996:96). He describes heart pulsations of a live animal: "[i]f you slice off the pointed end of the heart of a live dog and insert a finger into one of the cavities, you will feel unmistakably that every time the heart gets shorter it presses the finger, and every time it gets longer it stops pressing it" (Descartes 1985:317). So, why the insistence in making the public stare at or listen to stories basically converted into immutable stereotypes? Someone who knew better than falling for that ruse wrote:

> Do you really believe that the sciences would have originated and grown if the way had not been prepared by magicians, alchemists, astrologers and witches whose promises and pretensions first had to create a thirst, a hunger, a taste for *hidden* and *forbidden* powers? Indeed, infinitely more had to be *promised* than could ever be fulfilled in order that anything at all might be fulfilled in the realm of knowledge? (Nietzsche 1974:234-35).

Why is it that, in modern culture, scientists are made out to be inscrutable, pure, even stoic beings? It should be quite obvious that much of scientific human activity, including putting together of cabinets of curiosity, and of course even today's museum specialized collections – and the reason those wind up with fantastic components – is due to the obsessive – even deranged behavior – of the men and women that put them together. Collecting a range of objects from the natural specimen to the bizarre artifact are part of the human endeavor, just as much as doing science is; they are all part of an experience rich in discontinuities between logical and unexpected circumstances which are not neutered against human proclivities, impulses, or motives such as pure curiosity, one or another mania such as compulsive collecting. The history of the study of nature has to be told with fluctuations that allow events stemming from the standpoint of wonder, adventure, magic ingenuity, talent, hard work as well as human frailty. "[Here is a] good argument against those who admire science and are also slaves of reason. They have now to make a choice. They can keep science; they can keep reason; they cannot keep both" (Feyerabend 1978:16).

It is true that the rationale for the inquiry about nature, as well as the purpose of objects in collections has changed through time but wonder and irrationality as intrinsic parts of research have fallen by the wayside. Wonder, which is as irrational as is any other human impulse, is an important mover for human activity. To Aristotle it was a human capacity directly linked to a desire for philosophical inquiry; to Avicenna it was a source of pleasure and laughter, and to the preternatural philosophers of the sixteenth century, the *key* to reclaiming emotion in the pursuit of natural philosophy (Daston and Park 2001:159-160). Even scientists' workplaces – far from being the scrubbed laboratories of high-tech forensic science with neon lit surfaces – have more in common with their medieval counterparts than with the characterization "cleanliness is next to godliness" usually given to them.

> Wonder falls, indeed, from ordinary things and the soul neglects to inquire about them; but what rarely exists does excite wonder and induces inquiry and speculation about its causes (Avicenna quoted in Hansen 1985:66).

All these nuances would need to be apparent in contemporary exhibits to make them real and truly interesting; as they stand today they hardly elicit that sort of wonder.

Structuring, re-telling, illustrating this heritage, has remained akin to the processes of inscribing scientific data; a way of ascertaining and solidifying social hierarchy and constructing specific public visibility while remaining deeply rooted in a tradition that replicates cultural models that preserve the rigid and highly structured legitimacy of the scientific enterprise. All these issues are part of the construction of the display of different indices of social integration and respectability based on social, educational and economic determinants as well as a capital constructed out of academic and scientific power, social recognition and prestige (Bourdieu 1988:37-40) that are carried over to the realm of public visibility when exhibited.

Scientists are human beings who – wildly or overwhelmingly or even not successful – have striven to contribute one or another element to that particular constellation we regard as knowledge (Kuhn 1962:2), but that constellation is unfortunately narrowed down continuously to include a favorite few as if the general public were not capable of remembering more than three or four important names. In the United States, for example, with all the money invested in science and technology education and with the importance that *difference* has in their political discourse; Is it obvious to the public that color television was devised by a Mexican scientist? Or that Dna recombination was first experimented by an African American researcher? Or that the person responsible for the first images of the Dna structure, Rosslyn Franklin, was a woman? Of course not. What is important is that the prestige pyramid has only a select few at the top.

The history of scientific disciplines, just like the lives of scientists, is constructed and played out in a style which ultimately reinforces the justification of superiority of the sciences over other activities; the end result of such construction is no different from the narratives told about "primitive cultures" that make mystic appeals to origins myths that forbid bringing scientific rationality to bear on the true origins and activities of science (Harding 1986:212). These rhetorical tropes are just as full of conjured ancestors, remembrances of famous feats, fierce battles against the elements and obviously constructed victorious outcomes as those found in the most ancestral of human legends, despite the fact that scientific work is a constant struggle which does not always have a successful ending.

Figure 5: Galileo's finger; *Istituto e Museo di Storia della Scienza,* Florence. Photograph Sophia Vackimes.

Heroes'/scientists' acts are situated in "fabulous epochs" seeking to conquer the realm of "terrestrial and paradisiacal primordiality" (Eliade 1984:149) such mythical accounts "far from indicating a *fiction*" attempt to "reveal the *truth par excellence*" (Eliade 1984:138). It is little wonder to find that the lives of famous scientists like Copernicus, Kepler, Lavoisier, or Newton are constructed closely following the narrative of the hero of Western culture (see Dundes 1984).

The selection of totemic ancestors and the construction of their life narratives is deeply rooted in the deployment and combination of elements chosen from a cultural repertoire that gives real information in bits and pieces, giving them specific narrative structures which in turn morph into other meanings and functions. Recognizing such processes is certainly not an attempt to debase scientific practice and its products, but rather, a venture to break through mystical categories of thought that operate where we are usually made to believe they do not. In order to "describe and explain the congeries of error, myth and superstition that have inhibited the more rapid accumulation of the constituents of the modern science text" (Kuhn 1962:2), it is necessary to understand the nature of scientific accomplishment, scientific texts, and biographic narratives as a "world view transformed into an objective force" (Debord 1995:13).

For every branch of science there is a human icon behind it: old science, or new science, a celebrated researcher is undoubtedly linked to one or other endeavor. Separating those activities from other human experiences such as hunting, gathering, magical ritual, or tool making is as artificial as exhibiting them in a trendy, arbitrary or careless manner. The undermining of human accomplishment when deemed primitive or unscientific, or the presentation of feats of researchers and scientists blown out of proportion by curators and exhibit designers has become a caricature; swinging the pendulum to the extreme opposite, in a quest to create catchy exhibits such imagery is often recast – as is done in many films – making the science practitioner into someone with quixotic, strange or erratic behavior and who often bears a relationship to a brotherhood of other maddened individuals.

Examples of this phenomenon, typical of what exemplifies scientific narratives are apparent from Hollywood movies. *A Beautiful Mind,* based on the book by Sylvia Nasar, (1998), in its literary form it tells the story of Nobel Prize winner John Nash, his life, and his battle with mental illness. The final chapter – where the debate about conferring the prize upon him by the Nobel Committee – is told as a fascinating metaphor of chance and probability, the mechanics, politics, and machinations of conferring the prizes are exquisitely used as metaphor to illustrate precisely those fields for which he received the prize. However, the film version of this saga represented Nash's hallucinations as the most important aspect of his personality and converted his professional life into a melodramatic love story. In this tale there was not much for the public to learn about mathematics and much less about chance or probability, let alone game theory. It was the same with *Proof*, portrayed by Anthony Hopkins, in which a mathematics professor also suffers some sort of dementia, and his heroic daughter puts the pieces of his life together – but not his math; the same occurs with *Pi*, a film that deals with chance and probability, also due to the activity to a mad individual, in which black and white cinematographic virtuosity take over the center stage of the mathematical issues involved.

Automata, Astrolabes and Azimuths

The last of the three main prongs of the science exhibit repertoire is perhaps the most popular today, and is that which deals with man-made objects. Kunstraritäten once held astrolabes, telescopes, music machines, automata, clocks, and mechanical marvels as well as paintings and etchings of natural specimens, catalogs illustrating the botanical wonders of the New World, anatomical treatises, and portraits of scientists, patrons, etc. What we find today as their legacy is not always a careful taxonomical arrangement of scientific tools that teaches the principles of geology or biology but a highly sophisticated mixed set of objects that justifies institutional assumptions about technology intertwined into an interpretive apparatus that attempts to translate theoretical positions and natural phenomena via educational quick-fixes geared at a lay public.

The technomania which we face today is not new to the twentieth or twenty-first centuries; the allure that tools and machines cast over mankind reaches as far back perhaps as the construction of the definition of the genus Homo itself with the appearance, or rather the labeling of a creature who three plus million years ago crafted the first stone tools we know of as *Homo habilis*, the toolmaker, the precursor of today's machine-maker. Technology is present in science exhibits in many guises and has been a feature in collections for centuries; it remains a fascinating reflection on man's dealings around the planet: from the crudest Olduvai tools to the cruelest warfare haptic gear now being considered as gadget in upcoming science centers it remains an attractive alternative to truly dealing with science.

The expectation that machines could one day perform human functions has always been a subject of great speculation and expectation. Strange machines, interactive stations, simulators of physical phenomena are heirs to ancient instruments; the automata developed in Alexandria were perhaps the most fascinating of the objects held in the collections of the sixteenth and seventeenth centuries. These objects first appeared in the early third century B.C.E. in Alexandria in the form of small animals or machines that could perform curious tricks such a as bird that rose to flutter its wings and frighten away a snake that frightened its chicks (Stafford 2002:41). Scientists in Islam, inventors such as Ismail ibn al Razzas al-Jazari "created enormously complicated hydraulic automata of their own, including the marvelous water clocks of the late-twelfth century" (Stafford 2002:42). During the Renaissance Leonardo da Vinci tinkered with such a concept and devised sketches of such men/machines, and perpetuum mobile exercised the fascination of Montaigne and Descartes during the Enlightment. Today we have Rovers taking photographs of Mars, mechanical knives slaughtering chickens in high-tech food processing plants, and Japanese scientist Hiroshi Ishiguro is working on modeling his own mechanical clone. Sooner or later these will wind up in exhibits too.

At the *Deustches Museum* in Munich the emphasis on collecting, storing and exhibiting mechanical apparati is unusually evident. Their warehouses are probably the largest for a science and technology museum in the world; waking through them one can virtually witness all of mankind's technological feats – viewed from a Western point of view. A visit to the *Sony Wonder Technology Lab* in New York City reveals the long-time fascination of man-as-machine theme. Visitors are greeted at the center's door by a robot that carries out extensive conversations with visitors, and although most interactions are of the tourist sort – Where are you from? What are you doing in New York? Are you really a robot? There is obvious fascination and elation in those persons who engage in the conversation with the robot. The promises of *AI,* artificial intelligence, seem quite feasible especially when set against the aura of a science center in downtown Manhattan. However, the completion of a complete tour of the facility will show that it is a remote control operator who carries on the lobby interactions, and that the public has been misled.

The most attractive objects in most collections are no doubt those that emulate human activity and we seem to be approaching the time when Descartes's pronouncement of man as being a mere machine is not so distant a reality. However, these objects, typical of displays in many science centers:

> [I]mply a certain exaltation or conceit on the part of humankind, a presumption that we can have total control or omnipotence, play God, by stimulating, mastering, redefining, manipulating, and controlling, space, time, community, thought and life (Coyne 1999:4).

Pieces of a Great Blue Puzzle

The famous cabinets made reference to in the history of science contained items as varied as "amethysts, unicorn horns, a petrified human skull with coral growing out of it, Flemish landscape paintings, and Mexican idols" (Daston and Park 2001:267), however, even though they might appear to be so on the surface, they were not mere extravaganzas resulting from obscure quests of the dark ages. Kunstraritäten were important resources for scientific research and amassed such a profusion of objects that, once systematized, eventually became our modern collections of natural specimens.

Figure 6: The bizarre explains nature: cat with abnormal paws; Wellcome Wing, *Science Museum*, London. Photograph Sophia Vackimes.

Today science centers and museums increasingly draw inspiration from these collections and their dispositional arrangements. The incorporation the objects they contained as well as aesthetic principles that displayed them not only pays homage to the origins of modern science and particular philosophical and visual principles, but this recycling of a specific discursive style signals quite specific conceptual, rhetorical and ideological postures being taken in the museum world today. The contemporary re-incorporation of ancient aesthetics into the iconographic performance of modern institutions indicates aesthetic choices that, on the surface, appear to be merely design driven emulations of those institutions, but which upon closer observation, are not accidental or innocent aesthetic practices. Assemblages of natural objects, the illustration of the lives of famous men, or the showcasing of amazing artifacts, set within the context of *modern* cabinets of curiosity, signal ideologically driven messages about modernity and the dominant position of modern science.

Revamped cabinets of curiosities offer strange paradoxes to the interlocking dynamics of contemporary aesthetics and discourses. Objects plucked out of their familiar contexts and inserted into public spaces do not immediately become cabinets of curiosities because and most obviously, we are not in the sixteenth century. It is impossible to recreate those learning and exhibition situations without recreating a worldview. There are very, very few instances where cabinets of curiosity do indeed fit into a context and that is perhaps in historical museums that have such legacy; the *Boerhaave Museum* in Leyden, the *Medicinisk-Historisk Museum* in Copenhagen, for example. When everyone tries to have what those have the public spectacle of science mania kicks in; even if some institutions initially intended to create meaningful and truthful connections between reality and the modern viewer – which is what most science centers claim to do.

More often than not, science and technology are presented interchangeably without actual regard to the great differences between them even if technology – usually a detested subject in scientific for a – is *key* to scientific accomplishment. Flashing neon lights announcing $E=MC^2$, photographs showing a disheveled Einstein – to be also found in coffee mugs at the museum store – great soap bubbles busted by shrieking children in numerous science centers – and purportedly useful in the demonstration surface tension, have, in many instances, come to pass for teaching science. Besides not creating meaningful social connections, the myriad activities presented at such venues – be they sound effects, electrical games, and shocks or shadow theaters – engage the physical properties of matter as phantasmagoria or spectacle. Social responsibility, ethics, and trends are lacking where serious issues about scientific applications should be present. Of course these issues come up and are discussed within the science museum community itself: didactic exhibitions which have no other rationale can be “used for pure fun” while “art pieces with no explicit learning goals are used by visitors as structure constructivist learning tools” (Friedman 2005:15).

The spectacle of science predominates over relevant content. In a German traveling exhibit commemorating the life of explorer, botanist, and mineralogist, Alexander Von Humboldt small, discrete sections illustrated his travels through the New World. However, the seemingly most important section was to be found in the Amazon section of the exhibit, and was a tank full of piranhas. In an exhibit at New York’s *American Museum of Natural History* dealing with the complex issue of classification according to cladistics of extinct species, the mechanical dinosaur chewing up its food – in the style of a Spielberg film – was the most viewed item in the room. In all, the claim is often made that science deals strictly with facts drawn from nature, and that museums are dispassionate promoters of the wisdom it bestows on mankind. Even worse; science centers are widely perceived as neutral venues for discussion . . . unfettered by political adherence and independent (Johnson 2005:5) venues for communicating rational thought even though scientific facts are only one subspecies of scientific experience (Daston and Park 2001:236).

Natural specimens and human made artifacts become – in the exhibition context – powerful elements for the display of cultural wealth and institutional prestige; cultural positioning affects scientific data and in museums it is heavily negotiated. When Bruno Latour and Steve Woolgar wrote *Laboratory Life* (1979), they demonstrated the norms of internal negotiation and social reification of scientific research that occurs in laboratories; museums reify information in much the same way. Research, and exhibition are not only concerned with the quest for unbiased truth but also with political prowess and social positioning. The aura of superiority that has been created around science and its makers is the product of the quest for the proprietorship of the spoils of research that has been long ignored by researchers and critics. The exhibition world is part of the propaganda machinery accompanying feats that should be held accountable to the public; for "[t]o what other 'community of natives' would we give the final word about the causes, consequences, and social meanings of their own beliefs and institutions?" (Harding 1986:39).

Technomania

In its more abstract form, the technological museum is exemplified by *The Exploratorium* in San Francisco, the model for most science centers around the globe. This site, always a pioneer in its activities, contains hundreds of on-site scientific experiments as well as the grandest science website resource for educators. Its exhibits include sections titled: Sound and Hearing, Heat and Temperature, Patterns, Seeing, Tactile Dome, Motion, Electricity and Magnetism. The Mind and Hearing section, for example has "a varied collection of exhibits on language, memory, psychology, cognition, and learning" (Exploratorium 2003:1). Following its style *The New York Hall of Science* has activities titled: World Fair Rockets Reinstalled; Become a Forensic Science Teacher; Experience Flora and Fauna; and Get Spooked at Dr. Frankenstein's Lightning and Electricity Show. In these experiential situations the thread for careful thought can easily be lost, while science as divertimento is similar in both. The online invitation to visit *The New York Hall of Science*'s website presents a venture akin to an old *Indiana Jones* film or the recent film titled *A Night at the Museum*:

> This 30,000-square-foot exhibition is like an out-door laboratory packed with exhibits that invite not only hands-on, but whole body participation. Kids can hang upside down on the 3-D spider web, make water flow upwards on the Archimedes screw, sound the gong and experience the giant slides, windmills, water play area, light-activated kinetic sculpture, construction zone, teeter-totter which balances a dozen kids at once, and more! (NYHS 2003).

Such activities are created specifically for learning, and are thus set within the context of this science center in an effort to initiate the public in the understanding of the workings of nature. However, it is difficult to think about some sort of intellectual activity going on in young or older minds when dozens, or even hundreds of children are banging humongous copper gongs or squirting liquid while playing in the water area, or jumping up and down to create shadows in one or other interactive area. This worries the staff of the *New York Hall of Science* in Queens, New York: "We cannot control whether they use our exhibitions for play, or for acquiring specific knowledge from authorities or for something else entirely" (Friedman 2005:15)!

Educational expectations vary from institution to institution as they provide diverse modes of scientific information, but most exhibits follow ideological constants. When there is divergence, the pendulum swings far and wide; at some venues inventions are arranged as the outcome of scientific and technological progress, and scientific data are qualified as objective knowledge; while the superiority of science appears equated to flashy gadgetry. While the *Sony Wonder* exhibit space in New York City has an obvious commercial purpose and science is kept at minimum it is a good example of the technological swing; its halls are arranged chronologically and laud commercial achievement. At the *Science Center* in Oneonta, New York State, the sensorial experience gained through a "scientifically worthless exhibit plays a valuable part in promoting the exploration and understanding in science" (Read 2001:13)!

Science, Technology or Entertainment?

Umberto Eco wrote that "everything is repeated in circles, history teaches us because it shows us what does not exist, and what counts are the permutations" (Eco 2003:141, my translation), however, objects that are permutated carelessly and way too often are devalued in their mission as teachers which without context – uprooted from their social milieu – and this applies to objects extricated from laboratories, from the interior of a mine, or from a wondrous collection – lose their social functions. Depending solely on objects to tell the story of science puts a high toll on their efficacy – alters their scientific veracity, because objects in collections are inert, dead. It is museographic performance that gives them meaning. Teaching through socially dead objects illustrates the recurrence of "world-historical necromancy" (Marx and Engels 1852:104) that historic materialism challenged a century and a half ago.

Old exhibition tropes have been supposedly superseded by highly evolved communicative events put on by modern institutions. But, despite some superficial novelty, new exhibits look like old ones, textures are similar, discourses are similar, excuses are similar. The common rhetorical device used to describe scientific endeavor is that everything that science produces is beneficial to mankind; science continues to be shown to be pristine, and pure or as a progression of "best" "historical" events. Arguments are lamentably polarized in favor of more "modern" accounts that are constant reminders of exhibits at Victorian World Fairs. In the realm of biology, medicine, knowledge of new accomplishments relies on static objects from the past, shadowy references of mortifying items in jars, and butterfly corpses set in moth-balls or set, amazingly enough, in the context of cabinets of wonders.

Postmodern Tropes

Current museographical practices, styles – and fads – illustrate an absence of concern for how science and its products correlate to *real* events that affect *real* human beings. To be sure, postmodernism, with its premise that "science is an ideological product embedded in a particular cultural context" (Harris 1999:9) did influence the manner in which exhibits are created and has effectively been a potent force behind the re-vamping of much of today's museographic repertoire. But it has also contributed to exhibitionary excesses; minimalist styles, the newest of trends, have been a breath of fresh air in what used to be rooms crammed with confusing information or dusty jars full of specimens floating in formaldehyde. However, at other times the style has justified erasing the effects of the application of science and technology; the list all about accidents – military ones, industrial ones, totalitarian ones...

Back to the Renaissance?

In order to complement many exhibits, art is being invited to arbitrate scientific messages; contemporary artists, set designers, writers, and architects now make unchecked statements, and forward hazy assumptions about the role that science occupies in society. Postmodern discourse as well as its aesthetics have invaded the museographic landscape in efforts that "seek to replace science and reason with emotion, feeling introspection, intuition, autonomy, creativity, imagination, fantasy, and contemplation" [beginning with the premise that "to postmodernists, science is an ideological product embedded in a particular cultural context"] (Harris 1999:9).

As a result, despite the best curatorial efforts, false relationships are established and certified as valid. Installations that rely on aesthetics as conductor of knowledge often mask pertinent information on current science. In the sixteenth and seventeenth centuries "wonders as objects marked the outermost limits of the natural, wonder as a passion registered the line between the known and the unknown" (Daston and Park 2001:13) while contemporary exhibits use the "posh" look of postmodern cabinets of curiosity to take advantage of the visual spectacle their mélange offers. The strange, the shiny, the flashy has fascinated mankind for a long time (Stafford 2002:49), but, it is distressing to find the boundary between science and entertainment become so obvious. While some exhibition modes are more formal than others, and others are yet relaxed or even experimental, they are all geared towards the spectacular representation of science, leaving the abstract processes involved in the acquisition of knowledge on the dusty shelves of abandoned cabinets of wonder.

> Understood in its totality, the spectacle is both the outcome and the goal of the dominant mode of production. It is not something added to the real world – not a decorative element, so to speak. On the contrary, it is the very heart of society's real unreality. In all its specific manifestations – news or propaganda, advertising or the actual consumption of entertainment – the spectacle epitomizes the prevailing model of social life. (Debord 1995:13).

Today we live in the absolute certainty that images, and objects deliver truth: but objects cannot relay it alone. Seeing has been certified as the sine qua non of knowledge in our society and at its pinnacle, the scientific method. Yes, it is true that described either in its local or global dimensions, science and its techno-products, or art and its masters, present serious representational quandaries: for example, in creating an exhibit illustrating the production of nuclear power; where will boundaries be drawn, In the world of physics, or, in an imaginary war tribunal? In the discussion of fusion or fission, or, in a discussion on the exercise of evil?, which is a discussion some would definitively want to have.

Figure 7: Guide to be perplexed; *Medicinisk-Historisk Museum,* Copenhagen. Photograph Sophia Vackimes.

Plastinating, Pickling, Stuffing

In the realms of genetics or medicine, will we continue to learn about the body as fractured, cut into pieces, related to religion or superstition, instead of the body as a living unit, which considers the silence of the organism (Canguilhem 1978) or a feeling for the organism that Barbara McClintock wrote about (Fox Keller 1983). Why is it that the body is shown so often as variation of malformation? Why does this viewing exercise force a gaze that confronts the monstrous? Is there true didactic purpose in a crass exposure of what constitutes a "vulgar hierarchy of diseases"? (Canguilhelm 1991:39).

At the *Museo di Istoria Naturale*, *La Specola*, in Florence we see the human body represented via a myriad wax fragments. Upon a visit to the *Charité Medical Museum* in Berlin, we see arms, ears, legs, thighs, tongues, elbows, kneecaps, eyeballs, lips, femora, brains, muscles, testicles, mouths, lungs, kidneys, feet, hands, fingers, as spliced, cut, diced, dissected, plasticized, specimens riddled with disease; one's own body seems not worthy of having. These exhibits testify to the dissolution of the bond between body and human transcendence; the aggression shown towards the body attests to a post-Foucaultian order of things; an illustration of the butchery of bodies into spare parts, furthered by the replacement of such by metal prosthetics which certifies a new monstrous quality, a different order of signification (Haraway: 1991:4).

The disciplines of medicine, astronomy, mathematics, alchemy, or ethnobotany contain information drawn from cultures reaching all corners of the globe; but we have chosen to ignore those knowledges and their subtle meanings. We have left no space in contemporary thinking for the opportunity to allow our experiences to go beyond the opacity of modern life. We have long lost touch with any sympathy for the universe of meanings buried beneath our skin.

Figure 8: The body cut, spliced, pickled; *Charité Medical Museum,* Berlin. Photograph Sophia Vackimes.

Artists are being asked to bridge the gap between their craft and science, but artists seem so distracted with new media seem to have forgotten about the multiple meanings and messages embedded in individual histories imprinted on the human body. It is appalling to think that our modes of artistic questioning have been deleted or collapsed into the realm of facile illustrations; we are witnessing images product of a strange iconoclasm that ultimately banishes, crushes humanity.

While initially it is clear that "science is not autonomous, that it draws its form from its social and cultural roots" (Nader 1996:11) and that in artistic reactions important social preoccupations that are latent are expressed, it is largely unclear how genetic art should be approached since both art and science today are before uncertain territory. While it is intellectually untenable to argue that art should stay away from representing scientific matters, in fact, art should deal with them perhaps more freely, and frequently. However, "[r]epeated metaphors also serve to define experience, cultivate stereotypes, and construct shared meanings" (Lindee and Nelkin 1995:12), and increasingly, gimmicks that have but an arbitrary relation to increasingly slippery referents (Taussig 1993:xvii) are included in exhibits.

Figure 9: Bodies made up of spare parts – a common resource when learning about ourselves; *Deutsches Museum*, Munich. Photograph Sophia Vackimes.

Recasting Symmetries and Boundaries

Besides dealing with the more abstract tenets of the scientific subject, scientific representation must re-consider, as a defining feature, the role museums have in society; a role that affects us all and which should be open to criticism. While it is true that not all exhibits can be designed with political, historical, or even merely abstract aims in mind it is urgent to recognize is that the worldview that pervades most exhibits reflects a deep linearity, which is inherently flawed. Exhibits should reflect, with greater ability, shifts in social experience and sensibility, which at this time need to be explained in historical and phenomenological manners (Huyssen 2000:21), besides " visitors derive real pleasure from confronting matrial that makes them think about the world in which they live" (Bradburne 2002:6). New parameters for exhibitions must be devised conscientiously; a barrage of bad habits has been formed in the way reality is represented. Hopefully, the future museological exercise will be capable of engaging a new wisdom, a wisdom that "would above all mean recognizing the symmetry between substance and reality, the accidents occurring in social spheres instead of constantly trying to hide them" (Virilio 2000:54).

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Newton's Apple
The Coming into Being and Transformation of a Scientific Object

Konstanze Weltersbach[1]

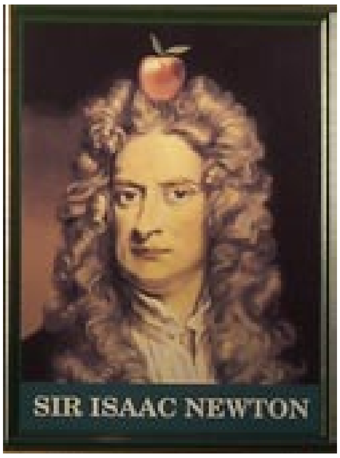

Figure 1: Icon of the Sir Isaac Newton Pub.

Introduction

During the Wandering Seminar's stop at Cambridge we stayed around the corner of the Sir Isaac Newton Pub. It struck me on the first evening, that the icon which illustrates the pub's name shows a well known Newton Portrait with an added apple sitting on his head – just as it must have sat on the head of William Tell's son in another great apple-epic (Fig. 1). Is it assumed that people would not be able to identify Isaac Newton without the apple, despite the name of the pub saying it all? And vice versa, does this imply that the apple is the key to identify the portrait as that of Newton?

At this point I decided to make it my object of the week and wrote the following lines: "Is this apple a scientific object? It might be…if it is the apple that helped Isaac Newton to discover the law of gravity. (…) We talk about "scientific objects" the whole time, but I'm sure we don't talk about the same thing. Is the term synonym to "scientific instrument"? This definition would make our lives much easier at the moment, but seems a bit limited. (…) But what if I used an apple to explain the law of gravity? Does it become a scientific object then? Or is it just a strange teaching device? When I am done with the explanation and put it back on the desk, does it turn back to a non-scientific object? (…)" The reactions towards my choice of object were very different, but seemed to follow a certain pattern: Most of the wanderers thought it to be a promising idea and

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1 This paper is a revised version of my presentation given at the Wandering Seminar's final workshop August 16th – 18th, 2007, in Berlin. I want to thank the network members for initiating the seminar, Hannah Lotte Lund for the organization, the workshop participants for their interest and very helpful comments, Sandra Martelli for pointing out my Gemanisms and of course all wanderers for their inspiring company and the great time.

the apple became a running gag (of course not as popular as the Mini-Guinea-Pig), while the majority of our hosts did not consider the possibility that the apple might really be a scientific object. Maybe our "wandering" experience did give us a different approach towards scientific objects.

This led me to the conclusion that it might be worthwhile to think about the apple a bit more, and I found more hints for the strong connection between Newton and the apple. As early as 1869 the story became the symbol of western science for the Japanese painter Hosai (Fig. 2).[2] More recent examples would be the following: In the introductory program to the 2002 "Great Britons" national poll conducted by BBC Two television Newton reached place 6 of the top 100 following Winston Churchill, Isambard Kingdom Brunel, Princess Diana, Charles Darwin and William Shakespeare.[3] The Isaac Newton segment consisted of a "Jackson Five song about 'the apple', some archive film on 'nature's suspender' – gravity – illustrated with footage of a woman fastening a suspender belt, and a discussion about whether the apple really did fall on his head".[4] In 2003 the poll was repeated by BBC World as "The World's Greatest Briton" with the additional option of online voting. This time Newton made first place. Tristram Hunt, the historian who presented the Great Britons profile of Newton, commented the result as follows:

> Newton's achievements affected all mankind and I think it is a proper reflection of his genius that a global audience has voted him the Greatest Briton. Indeed, it was Newton's advances in physics – his understanding of gravity and planetary motion – that have sent satellites into space and allowed the series to be beamed round the globe. The world has now repaid the favour. [5]

Countless scientists have used the apple story as an illustrating example. It is used to show "how things would be done right" if Newton really wanted to prove anything scientifically by a falling apple.[6] Medical doctors compare the common practice of practitioners with "cutting open Newton's apple to find the cause of gravity".[7] Botanists elevate Newton to the rank of an "honorary botanist" and describe the model of Gravisensing as "Newton's Law of Gravitation from the apple's perspective".[8]

What is so special about this apple?

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2 Drake, Stillman: *Newtons Apfel und Galileis "Dialog".* Spektrum der Wissenschaft, Oktober 1980, p. 124-131.

3 http://www.bbc.co.uk/pressoffice/pressreleases/stories/2002/11_november/25/greatbritons_final.shtml

4 Frayling, Christopher: *Mad, Bad, and Dangerous. The Scientist and the Cinema.* London 2005, p. 17.

5 http://www.bbc.co.uk/pressoffice/bbcworldwide/worldwidestories/pressreleases/2003/08_august/bbcworld_great_britons.shtml

6 Yankelowitz, Berril Yushomerski: *Biology, Blind Men, and Elephants.* British medical Journal, 23-30 Dec. 1978, p. 1775.

7 Underwood, Peter; Gray, Dennis; Winkler, Robin: *Cutting open Newton's apple to find the cause of gravity. A reply to Julian Tudor Hart on the future of general practice.* In: British medical Journal 291, 9.11.1985, p. 1322.

8 Wayne, Randy; Staves, Mark P.: *A down to earth model of gravisensing or Newton's Law of Gravitation from the apple's perspective.* Physiologia Plantarum 98, 1996, p. 917-921.

Figure 2: This Japanese drawing is part of a series of prints showing "great men of the western civilization". The writing translates as follows: "Isaac Newton, very great theoretical thinker, but not conceited".[9]

The apple story

The apple story itself is rather short. According to the most common version, Newton was forced to return home from his studies at Trinity College when the University of Cambridge had to be closed due to the outbreak of plague in 1665-66. These years were generally productive for Newton, as he also developed his method of the fluxions – later known as the calculus – to the point where he was able to use it to prove many far-reaching conclusions in mechanics and astronomy.[10] One day, contemplating in his garden, he observed an apple fall from a tree and wondered about the reason for its perpendicular trajectory. This led him to draw parallels between the forces that effect objects on earth and equally across the universe.

The importance of a discovery becomes obvious only in retrospect.[11] When the event supposedly happened, Newton could neither anticipate the impact his discovery would have nor the reputation he would gain. Nevertheless, it would be interesting to know what triggered Newton to introduce – or invent – the story at this particular point, a few months prior to his

9 Drake, 1980, p. 124.
10 Aughton, Peter: *Newton's Apple. Isaac Newton and the English Scientific Renaissance.* London 2003.
11 Schaffer, Simon: *Scientific Discoveries and the end of natural philosophy.* Social Studies of Science 16(3), 1986, pp. 387-420.

death. He told the story to at least four people.[12] It seems clear that he wanted to make sure it would get passed on. His niece passed the story on to the French Philosopher Le Bovier de Fontenelle.[13] Voltaire took it from there and spread it:

> Un jour, en l'année 1666, Newton, retire à la campagne, et voyant tomber des fruits d'un arbre, à ce que m'a conté sa nièce (madame Conduit), se laissa aller à une méditation profonde sur la cause qui entraîne aussi tous les corps dans une ligne qui, si elle était prolongée, passerait à peu près par le centre de la terre.[14]

Another listener was his friend William Stuckeley, who was especially impressed by the connections Newton drew between the movement of the apple and the Moon:

> The notion of gravitation … was occasion'd by the fall of an apple, as he [Newton] sat in a contemplative mood. Why should that apple always descend perpendicularly to the ground, thought he to himself. Why should it not go sideways or upwards, but constantly to the earth's centre? Assuredly, the reason is, that the earth draws it … there is a power, like that we here call gravity, which extends itself thro' the universe.[15]

These are just two examples of many early adaptations.[16] Later Isaac Disraeli added a twist; the that apple fell on Newton's head while he was sitting under the apple tree knocked his phrenological organ of causality.[17] This is the image that has survived until the present day in many, many versions (Fig. 3).

Nevertheless, the apple story did not become famous until 100 years after Newton's death, when his biographers, the French Jean Biot and the Scotsman David Brewster argued about the true biography.[18]

The fascination with the story

Many other apple stories are in circulation. For example, it is said that sweet apples are good for the IQ.[19] The scent of fouling apples inspired Friedrich Schiller to the point that he always kept some in his desk drawer.[20] Apple-Computer's original Logo was a man, sitting under an apple

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12 Fara, Patricia: *Newton. The Making of Genius.* London, 2002., p. 197.

13 Bührke, Thomas: *Sternstunden der Physik. Von Galilei bis Lise Meitner.* München, 2003, p. 29.

14 "Oeuvres complètes de Voltaire. Éléments de la Philosophie de Newton, divisés en trios parties" Avertissement de Beuchot, Vol. 38, p. 196, Paris, 1830. Voltaire mentioned the apple story first 1741 in a revised version of his "Philosophie de Newton" (1738) in the 3me part, Chap. 3. There might be an earlier account in Volaire's work in the Lettres Ecrites de Londres sur les Anglois et autres Sujets, par M.D.V.***, Basle, 1734. This work is recognized as Voltaire's, but does not bear his name. See: McKie, D.; de Beer, G. R.: *Newton's Apple.* Notes and Records of the Royal Society of London, 1951: 46-54, p. 49. Voltaire's Friend, the Marquise du Châtelet, translated Newton's "Principia" into French and helped the wide adoption of Newton's theories.

15 Stuckeley, William: Memoirs of Sir Isaac Newton's Life, Being Some Account of His Family and Chiefly of the Junior Part of His Life, London, 1936. See: Fara, 2002, p. 197.

16 for more detailed insight: McKie and de Beer, 1951.

17 Fara, 2002, p. 194.

18 Fara, 1999, p.168.

19 Füllemann, Verena und Markus; Bänninger, Alex: *Faites vos Pommes! Eine Art Kulturgeschichte des Apfels.* Bern, 1997, p. 127.

tree, reading a book. After the redesign, only the bitten apple remained.[21] And of course there is the ancient myth of the Apple-Shot (Apfelschuss), that is known from Persian, Danish, Norwegian, Icelandic and of course Swiss heroic sagas: In the Swiss version, it is the story of William Tell.[22]

Figure 3: "The punch cartoonist John Leech's satirical illustration of Newton receiving his famous flash of inspiration from a falling apple in his garden at Woolsthorpe."[23]

However, most authors who are concerned with Newton's apple story do not compare it with these saga type stories but rather with "myths and half truths"[24] of science, such as Archimedes' Eureka, Galileo's cannonballs, Darwin's finches, or Watt's boiling kettle. These myths depict great discoveries, mystified by the image that all it takes is one moment of genius inspiration. As such, writers concerned with science myths threat them equally. The way these stories are usually perceived becomes clear in a quote I selected from my actual field of research (palaeoanthropology): "In a manner which matches the fortuity, if not the consequence, of Archimedes' bath and Newton's apple, the fossil footprints [of Laetoli] were eventually noticed one evening in September 1976 by the paleontologist Andrew Hill, who fell whilst avoiding a ball of elephant dung hurled at him by the ecologist David Western".[25] I want to argue in opposition to that understanding that Newton's apple does own a different quality compared to these other stories.

Legend says that Archimedes ran through the streets of Syracuse shouting "Eureka", right after he lowered himself into a bathtub and observed the water being displaced by his own body. This way he found the principle of buoyancy. Should the naked Archimedes be for buoyancy what the

20 Eckermann, Johann Peter: *Gespräche mit Goethe in den letzten Jahren seines Lebens.* Michel, Christoph (ed.): Johann Wolfgang Goethe. Sämtliche Werke. Briefe, Tagebücher und Gespräche, Band 12 (39). Frankfurt, 1990, p. 632.

21 http://www.designguide.at/apple_logo.html

22 www.tell.ch

23 Fara, Patricia: *Catch a falling apple: Isaac Newton and myths of genius.* Endeavour 23 (4): 167-170, 1999, p. 167.

24 Nicholls, Henry: *Tall tales and tortoises.* NewScientist, 15. July 2006, p. 21; Fara, 1999, p. 168.

25 Reader, John: *Missing Links: The Hunt for Earliest Man.* London, 1988.

apple was for gravity? Eureka is rather an expression of joy and excitement over the discovery and does not symbolize the discovery itself.

Galileo on the other hand, used a cannon ball and a musket ball, which he dropped both off from the leaning tower of Pisa to demonstrate that unequal weights of the same material, moving through the same medium (air), move with equal speed. Other versions tell of iron and wooden balls, some authors doubt the whole story.[26] Being more a demonstration than a sudden insight into nature's laws, Galileo's action would correspond to Newton dropping an apple himself to proof its fall.

Darwin and the finches, these "iconic birds", appeared the first time alongside in print in 1935, about 100 years after the Beagle reached Galapagos. Darwin himself mentioned them only sporadically.[27] I remember the finches well from biology class in school where their beaks (and the cichlids in the Victoria Lake) illustrated evolution at work. They could stand for evolution as the apple stands for gravity, but Darwin – for what I know – never said that the finches inspired him to discover the laws of evolution. A finch does not symbolize Darwin. More often in popular appearances a dog stands at his side – a beagle, of course.[28]

Concerning James Watt, legend tells that he watched a boiling kettle as a child, which lead to a lifetime's interest in steam. Fact is that he invented the separate condenser for the Newcomen steam engine. However, he did not build it on scientific principles, in this case Black's principle of latent heat, nor did he independently re-invent the principle.[29] Thus, even if the story about watching a phenomenon influenced his future career and might even have inspired an invention story was true, it certainly did not lead to a scientific discovery, as it is the case with Newton's apple.

Do all these phenomena belong to the same category? Since Archimedes' shout of Eureka was out of excitement about his discovery and Watt was put on his career track by watching a boiling kettle, only three events – Newton's apple, Galileo's cannonballs and Darwin's finches are directly linked to science. However, Galileo was producing evidence for a hypothesis he had already formulated and Darwin did not deem the finches to be crucial to his theory. Only Newton made the apple part of his scientific discovery, and through this part of his scientific material culture. He invented the apple as a scientific object itself.

Self mystification

The question remains why. Newton can be seen as a stereotyped scientist when it comes to his neglect of physical needs (he sometimes forgot to eat) and his devotion for whatever topic he focused on: In the late 17th and early 18th century Newton was presented as the first real scientist hero, who single handedly created the most important "system" since the days of Plato and Aristotle – although especially by versifiers.[30] Today he is often described as "neurotic",[31] "possessive about his findings",[32] and "vindictive".[33] Patricia Fara puts it as follows: "Today's

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26 Drake, Stillman: *Galileo at Work. His Scientific Biography.* Chicago, 1978, p.20 f.
27 Nicholls, 2006.
28 The hitchhikers guide to the galaxy (Douglas Adams, 1979); Young Einstein (Yahoo Serious 1989).
29 Dorn, Harold: *Watt, James. Dictionary of Scientific Biography.* New York, 1980, p. 196.
30 Frayling, 2005, p. 32.
31 Schneider, Ivo: *Isaac Newton. Lexikon der bedeutenden Naturwissenschaftler*, München, 2004.

Newton is an unpleasant, self-preoccupied introvert who is obsessed with alchemical experimentation, but at the same time he remains an icon of rationality. This duality as both an insane genius and a dispassionate scientist is unique to Newton. (…), only Newton is simultaneously mad, bad and brilliant."[34]

An apple is a natural thing that is not made by man – it is different, for example, from Galileo's cannonballs. This naturalness emphasizes the fundamental connection of Newton's discovery and the natural world. Of course Newton was aware of the other implications apples had. Ancient myths range from the apple of discord, the cause of the beauty pageant between Hera, Athena and Aphrodite, to Atalante, who below the line was tricked into marriage because she could not resist the beauty of three golden apples. The apple from the tree of knowledge in Christian mythology bore two further meanings: The rotten apple as a symbol for the primordial sin (Ursünde), and the apple in the hand of Baby Jesus as a symbol for salvation.[35] By choosing an apple for a scientific object, Newton connected his work and his person with a symbolism of divine inspiration. The apple in the Garden of Eden was the only fruit that had to be plucked, while all other fruits fell to the ground when they were ripe.[36] This accentuates the divine intervention in the event. God let the fruit of knowledge fall for Newton and Newton was the recipient of divine action. However, Newton's observation was a conscious act. By noticing the significance of the apple's fall, he accepted his fate to bring scientific enlightenment to the people. In contrast to this, Isaac Disraeli's twist to the story – the apple fell on Newton's head – accentuates the passive reception of the discovery. Newton had to notice the apple, he did not deliberately choose to notice its fall. If you want to find similarities between Newton's experience and another science myth, the passiveness and inevitableness in Disraeli's version makes it comparable to August Kekulé's "discovery" of the benzene ring.[37] Kekulé like Newton invented the story himself a long time after the event supposedly happened, in this case in 1890. One day in 1861 or 1862, while writing on a teaching book in Gent, Belgium, Kekulé fell asleep and dreamt of atoms and the structures they formed, just as it had happened to him many times before. But this time it was different. Long chains of atoms meandered and snaked in front of his eyes, and suddenly one of the snakes bit into its own tail. Kekulé spent the rest of the night to figure out the consequences of what he at this point already calls a hypothesis.[38] The snake in his vision resembles the alchemical *ouroboro*, which symbolizes ideas of cyclicality, unity, or infinity. Although Kekulé himself referred to his work, his recent impressions, etc., as the origin of his dreams, a mystic quality of visionary powers remains. The apple and the dream are both stories of revelation.

While Newton made sure that enough people heard the story to pass it on, he shaped the perception of his scientific achievements and initiated a further mystification of his person. Although Newton could not foresee the impact of his story, he chose an object to embody the quintessence of his discovery, which was charged with enough symbolism to put the event and through this, the nature of his achievements into a "mythical time and place". At the same time

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32 Youschkevitch, A. P.: *Newton, Isaac. Dictionary of Scientific Biography*, New York, 1980.
33 Hawking, Stephen: *On the Shoulders of Giants*. London, 2002.
34 Fara, 2002, p. 274.
35 Die Natur und ihre Symbole. Bildlexikon der Kunst.
36 I thank Lorraine Daston for this remark.
37 Thanks to Peter Geimer for pointing me in the direction of Kekulé.
38 Göbel, Wolfgang: *Friedrich August Kekulé*. Leipzig, 1984, p. 54.

the story influenced ongoing discussions about the nature of scientific discoveries. Should they not be the rewards of hard work and laborious studies rather than the results of a sudden flash of inspiration?

Figure 4: "Newton's apple tree as it appeared in 1816".[39]

The Apple Trees

If the apple ever existed, it surely did not survive to our days. There is no object today we can refer to as Newton's apple – or is there? Something remained to connect us to the apple event and through this to Isaac Newton himself: The tree the apple fell from, also referred to as the "tree that illustrates a law of physics" (Fig. 4).[40] In Newton's times, trees stood for the growth of human wisdom, apple trees in particular for holiness and Englishness at the same time.[41] In addition to the apple's symbolism it sets Newton in a rural scene full of divine and national connotations. The apple tree was more than a substitute for the apple. It bore its very own implications for Newton's story, and it was predestined to become a center of hagiography. However, the original apple tree itself is most likely not alive anymore – the maximum age apple trees reach on average being about 200 years. Nevertheless, due to the continuity of ownership of Woolsthorpe Manor and the survival of maps and drawings, there is indeed a tree connected to Newton's apple. This particular tree was chosen – most likely within 50 years of Newton's death – for one simple reason: if the incident happened in Newton's garden and not in the orchard or at any other place, there was only one apple tree growing there.

Rumor in the middle of the 19th century had it that the original tree had been blown down and converted into a chair by E. Turnor of Stoke Rocheford (who also mentioned the apple story in 1806);[42] the chair is today in a private collection (Fig. 5). But not all of the tree's roots were taken

39 Keesing, R. G.: *The history of Newton's apple tree.* Contemporary Physics 39(5), pp. 377-391, 1998, p. 384.
40 Karagianis, Liz: *Newton's apple tree bears fruit at MIT.* MIT Tech Talk, October 4, 2006.
41 Fara, 2002, p. 203.

out, and a dendrochronological examination combined with radiocarbon dating suggest that the tree growing in Woolsthorpe Manor today is the same tree that was identified as Newton's apple tree in the early 19th century. The tree's supposed offspring – some of which have been genetically fingerprinted – are also alive and fruitful, although some have been cut down for "ignorance of what they were".[43] Some thrive in Cambridge, in Pune in front of India's Institute of Astronomy, and in Woolsthorpe itself, and at many other places. The offspring's offspring bear the same aura: The MIT's apple tree grew from a cutting of a tree in England's Royal Botanical Gardens, which was grown from a cutting of Newton's apple tree. When the trees bear fruit, they become an attraction for pilgrimage: The apples on the MIT's tree are worth a note in the MIT Tech Talk,[44] the apples from the tree in Pune attract tourists from Bombay 300 km away.[45] Some of Newton's aura, his spirit and brilliancy, was inscribed into the apple tree and it seems to be carried over by its offspring. The descendants of the original apple tree turned into third-class relics (mittelbare Berührungsreliquien). Even when the relics are split up (parts of the tree chopped of) and spread over the world, the aura is not reduced.

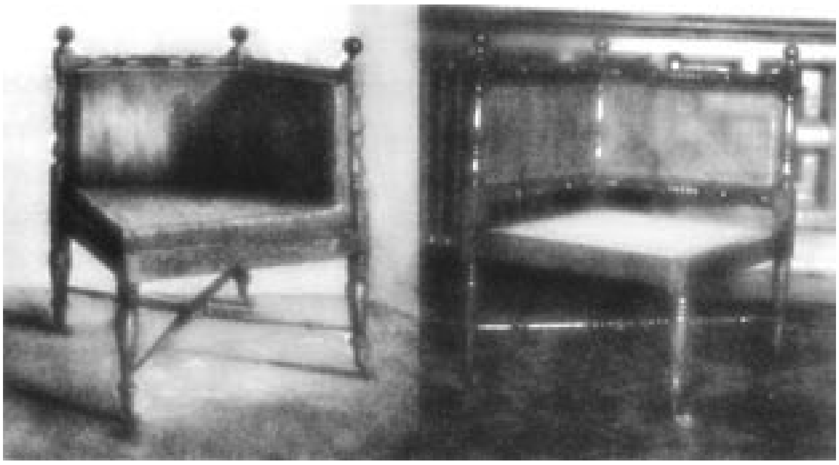

Figure 5:"Charles Turnor's watercolour of the chair made from some of the wood from Newton's apple tree, and a modern photograph of the chair (...). The chair was at Stoke Rochford Hall when photographed in 1977, but is now in a private collection."[46]

Conclusion

Objects stabilize our sense of who we are by giving concrete evidence of one's place in a social network.[47] By introducing the apple as a scientific object Newton took an active part in shaping his posthumous reputation. The traditional Christian and national symbolism of apples and apple trees served as a "built-in justification" for the story. Scientific genius and divine intervention

42 Turnor, E.: Collections for the History of the Town and Soke of Grantham, p. 160, London, 1806. See: McKie, Brewster, 1951, p. 52.
43 Keesing, 1998, p. 387.
44 Karagianis, 2006, p. 8.
45 Fara, 2002, p. 192.
46 Keesing, p. 388.
47 Csikszentmihalyi, Mihaly: *Why we need things.* In: Lubar, Steven; Kingery, W. David: History from Things. Essays on Material Culture. London, 1993, p. 20-29.

meet in Newton's discovery. I do not know what triggered Newton to tell the story several years after the event supposedly happened. Nevertheless, stories like this can only be invented or introduced in retrospective (just as "discovery" is a retrospective label).[48] Believers and skeptics adapted the story because of its implications on the ongoing discussions about the nature of scientific discoveries. As time went by, Newton's apple became part of a hagiography of scientific genius. Therefore the meaning of the apple shifted from being part of a scientific discovery to a symbol for both brilliancy and for Newton as a person, which is why the story is often compared to other science myths such as Galileo's cannonballs and Darwin's finches. However, Newton's story has a different quality. It is directly linked to a scientific discovery and was chosen by the discoverer himself. When Newton pointed at the apple and made it "his" object, he set its spiritual qualities free. A mundane object and a mundane event connect the scientific genius Isaac Newton with the realm of everyday experience.

But the apple is long gone, and hagiography needs a localization (Verortung) of its subject. The apple trees carry the aura of Newton's discovery and his genius. This, in combination with the genetic fingerprint – which gives proof of their "historische Zeugenschaft" – gives them a museum-object like quality. They turn into valid memorial sites.[49]

Figure 6: "Astrophysicist Stephen Hawking, paralyzed by Lou Gehrig's disease, floats during a zero-gravity flight; an apple, a tribute to Isaac Newton, drifts along with him."[50]

Stephen Hawking emphasized the legitimacy of his succession to Newton when he had his picture taken under the apple tree at Woolsthorpe on the occasion of the 300th anniversary of the publication of *Principia*.[51] When on another occasion – a zero gravity flight – he was pictured with an apple drifting along with him (Fig. 6),[52] the transformation from Newton's apple as a scientific

48 Schaffer, 1986.
49 Geimer, Peter: *"Hier". Bern, Kramgasse 49.* In: Hagner, Michael: Einstein on the Beach, Frankfurt, 2005, p. 274-290.
50 Whoriskey, Peter: *A Long-Awaited Taste of Outer Space. Stephen Hawking Takes a Buoyant Ride on a Zero-Gravity Flight.* Friday, April 27, 2007; Page A01. http://www.washingtonpost.com/wp-dyn/content/article/2007/04/26/AR2007042602709.html
51 Fara, 1999.
52 Whoriskey, 2007.

object to a symbol for Newton, his achievements and his brilliancy went full circle. Any given apple can fill in for Newton, much better than a portrait could.

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