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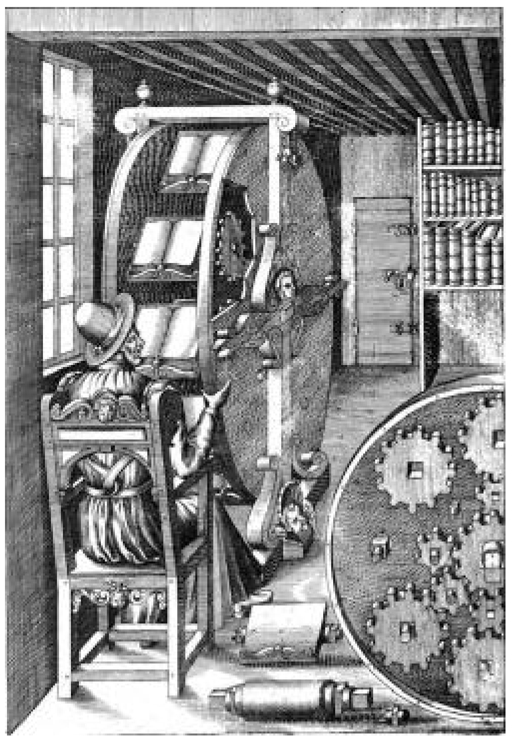
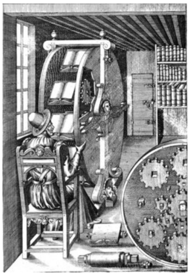
THE CIRCULATION OF SCIENCE AND TECHNOLOGY



The Circulation of Science and Technology

Cover



Bookwheel, from Agostino Ramelli's "*Le diverse et artifiose machine*", 1588.

The circulation of science and technology is not an automatic process. Ingenious techniques are needed to make the locally attached scholar a cosmopolitan character with simultaneous access to multiple sources of knowledge. And machines themselves may incorporate sophisticated knowledge as suggested by the epicyclic gearing arrangement that keep the books at a constant angle adapted by Ramelli from astronomical clocks. The bookwheel, by displaying the mathematical prowess of the Italian military engineer, works as an excellent metaphor both of the deep relations between science and technology and of the highly demanding task of putting them in circulation.

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Editorial Note

Launching HoST and 'The Circulation of Science and Technology'

By Tiago Saraiva[*]

The publication of the first number of HoST is the direct result of a joint effort by a group of Portuguese scholars[1] aiming to strengthen the field of History of Science and Technology in a small country of the European periphery. The big challenge was how to do it avoiding the traps both of Portuguese centrism and of excessive internationalism. We did not want to limit ourselves to an autistic dialogue around Portuguese issues, but we were well aware of the existence of an extended number of excellent international journals both on history of science and history of technology. We decided that a valuable way of nurturing a sustainable community in the field was to promote a journal where local scholars would have to face subjects of international relevance and dialogue with internationally

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[1] The editorial board of HoST is formed by Ana Carneiro, Maria Paula Diogo, Henrique Leitão, Ana Cardoso de Matos, Tiago Saraiva and Ana Simões. We also want to acknowledge the generous funding of our common endeavour by our own institutions: Institute of Social Sciences – University of Lisbon; Interuniversitary Centre for the History of Science and Technology – Faculty of Sciences (University of Lisbon) and Faculty of Sciences and Technology (New University of Lisbon); Interdisciplinary Centre for History, Cultures and Society (CIDEHUS) – University of Évora.

recognized historians. In order to promote such a confrontation, the editors also launched an annual workshop (typically in June) acting as the main supplier of a thematic summer issue.

Although HoST thrives to include Portuguese contributions in every issue, it is totally open to original research on the cultural and social dimensions of science and technology in history across the world. More than that, we wish to make the global geography of HoST papers a distinctive feature of the journal. The constitution of the editorial advisory board is also a declaration of intentions concerning the importance of having an active collaboration from different regions of the planet and distinguishes HoST from most of the journals of the field.

Such mix of global and local ambitions could only be attained by committing ourselves to a publication in English, the only language able to guarantee a cross-cultural dialogue, even when the level of the written English of our journal will not probably reach the high standards of the best publications in the field. The option of publishing online on a totally open access basis goes in the same direction of enlarging the potential community of HoST readers and contributors. One must recognize the opening up of perspectives to scholars outside the usual central countries offered by the use of the internet, and it would be a shame to throw away such advantages by following the bad habits of too many academic publishers who contribute to the growing costs of access to knowledge.

The will to expand the hosting capacity of the journal is also asserted by the decision of placing together history of science with history of technology. In conjunction with its worldwide scope, this will be another distinctive mark of HoST, an almost natural decision for a group of historians living in a peripheral region where such distinctions have always been blurred. But what was commonly seen through the lens of scientific and technological backwardness, with poorer countries not having the resources to pursuit more fundamental science, is now perceived as a highly artificial separation of fields, as confirmed by the growing use and acceptance of the concept of technoscience. There are many examples of the benefits of leaving behind such distinctions but few are as convincing as Peter Galison's book on two of the most cherished symbols of high theoretical Science, Einstein and Poincaré.[2] As Antonio Lafuente writes in his essay review for this first issue of HoST on Galison's "Einstein's Clocks, Poincarés' Maps", "to separate our ideas from the machines with which we produce them and realize them is tantamount to refusing to understand how the world in which we live was created". Such words are a very good justification to bring together in the same journal the history of science and the history of technology despite the venerable traditions of both disciplines.

It is also no coincidence that the first workshop organized by the HoST editors was meant to deal with "The Circulation of Science and Technology: Places, Travels and Landscapes". After all, HoST itself was forcing us to a reflective exercise on how to come to terms with problems around

[2] Peter Galison, *Einstein's Clocks, Poincaré's Maps. Empires of Time* (New York / London: Norton, 2003).

peripheral histories, international communities and *glocal* agendas[3]. It seemed an obvious choice to take Circulation as the major topic of HoST first issue. But perhaps more important than our own concerns (obsessions?) was the shared conviction that historians of science and technology have been dealing with circulation issues for quite a long time, and that their narratives have offered an image that does not fit in the majority of general accounts on globalization. If on the one hand globalization gurus sustain the flatness of the world and the endless expansion of international networks[4], on the other historians of science and technology have stressed the crucial role of the local dimension of knowledge production. Instead of considering circulation as an automatic phenomenon following the universal character of science (or the market, the new gurus would say), they have suggested that there is much effort in making knowledge and technology which are locally produced into suitable things for circulation.[5] Without standards, protocols and communities of experts, scientific objects and technical devices would have many difficulties in

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3 A similar intellectual agenda dealing with the same kind of problems animates the research network STEP (Science and Technology in the European Periphery). See www.ca.uoa.gr/step.

4 A good example of such literature is Thomas L. Friedman, *The World is Flat: a Brief History of the Twenty-first Century* (New York: Farrar, Starus and Giroux, 2005).

5 Good accounts of such historiography may be found in David N. Livingstone, *Putting Science in its Place. Geographies of Scientific* Knowledge (London / Chicago: Chicago University Press, 2003); Roy Macleod ed., “Nature and Empire. Science and the Colonial Enterprise”, *Osiris*, 2000, *15*. Also important for the argument are Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900 (*Hampshire: Palgrave Macmillan, 2007); M. Norton Wise ed., *The Values of Precision* (Princeton, NJ: Princeton University Press, 1995).

flying away from their local context. Natural History Museums, Botanical Gardens or National Bureaus of Standards may be profitably studied as places for enhancing circulation, central nodes of extended networks trough which flow instruments, materials, people and practices.

Circulation has been an instrumental concept for replacing old theories of diffusion by richer accounts where local contexts play a prominent role. The opening article of HoST by M. Norton Wise on “What can local circulation explain?” makes a strong case about the importance of the cultural resources at Helmholtz disposal in Berlin’s urban context for the building of his frog-drawing-machine. In spite of declarations of good will, most of the history of science devoted to the local nature of science practices has difficulties in demonstrating the usefulness of knowing local contexts for understanding science production. The article not only fully accomplishes this aim, but also goes a step further concerning the political economy of laboratories. By dealing with cultural resources as if they were material ones, it makes the Dürer Renaissance as material to Helmholtz as the prisms of the Cambridge fairs were to Newton. The concept of cultural resource is a very attractive one for replacing, or at least remaking, the now common approach to the material culture of science production, without falling in the old trap of a cultural context that one ever understands how it articulates with the core of science.

Fuzzy ideas about influence have lost their appeal in favor of thicker descriptions that follow the actual trajectories of things in circulation. Ana Cardoso de Matos and Paula Diogo’s article, “Bringing it all back home”, is a good example of the benefits of putting flesh into general ideas such as the French influence on Portuguese engineering practices in the second half of the nineteenth century. By following Portuguese engineers in action they are able to put forward a topology of centers of circulation that include engineering schools, industrial sites and world exhibitions. Instead of a mere center/periphery (Paris/Lisbon) relation, the authors place the engineer's travels to those centers in relation to local agendas of professional identity and state modernization.

The stress on the creative role of the appropriators of technology is also a key concept of David Edgerton's contribution on "Creole Technologies and Global Histories". While the previous article was centered on technological experts, Edgerton aims at extending the number of actors in the history of technology. His main goal is to make technology a crucial component of any narrative dealing with poor countries as well as making low-tech devices central to the understanding of the rich world. Perhaps more traditional historians of technology will be shocked by his provocative prose where rickshaws and corrugated iron take the place of dams and the green revolution to properly assert the local relevance of technology. It seems that what Edgerton is doing is to bring into the realm of the history of technology large plots of the population largely ignored by the scholars of the discipline. There are, for example, numerous books on the role of technology in the building of the network city in Europe and the United States, but till now we had no account of the technological nature of expanding bidonvilles in the megacities of the poor world.

Circulation attaches new identities to things. This is very obvious for the different historical uses of corrugate iron or the new identity experienced by Portuguese engineers as they travel across Europe. It also stands for Helmholtz's frog-drawing-machine growing from the use of Berlin's cultural resources related to curves. What is striking in the case presented by Ricardo Roque in "Wordless Skulls" is that what could be seen as a typical example of how museums put objects in circulation by the production of collecting and exhibiting protocols is instead a narrative of how some objects may get stuck in museums without being able to circulate. His collection of Timor skulls, useless to the commoditization project of the Portuguese colonial possessions, became wordless objects with no attached significant discourse. Roque evokes Star's and Bowker's argument about how classifications can 'break, twist, or torque' the biographies and bodies of persons, to make an analogy of how classification and description systems can also twist the lives of objects like his collection of skulls. But from his text one cannot avoid the conclusion that without the ability to apply such classifications, things may just die in the oblivion of Museum's deposits. We are thus faced with a magnificent counterfactual of how things not circulating become irrelevant. It is then no surprise that we make every effort to maximize the circulation of HoST as much as possible.

What Can Local Circulation Explain?

The Case of Helmholtz's Frog-Drawing-Machine in Berlin

*By M. Norton Wise**

"Circulation" seems to have replaced "travel" as a favored concept in history and social studies of science and to have taken on new significance. Formerly, circulation referred primarily to diffusion or spread, such as the diffusion of knowledge through the republic of letters or of paper-making from China to Europe. Circulation now often highlights exchange: exchange of people, materials, instru-

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For valuable discussions and sources I am indebted especially to Sven Dierig, Mechtild Fend, and Elaine Wise as well as to participants in colloquia and workshops at Harvard University; Internationales Forschungszentrum Kulturwissenschaften, Vienna; Max Planck Institute for History of Science, Berlin; Pennsylvania State University; University of California, Berkeley; University of Lisbon; and UCLA.

ments, and practices between laboratories in a network. In this sense, exchange helps to explain how standards become established for precision measurements.[1] Circulation can also draw attention to the role of a particular location or country as a center of circulation within a larger network. For this purpose in 2005 the Dutch and Belgian History of Science Societies chose circulation as a subject that could serve to integrate, or at least interrelate, their diverse interests in the role that the low countries have played in the history of science and that they continue to play in the European Community.[2] I would like to suggest here another function for circulation, in cultural history of science, especially the intensely local studies currently being produced. For that purpose I will develop an example drawn from a book manuscript on *Bourgeois Berlin and Laboratory Science*. I hope to show how circulation helps us to understand that the resources available to Hermann Helmholtz and his friends in the Berlin Physical Society in the late 1840s were cultural resources. The story will culminate in Helmholtz's early work on muscle and nerve physiology, as illustrated by his frog-drawing-machine (figure 20 below). The focus will be on the status of the line and the curve as they circulated among the representatives of neoclassical aesthetics, industrial promo-

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[1] Joseph O'Connell "Metrology: The Creation of Universality by the Circulation of Pariculars", *Social Studies of Science*, 1993, *23:*129-173; Simon Schaffer, "Accurate Measurement is an English Science", in *The Values of Precision*, ed. M. Norton Wise, (Princeton: Princeton University Press, 1995), pp. 135-172.

[2] Conference organized by Lissa Roberts and Bert Theunisson on "The Circulation of Knowledge and Practices: The Low Countries as an Historical Laboratory," Woudschoten, 27-28 May 2005.

tion, military modernization, and science education in Berlin in the 1830s and 40s.

Figure 1. Franz Krueger, Parade auf dem Opernplatz (Berlin), 1824-1830.

Consider the painting in figure 1 of “Eine Parade,” by Franz Krueger, one of the exponents of what may be called Berlin Realism, referring here to Krueger’s portraiture of people, horses, and buildings. The painting depicts a parade of heavy cavalry down *Unter den Linden* in 1824, celebrating their honorary commander, Archduke Nicholas (Tsar Nicholas I from 1826) and his wife Charlotte, daughter of the Prussian King, Friedrich Wilhelm III. The cavalry is passing before the King with his military high command in the left background. But the real subject of the painting lies instead in the right foreground, where a crowd of citizens is gathered (figure 2). Here Krueger has done much of my work for me. He has assembled a who's who of bourgeois culture, including a number of the people who will play leading roles in my story, and set them in interrelation.[3]

Figure 2. Well-placed citizens of Berlin.

Behind the coiffed woman in white in the right front (the actress Caroline Bauer), recognizable in figure 3, are Gottfried Schadow (balding and hatless), head of the Academy of Art; Carl Friedrich Schinkel (right of Schadow),

[3] Renate Franke, *Berlin vom König aus zum Schusterjungen: Franz Krügers "Paraden" Bilder preußischen Selbstverständnisses* (Frankfurt am Main: Peter Lang, 1984), makes a convincing argument for seeing Krüger's parade pictures as bourgeois self-representations and includes identification keys for many individuals, with discussion pp. 128-144.

the architect who designed the neo-classical guardhouse (Neue Wache) behind the crowd; and Christian Daniel Rauch (right of Schinkel, tall, in top hat), who sculpted the statue standing in front of the guardhouse of General Scharnhorst, hero of the War of Independence from Napoleonic France, 1813-15. This closely connected group, along with other artists in the painting, like Krueger himself, repre-sents the reforming ideals of Berlin art, which aimed to guide the populace in achie-ving the aesthetic and moral status of citizens in a modern state, a new democratic Athens.

Figure 3. Schadow, Schinkel, and Rauch.

Another group, who will appear importantly below, stands behind the brown and white horses in the left front, detailed in figure 4. They include Alexander von Humboldt (in tophat on the left), who had only returned to Berlin in 1827 after 20 years in Paris, where he published the many volumes documenting his expedition to South America and Mexico; Gaspare Spontini (right, tall, in tophat), composer and director of popular operas, sometimes with Humboldtian tropical scenery designed by Schinkel; and P.C.W. Beuth (rear, in red-banded cap), leader of the industrialization movement of the Prussian government and intimate friend of

Schinkel, who in turn was a longtime friend of the Humboldt family. Krueger here seems to want to capture a new constellation of cultural forces in Berlin in the late twenties.

The celebrated Humboldt, whom Krueger has imported here although he was not yet in Berlin for the 1824 parade, had won popular acclaim with his famous Kosmos lectures in 1827-28. He embodied the excitement of foreign landscapes and peoples along with an anticipated rejuvenation of all fields of natural science. Spontini reinforced the exotic Humboldtian image with operatic dramas. Meanwhile, Beuth stood at the center of the science-technology nexus as the leader of Prussia's drive to industrialize and as founder of new industrial institutions: the Technical Institute (*Gewerbeinstitut*) and the Society for the Advancement of Industry (*Verein zur Beförderung des Gewerbefleisses*). In these efforts he worked closely with Schinkel, as also in the reformed School of Architecture and Civil Engineering (*Bauschule*). Helmholtz and the ambitious young scientific modernizers who formed his immediate group of friends during his medical education in Berlin belonged to the next generation. They acquired their cultural identities within this milieu of material and social progress guided by neo-classical aesthetics and they sought to

Figure 4. Humboldt, Beuth, and Spontinni.

bring those ideals into the sciences when they established the Berlin Physical Society in 1845.[4] Like many of his peers, Helmholtz maintained a deep engagement with music and art throughout his life. As is well known, he was an accomplished pianist, but his drawing skills were also impressive, following five years of instruction in the Potsdam Gymnasium where his father was subrector (third in line).[5] The "godfather" of the Physical Society was Gustav Magnus,[6] whose brother Eduard was the most successful portrait painter in Berlin. Eduard maintained close ties with the already well-known painter Adolph Menzel, with whom Helmholtz would soon come in contact through his marriage to Olga von Velten. She was the niece of Helmholtz's superior while serving as a military doctor in Potsdam, Wilhelm Puhlmann, founder of the Potsdam Society of Art and a close friend of Menzel. These tight circles of relations begin to suggest why circulation captures something critically important to local culture. The circles extend easily through Helmholtz's closest friends in the Physical Society. Ernst Brücke's father, two uncles, and a stepbrother were Berlin artists and he himself remained active in the arts throughout his life. Emil du Bois-

4 On the founding of the Society see Wolfgang Schreier and Martin Franke, with the assistance of Annett Fiedler, "Geschichte der Physikalischen Gesellschaft zu Berlin," in *Festschrift: 150 Jahre Deutsche Physikalische Gesellschaft*, ed. Theo Mayer-Kuckuk, special issue of *Physikalische Blätter*, 1995, 51, F-9 — F-59.

5 This assumes he followed the usual course of instruction. See "Der Jahresberich", by Director Dr. Rigler, in *Zu der öffentlichen Prüfung der Zöglinge des hiesigen Königlichen Gymnasiums den 21sten und 22sten März laden ganz ergebenst ein Director und Lehrercollegium* (Potsdam: Decker'schen Geheimen Oberhofbuchdruckerei-Etablissement, 1837), pp. 45-58, on 53.

6 Dieter Hoffmann, ed., *Gustav Magnus und sein Haus* (Stuttgart: Verlag für Geschichte der Naturwissenschaften und der Technik, 1995).

Reymond always regretted that he had not taken up a career in art, like his aunt, his grandmother, and his renowned great grandfather Daniel Chodowiecki.[7] Given these relations with artists, it will be useful to begin exploring circulation with respect to drawing in art and the perceived significance of the line or curve.

Dürer Renaissance

Complementing Humboldt's *Kosmos* lectures at the *Singakademie* in the spring of 1828 was Spontini's romantic opera *Nurmahal*, with sets by Schinkel featuring exotic tropical vegetation inspired by Humboldt's *Vues des Cordillieres*. But another event marked the aesthetic character of Berlin art. On the 18th of April 1828, the 300th anniversary of Dürer's death, a great commemoration was held in Berlin, as well as in Dürer's native city of Nürnberg. The iconic status that Goethe was already acquiring by that date for German culture is well known; less familiar may be the fact that Dürer

[7] For perceptive discussions see Sven Dierig, "Apollo's Tragedy: Laboratory Science between Calssicism and Industrial Modernism," in *Science as Cultural Practice,* eds. Moritz Epple and Claus Zittel (Berlin: Academie Verlag, 2007), and *Wissenschaft in der Maschinenstadt: Emil du Bois-Reymond und seine Laboratorien in Berlin* (Göttingen: Wallstein, 2006), pp. 10-16, 122-144 and *passim*; Timothy Lenoir, "The Politics of Vision: Optics, Painting, and Ideology in Germany, 1845-95", in *Instituting Science: The Cultural Production of Scientific Disciplines,* ed. Timothy Lenoir (Stanford; Stanford Univ. Press, 1997), pp. 131-178; and Gary Hatfield, "Helmholtz and Classicism: The Science of Aesthetics and the Aesthetics of Science", in *Hermann Helmholtz and the Foundations of Nineteenth-Century Science*, ed. David Cahan (Berkeley and Los Angeles: Univ. California Pr., 1993), pp. 522-558. Ernst Theodor Brücke, *Ernst Brücke* (Vienna; Springer, 1928), pp. 2-4, 137. Ernst Brücke, *Schönheit und Fehler der menschlichen Gestalt* (Wien & Leipzig; Braumüller, 1892). Emil du Bois-Reymond, "Naturwissenschaft und bildende Kunst", in *Reden von Emil du Bois-Reymond,* ed. Estelle du Bois-Reymond (Leipzig; Veit, 1912), vol. 2, pp. 390-425.

had become the personification of Germanness at a time when the Germans had discovered the gothic as their own, a wellspring of their unifying national character even though political unity eluded them. Dürer *was* the gothic, incorporating the romantic, the rational, and the Christian in one figure. This theme appears in an altar wall designed by Schinkel that graced the auditorium of the *Singakademie* in Berlin for the celebration there (figure 5).[8]

Dürer's larger-than-life statue, modeled after the most famous of his christomorph self-portraits, stands in the middle beneath a large painting of the ascent of Christ into heaven. The seated female figures to his right and left recall his work in the areas of "linear perspective", "painting", "sculpture", and "military architecture", the interrelation of which thematizes the present chapter. Importantly also, Schinkel had no difficulty incorporating the gothic Dürer into his own modernizing neo-classical statuary and frame, for he himself had recently made that transition in his architecture following the War of Independence (1813-15).[9] Schinkel's neo-classicism looked forward, toward an age of technology and industry, and it brought aspects of the Dürer renaissance with it.

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8 Jan Bialostocki, *Dürer and his Critics, 1500-1971: Chapters in the History of Ideas Including a Collection of Texts* (Baden-Baden: V. Koerner, 1986), pp. 121-123; Matthias Mende and Inge Hebecker (eds), *Das Dürer Stammbuch von 1828* (Nürnberg; Carl, 1973), pp. 113-115.

9 The literature on Schinkel is immense but a cogent interpretion is Barry Bergdoll, *Karl Friedrich Schinkel, An Architecture for Prussia* (New York: Rizzoli, 1994).

Figure 5. Karl Friedrich Schinkel, Dürer altar, 1828.

One such aspect was what Berlin artists admired as Dürer's realism, which provided a point of reference for their own realist tradition. That tradition has often been referred back to du Bois's great-grandfather Chodowiecki, whose woodcuts recall Dürer's. Another canonical reference is a sharp critique from Goethe in 1800, who complained that Berlin artists had lost sight of the universal ideals of classical Greece and become mired in provincialism, both historically and geographically: "In Berlin . . . naturalism seems to be at home with the demand for realism and utility and generally to manifest the prosaic Zeitgeist. Poetry is suppressed by history, character and the Ideal by portraiture, . . . and the universally human by nationalism". In response, Gottfried Schadow, sculptor, painter, and soon to be director of the Academy of Art, called on the memory of Chodowiecki and Dürer in defense of a naturalism that mirrored real people with real emotions living in particular locations. In Berlin, he said, "one gives priority to those artworks that truly and honestly depict an existing model; every work of art is treated here as a portrait, a reflection of nature [*Konterfei*]". A representative example is his famous double sculpture of the two princesses (*Prinzessinnen von Preussen*, 1795-97), the future Queen Luise and her sister Fredericke. Regarded as an epitome for German neo-classicism, it presents their teenage beauty in lifelike individual portraits, expressed through the pure lines of universalizing classical purity. The universal lies within the particular, he insisted, and not the particular within the universal.[10]

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[10] Johann Wolfgang Goethe, "Flüchtige Uebersicht über die Kunst in Deutschland", *Propyläen,* 1800, *3*, repr. (Stuttgart; Cotta, 1965), 1065; Johann Gottfried Schadow, "Ueber einige in den Propyläen abgedruckte Sätze Goethes . . . (1801)", *Gottfried Schadow: Aufsätze und Briefe*, ed. Julius Friedländer (Stuttgart; Ebner & Seubert, 1890), pp. 45-55; both in *Kunsttheorie und Kunstgeschichte des 19. Jahrhunderts in Deutschland: Texte und Dokumente*, Vol. 1: *Kunsttheorie und Malerei; Kunstwissenschaft,* eds. Werner Busch and Wolfgang Beyrodt (Stuttgart; Reclam, 1982), pp. 91-100. Schadow's sculptures are depicted and described in *Nationalgalerie Berlin: Das XIX. Jahrhundert: Katalogue der ausgestellten Werke* (Berlin; E.A. Seemann, 2001), pp. 359-363: *Prinzessinnen Luise u. Fredericke von Preussen*, 1795-97, Inv.-Nr. B II 34.

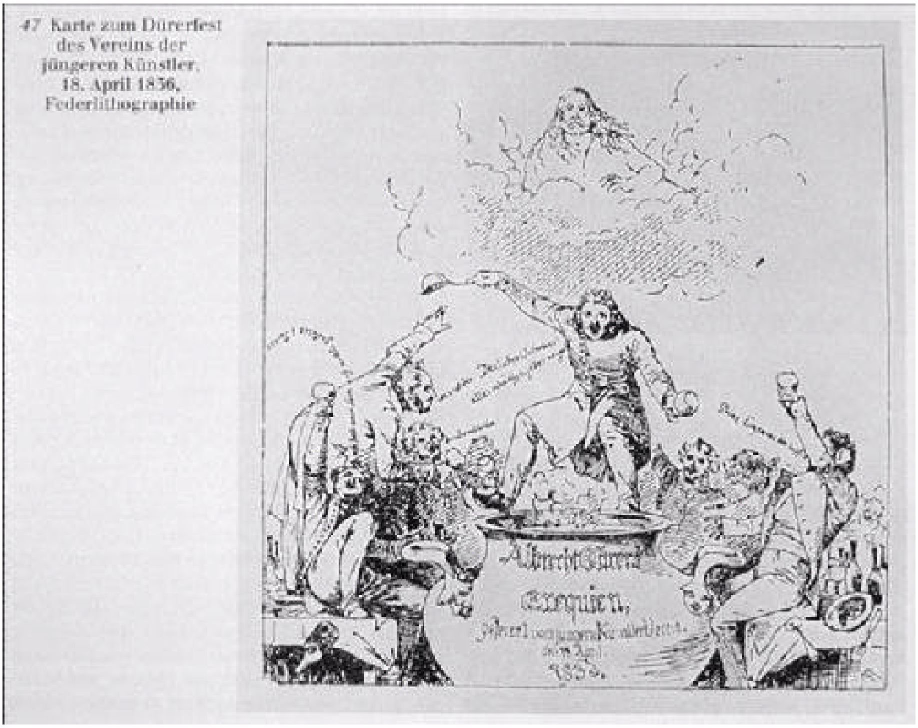

Figure 6. Adolph Menzel, Dürerfest, Union of Younger Artists, 1836

It was Schadow who organized the Dürer celebration in 1828. By that time he had himself become the representative of established academic art. A rather rebellious younger generation had emerged with full self-consciousness, having organized themselves in 1825 into the Union of Younger Artists. But even in their desire for greater freedom, they maintained Schadow's realist principles along with his pursuit of a truly national art, though with less reverence. Dürer remained their spiritual referent and the focus of a raucous yearly party (figure 6). Adolph Menzel joined them in 1834. This invitation card for the Dürerfest of 1836 is one of a series he produced from 1834 to 1837. Godfather Dürer frowns benevolently down from the clouds on his drunken disciples.

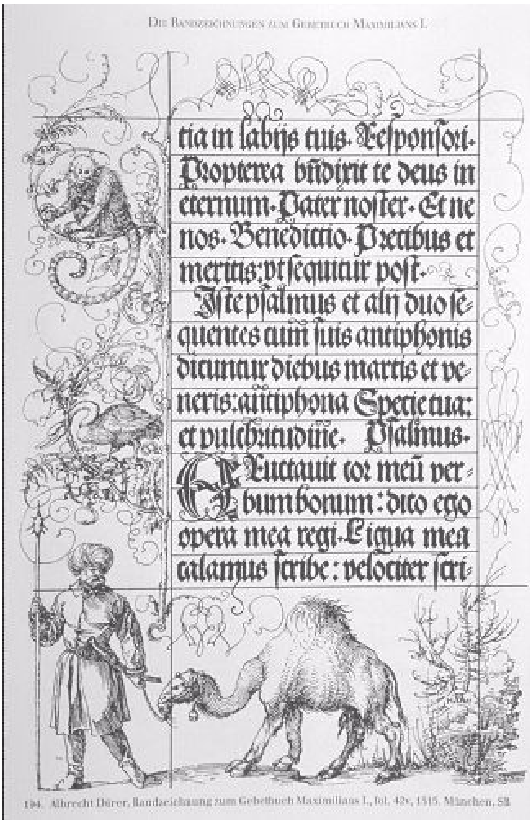

Figure 7. Albrecht Dürer, Prayerbook, 1808.

It is Dürer's line that interests me here. It had become widely available through his famous illustrations for the Prayerbook of Emperor Maximillian I. A lithographic reproduction appeared in 1808 with regular republications afterwards.[11] Dürer's drawings in the margins, exemplified in figure 7, were the focus of attention. The lines of the gothic images metamorphose from one form to another and thence into snorkel-like lines and intricate arabesques. The style found numerous imitators in the 19th century, especially following the 1828 celebrations.[12] Another of Menzel's invitation cards for the annual Dürerfest of the Union of Younger Artists in 1837 gives a

[11] Gebetbuch pub. Info, with lithographic editions of 19th C.

[12] E.g., Eugen Neureuther, *Randzeichnungen zu Goethes Balladen und Romanzen: Baierische Gebirgslieder* (1829-1839; 1855), facsimile of 2nd ed. (Unterschneidheim; Alfons Uhl, 1977). Werner Busch, *Die notwendige Arabeske: Wirklichkeitsaneignnung und Stilisierung in der deutschen Kunst des 19. Jahrhunderts* (Berlin; Mann, 1985), gives a thorough discussion of the arabesque genre, taken in its broadest sense to characterize an era of complexly interwoven modes of literary as well as graphic representation.

typical example (figure 8), here depicting Dürer's funeral with his long-time friend Peuckheimer giving a farewell blessing. Notice how Menzel's line moves smoothly between the plant forms, the written message, and the arabesque at the bottom, which symbollically ties the whole together.

A more elaborate example is the certificate of membership of the Berlin Physical Society (figure 9), which Du Bois-Reymond drew in 1845, organized by the line that metamorphoses from form to form: from the tree with its society of experimenting youth to the arabesque at bottom center, to the writing of Du Bois's name, "Emil Bois" at bottom center, to the name of the engraver, H. R. Heidel at bottom right, who would become an associate member of the Society.[13]

Figure 8. Adolph Menzel, Dürerfest, 1837

Apparently Du Bois conceived his iconography and employed his own line within

[13] Hermann Rudolf Heidel (1811 – 1865), sculptor and draftsman, later a member of the Berlin Physical Society. I thank Gerhard Rupp for information on Heidel.

what had become a popular genre in the Dürer revival, carrying considerable symbolic significance for hopes of rejuvenation of the German nation. It may be indicative of a more direct parallel between Menzel's and Du Bois's images that in 1841 Du Bois founded a similarly progressive group calling itself the Union of Younger Natural Scientists (*Jüngere Naturforscherverein*), whose members would form a nucleus for the Physical Society four years later.[14] Like the Younger Artists and the Younger Natural Scientists, the Physical Society presented itself as a vanguard for this movement into the future. I will return to their means of achieving it below.

Figure 9. Certificate of membership, Berlin Physical Society

[14] Estelle du Bois Reymond, *Jugendbriefe von Emil du Bois-Reymond an Eduard Hallmann* (Berlin; Reimer, 1918), 29 March 1841, p. 86. Finckelstein, *Emil du Bois-Reymond*, p. 213. Ingo Schwarz und Klaus Wenig, eds., *Briefwechsel zwischen Alexander von Humboldt und Emil du Bois-Reymond* (Berlin; Akademie Verlag, 1997), p. 36.

But I want to pursue more deeply the function of Dürer's line. Friedrich Teja-Bach has given an illuminating analysis. He shows the lines and arabesques to be integral to Dürer's theory and practice of drawing. They interpret, so to speak, the naturalistic images of the drawings. Compare in figure 7 the arabesque in the top border with the camel at the bottom. As can be seen by superposition (figure 10), the arabesque provides a kind of paraphrase or epitome of the camel. It consists of a line which gives the basic shape of the camel and then returns to play rhythmically on its own forms in a suggestion of the organic unity of the actual animal and perhaps its rythmic movement.[15]

This example suggests that Dürer's arabesque provides an abstract essence of naturalistic objects and processes. That is, the abstract line represents an ideal form, in the sense of a Platonic idea. That Dürer intended this Platonic reading seems to be unproblematic among art historians. It attains more depth through Teja-Bach's discussion of how Dürer treated his line as a form of writing.[16] While the pictures continue the text allegorically, the snorkel-lines and arabesques write out the pictures in an ideal symbolic form.

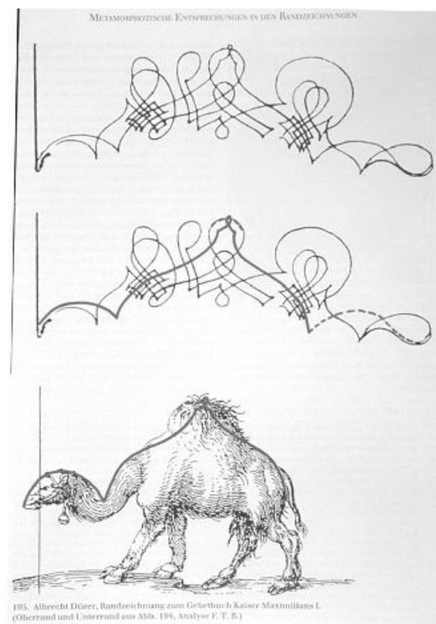

Figure 10. Analysis of Durer's arabesque and camel by Friedrich Teja-Bach.

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[15] Friedrich Teja-Bach, *Struktur und Erscheinung: Untersuchungen zu Dürers graphischer Kunst* (Berlin; Gebrüder Mann, 1996), pp. 165-193; camel, p. 172-173, 177.

[16] Ibid., pp. 282-297.

A similar relation between object, arabesque, and writing is apparent in the drawings of DuBois and Menzel above (figures 7 and 8). The effectiveness of these depictions, however, seems to have depended on other, much more widespread, expressions of the relation between objects and curves. Consider a depiction of "The Origin of Drawing" (figure 11) done in the 1830s by a Professor at the Academy of Art, Johann Erdmann Hummel, who taught architecture, projection, and optics. Hummel's picture continues an origin myth, also often labelled „the origin of painting", which goes back to Pliny the Elder and continued as a literary tradition into the modern period. But it came to be widely represented in drawings and paintings only from about 1770, in close association with neo-classical ideals, as well as with the popular art of the silhouette and Johann Caspar Lavater's *Physiognomische Fragmente*, illustrated by Chodowiecki.[17] At least six of these allegorical depictions were produced by a lineage of Berlin artists: Christian Bernhard Rode (1790), Schadow (1804), Franz Ludwig Catel (1806), Schinkel (1830), Hummel (1830s), and Wilhelm Eduard Daege (1834).[18] As the story goes, a Corinthian maid named Dibutades, whose young lover had to depart on a long journey the following day, was

[17] Robert Rosenblum, "The Origin of Painting: A Problem in the Iconography of Romantic Classicism", *Art Bulletin,* 1957, *39*:279-290, discusses both linearity and silhouettes. Frances Muecke, "'Taught by Love': The Origin of Painting Again", *Art Bulletin,* 1999, *81*:297-302. I thank Claudia Swan for discussion and references.

[18] Hans Wille, "Die Erfindung der Zeichenkunst", in *Beiträge zur Kunstgeschichte: Eine Festgabe für H. R. Rosemann*, ed. Ernst Guldan (Munich; Deutscher Kunstverlag, 1960), pp. 279-300, who shows a different version of Hummel's drawing, dated 1834, and does not mention Daege. *K. F. Schinkel: Architektur, Malerei, Kunstgewerbe* (Berlin, 1981), catalogue no. 207a, p. 267. Wilhelm Eduard Daege in *Nationalgalerie Berlin*, Inv.-Nr. A I 216.

inspired to outline his shadow on the wall in order to keep his image clearly before her during his absence. Thus drawing and painting originated in love. Her father Butades, being a potter, filled the silhouette with clay and fired it in his kiln, producing a permanent image.

Figure 11. Johann Erdmann Hummel, Origin of Drawing, 1835.

In the neo-classical aesthetics of the late Enlightenment and Romanticism the story had particular relevance because it gave such prominence to the firmly drawn line, as opposed to color, as the foundation of art. This emphasis was appropiately figured in all of the „origin“ drawings and paintings as the line of the silhouette obtained by linear projection. Sharp outlines and smooth surfaces, symbolized definiteness, unity, and above all, rationality.

Hummel's rendering, while maintaining the ideals of neo-classicism, transforms both the story of Dibutades and the genre of depictions based on it. Normally the potter Butades did not actually appear at all. And if he had, he would have been producing a flat clay model of the silhouette of Dibutades' lover. Here his role is both prominent and different. He is engaged in his everyday work of producing large numbers of vases, all with the same classical form, which we see his assistant arranging on drying racks in the background. The origin of drawing is now manifested in the potter's sharp-eyed concentration on the relation of his daughter's drawing hand to his own shaping hand, the relation of the artist to the craftsman. Just as Dibutades' line captures the visual essence of her lover, so a similar line becomes the materialized essence of Butades' vase, whose classical silhouette he shapes in the clay as it rotates on the potter's wheel.

Hummel thus closely juxtaposes the work of art with craft manufacture and connects them through the classical line. His metaphorical picture also seems to depict his teaching of projective drawing at the Academy of Art, where he promoted the training of the mind through the hand and eye. A grasp of the basic principles of geometrical projection acquired through „numerous examples and drawings" lay behind the capacity to render correctly, as though by second nature, the realistic effects of light and shadow. "Through industrious exercise", he said, "the mind as well as the eye becomes practiced in correctly conceiving the appearances in nature and in making the laws on which they rest more intuitively apparent [*anschaulicher*]".[19] This view of *anschaulich* representation of laws as curves begins to get to the heart of the present paper.

To see Hummel's conception of the potter's curve in relation to practical use, one need only look at drawings that Schinkel and Beuth published as *Prototypes for Manufacturers and Craftsmen* for students at Beuth's *Gewerbe-Institut* (figure 12). The collection constituted a kind of canon of aesthetic forms, all classical, for the consumer goods of bourgeois life: tableware, wallpaper, fences, furniture, and architectural ornamentation. It formed part of a widespread attempt to elevate public taste and civic virtue through the artistic quality of the material environment within which the citzens of a modern state would live their lives. As shown for the elegantly simple vases, the *Prototypes* made quite explicit the sought-after relation between ideal curves and manufactured

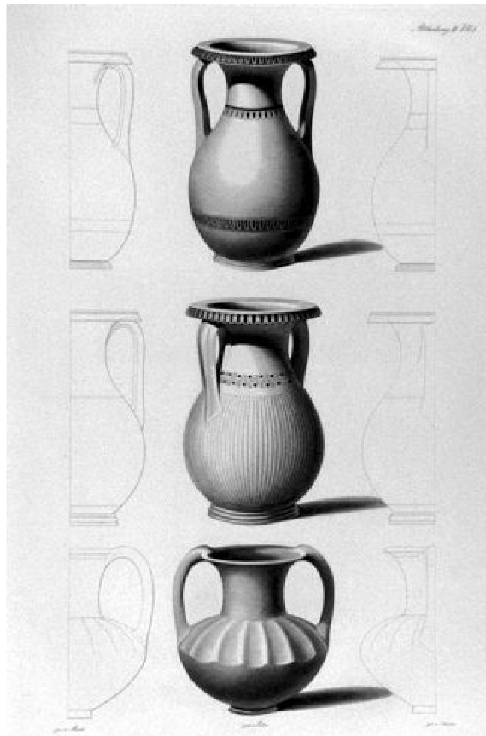

Figure 12. P. C. W Beuth & K. F. Schinkel (eds), Prototypes for Manufacturers and Craftsmen, 1821

[19] Johann Erdmann Hummel, *Die freie Perspektive erläutert durch praktische Ausgaben and Beispiele, hauptsächlich für Maler und Architekten*, 2 vols. (1823; 1825), 2nd ed. (Berlin; Herbig, 1833), *vol. 1*, pp. vii-viii. See also, Hummel, *Geometrisch-praktische Construction der Schatten für Architekten und andere zeichnende Künstler* (Berlin; Herbig, 1842).

objects.[20] The collection as a whole emphasizes not only the smoothly flowing lines but also the familiar harmonic and periodic curves employed for cornices, decorative borders, fences, and wallpaper.

Importantly, Schinkel and Beuth make no distinction in their Prototypes between craft and machine manufacture, even though Beuth served as the most prominent promoter of industrial machinery in Prussia.[21] Indeed, with few exceptions, manufacture remained craft work, even when carried out with machines. More generally, the age of machine manufacture had not yet come to be seen as a tasteless era of „mechanical reproduction“ but rather as an era in which a broader cross-section of society could share in the great neo-humanist project of personal self-realization (*Bildung*) and cultivation through the universal forms of classical art and architecture.

The project did not stop with students at the *Gewerbeinstitut* and *Bau-Akademie* but extended directly to Industry itself through such organizations as Beuth's Union for the Advancement of Industry (*Verein zur Beförderung des*

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[20] Technische Deputation für Gewerbe [P. C. W. Beuth and K. F. Schinkel] (eds.), *Vorbilder für Fabrikanten und Handwerker*, (Berlin, 1821). Conrad Matschoss, *Preußens Gewerbeförderung und ihre grossen Männer, dargestellt im Rahmen der Geschichte des Vereins zur Beförderung des Gewerbefleißes 1821 – 1921* (Berlin; Verein Deutscher Ingenieure, 1921), gives extensive discussion of Beuth's activities in promoting industry. See also Matschoss, "Geschichte der Königlich Technischen Deputation für Gewerbe. Zur Erinnerung an das 100 jährige Bestehen. 1811-1911," *Beiträge zur Geschichte der Technik und Industrie. Jahrbuch des Vereines deutscher Ingenieure*, 1911, *3*:239-275, esp. 239-250.

[21] Dierig, "Apollo's Tragedy", (cit. n. 7). The students trained in the crafts at the Gewerbe-Institut, with courses in drawing, modeling, and the natural sciences, fit more nearly the model of Halske than of traditional craftsmen. They were groomed to play an entrepreneurial role.

Gewerbefleisses), the pendent to the *Gewerbeinstitut*. Its membership placed craftsmen and entrepreneurs alongside professors, artists, and state administrators. Specifically, while Schadow, Schinkel, and Rauch all participated on the administrative committee for Architecture and Fine Art, Hummel's brother Caspar, a mechanic and founder of a machine factory in Berlin, served with other shopowners, professors, and state administrators on the corresponding committee for Mechanics and Mathematics.[22]

Geometrical Realism

Having observed some of the ways in which curves were seen to capture essences in both theoretical and practical terms, I want to return to Hummel's "Origin of Drawing" (figure 11) to raise a closely related subject, to which Dürer's name had been attached since the 16th century: geometrical drawing and perspective, but in the new 19th century form of projective geometry. It will be apparent that Hummel places the origin of the classically curved but otherwise arbitrary lines of drawing within a highly mathematized space, ruled by linear perspective and by the linear projection of shadows cast by the oil lamp of enlightening antiquity. As professor of architecture, projection, and optics at the Academy of Art, Hummel specialized in producing such constructions in ever

[22] *Verhandlungen des Vereins zur Beförderung des Gewerbefleisses* (1822), 13.

more intricate detail, using multiple lighting sources, multiple mirrors, and multiple perspective.

Hummel received high praise from the critics for the extraordinary optical effects that he was able to incorporate in a fully natural manner. For this period, artistic sensibilities in Berlin cohered rather well with geometrical precision in drawing. Architectural realism in painting, for example, characterized not only the works of Schinkel but of well-known painters like Franz Krüger and Eduard Gaertner. Gaertner's "Klosterstrasse" (figure 13), almost photographic in detail, appeared in an engraved version for a great collection in Nürnberg, contributed by artists from all over Germany to honor Dürer.[23] With its depiction of Beuth, Schinkel, Gaertner, Krüger, and Rauch in the street in front of the *Gewerbeinstitut*, it suggests how closely related were the fine and manual arts in Berlin. One specific vehicle for this (partial) convergence in technique was the teaching of projective geometry — Hummel's subject — to students of art, engineering, and technology alike, from the *Kunstakademie*, to the *Bauschule*, to the military schools.

The subject came to Berlin largely as an import from France during and after Napoleon's occupation and followed the mathematical theory and practices of the engineers, Monge, Dupin, and Poncelet (though Hummel preferred the techniques of the earlier Berlin mathematician, Johann

[23] Eduard Gaertner, *Klosterstraße*, engraving, 1830, in Mende and Hebecker, *Dürer Stammbuch von 1828*, (cit. N. 8), p. 152. The Stammbuch continued to grow for several years after 1828.

Heinrich Lambert).[24] At the technical schools, both civilian and military, projective geometry provided part of the foundation for subsequent courses in mathematics and mechanics, as well as drawing.

Figure 13. Eduard Gaertner, Klosterstrasse, Berlin, 1830

A good example comes from Du Bois Reymond's closest friend during his youth, Anton Hallman. Figures 14a,b suggest the transition from student exercises in projective

[24] Lorraine Daston, "The Physicalist Tradition in Early Nineteenth Century French Geometry", *Stud. Hist. Phil. Sci.*, 1986, *17* :269-295, offers a good introduction to the subject. Ken Alder, "Making Things the Same: Representation, Tolerance and the End of the *Ancien Régime* in France," *Social Studies of Science*, 1998:*28*, 499-545, places projective geometry among a differentiated set of attempts to attain a perspectival representation, or mechanical objectivity, pp. 513-518. This reading would be too mechanical for the Berlin artists, architects, and engineers discussed here.

geometry to a fully realized artist's drawing in the architectural realist style of a Krüger or Gaertner. Interestingly, Hallman learned his projective geometry at the *Artillerieschule* in Hannover.[25]

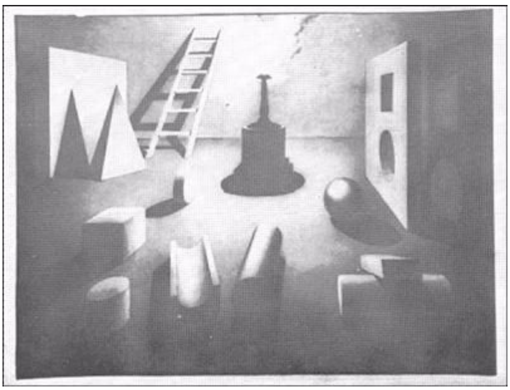

Figure 14a. Anton Hallmann, studies of projective geometry

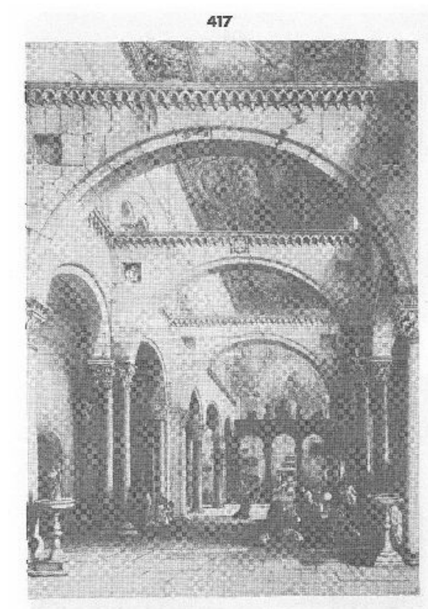

Figure 14b. Anton Hallmann, studies of projective geometry

Werner Siemens provides another marker for this movement in his study of projective geometry with Captain Meno Burg at the Artillery and Engineering School in Berlin,

[25] Sabine Fehlemann, *Der Maler-Architekt Anton Hallmann, 1812-1845. Leben und Werk mit einem Oeuvre-Verzeichnis* (Diss., Munich, 1974). Dierig, "Apollo's Tragedy", (cit. n. 7), and Sven Dierig and Thomas Schnalke, *Apoll im Labor: Bildung, Experiment, mechanische Schönheit*, exhibition catalog (Berlin: Berliner Medizinhistorisches Museums der Charité, 2005), pp. 39-64.

which he attended from 1835 to 1838. Like Hummel at the *Kunstakademie*, Burg presented projective geometry as the vehicle for learning to produce correct representations according to "mathematical laws". Again like Hummel, Burg couched this mathematical ideal in the all-important language of neo-humanist *Bildung* — self-realization, creative action, reaching the inner form of things — all expressed through the properly expressive line:

> The draftsman must create out of himself . . . and, in using the forms and measures that have been given to him, become capable of allowing the picture, in its outlines and in its inner forms, gradually to emerge in lines.[26]

Burg's students at the Artillery and Engineering School, like Hummel's at the Academy of Art, could reach beyond mechanical reproduction to an authentic creative work only through extensive theoretical and practical exercise with the mathematical laws of projection, until these laws became expressions of the self, even in a drawing by Lieutenant Siemens of a cannon being placed on a wall, shown at the annual exhibition of the Academy of Art in 1838 with the title "Part of a wall with a windlass and 12 pound cannon."[27] Here was an aesthetics for a particular time and place. What may look today like „mechanical drawing" was in

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[26] M. Burg, *Geschichte meines Dienstlebens* (1847), 3rd ed. (Leipzig: Kaufmann, 1916), pp. 71-75, paraphrasing his original memorandum of 1816. On Burg and his geometrical drawing, see also, Kathryn Olesko, *Precision in German Society, 1648-1989* (in preparation), ch. 6, "Aesthetic Precision".

[27] Siemens' drawing is listed in Helmut Börsch-Supan, ed., *Die Kataloge der Berliner Akademie-Ausstellungen 1786-1850*, 2 vols. & *Registerband* (Berlin: Bruno Hessling, 1971), 1838, no. 908.

the eyes of the Berlin drawing instructors a path toward attaining *Bildung* and an aesthetics for the modern world.

Had Werner Siemens had the financial means to study at the School of Civil Engineering and Architecture (*Bauschule*), as he had wished, he might have learned his projective geometry from none other than the precocious young mathematician Gustav Lejeune Dirichlet, already a member of the Academy of Sciences and associate professor at the University, although his primary teaching duties were at the War College (*Kriegschule*), where he included project-tive geometry in the first year of a three year sequence. Dirichlet also taught projective geometry for the *Bauschule*, with classes meeting at the *Gewerbeinstitut*, in 1835. Earlier, the instructor was another university professor, Martin Ohm, a serious mathematician himself and brother of Georg Simon Ohm of Ohm's-law fame.[28] That such high-powered analysts were teaching projective geometry to architects and civil engineers, military officers, and future technological entre-preneurs speaks once again to the perceived centrality of the subject and to its role as a medium of exchange — both aesthetically and practically — circulating through the fine arts, modern industry, and the mathematical sciences in a culture obsessed with neo-humanist and neo-classical ideals.

[28] E. Lampe, "Dirichlet als Lehrer der Allgemeinen Kriegsschule", *Naturwissenschaftliche Rundschau*, 1906, *2:*482-485. Eduard Dobbert and Alfred G. Meyer, *Chronik der königlichen technischen Hochschule zu Berlin: 1799-1899* (Berlin: Wilhelm Ernst & Sohn, 1899), pp. 43, 48.

The Mathematics of Curves

The widespread teaching of projective geometry begins to suggest why the progressive young men of the Berlin Physical Society might have been particularly interested in the role of curves in the sciences. But it does not yet suggest how they learned to connect the irregular curves of nature's reality with the highly *regular* idealized forms of geometry. It was a longstanding problem. Dürer himself had worked on it with little success. Without going into the long history of the problem, it will be useful here to describe briefly the new approach followed by Dirichlet and Ohm.

While Dirichlet was teaching at the military and technical schools, as well as the University, he was also developing the methods of mathematical analysis that initially won him his fame. Most important for physical scientists was a rigorous proof, first presented in 1829, of the generality of the recent discovery by the French engineer and mathematician Joseph Fourier that many mathematical functions could be represented as an infinite sum of sine and cosine functions, or „Fourier series", of which the harmonic vibrations of a violin string are a familiar example.[29]

Fourier used such series primarily to solve problems in heat conduction, published in 1822 as the *Analytical Theory of Heat*. Dirichlet studied in Paris from 1822-26, where Fourier became his mentor, and when he arrived in Berlin in

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[29] G. Lejeune Dirichlet, "Sur la convergence des séries trigonométriques qui servent a représenter une fonction arbitraire entre des limites données", Crelle's *Journal für die reine und angewardte Mathematik, 4* (1829), 157-169, in *G. Lejeune Dirichlet's Werke* , 2 vols (Berlin; Reimer, 1889 & 1897), Vol.*1*: 118-132.

1828 he continued work on Fourier series. Without entering on the technical treatment, it is correct to say that Dirichlet established the validity of the Fourier series representation for a very broad class of functions of interest in the physical world, so broad that they exceeded the confines of functions that could be expressed in algebraic form. Throughout the great flowering of analytic mathematics, from D'Alembert and Euler through Lagrange and even Cauchy in Dirichlet's own time, the generality of mathematical analysis and its use in analyzing physical problems continued to run up against the view that a valid function ought to obey an algebraic law. For this and related reasons, Fourier analysis continued under a mathematical cloud even after its use in physics had begun to spread.[30]

In 1837 the Berlin physicist Heinrich Wilhelm Dove inaugurated the annual review *Repertorium der Physik*. Although the review would deal primarily with experimental physics, as did Dove himself, he had invited Dirichlet to join the editorial consortium as the representative for mathematical physics. For the first volume, Dirichlet chose to present his most important results on Fourier series, since, as he put it, „The peculiar series, which represent functions in a definite interval and which are entirely without law or follow entirely different laws in different parts of this interval, have found . . . numerous applications in the analytical treatment

[30] Ivor Grattan-Guinness, *The development of the foundations of mathematical analysis from Euler to Riemann*, (Cambridge; MIT, 1970).

of physical problems."[31] Through the *Repertorium* Dirichlet reached a very broad audience of experimental as well as mathematical physicists with his message, which deserves reiteration in terms of curves.

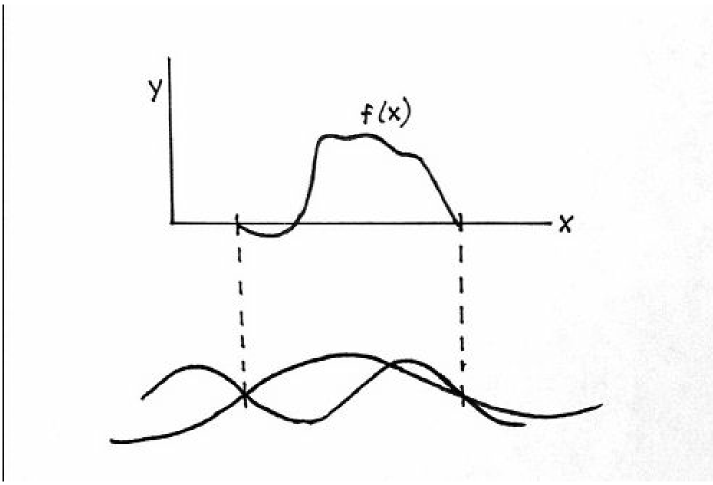

Figure 15. G. Lejeune Dirichlet, Function as curve (top) and harmonic analysis (down), 1837

He argued, first of all (figure 15 – top), that a mathematical function — more specifically, a single-valued function, whether continuous or discontinuous — need conform to no algebraic expression at all, no law, as he put it, but could be defined geometrically, as any freely-drawn curve: "This definition ascribes to the individual parts of the curve no general law; one can think of it as compounded of the most diverse parts or as drawn entirely without law."[32] For

[31] G. Lejeune Dirichlet, "Ueber die Darstellung ganz willkührlicher Funktionen durch Sinus- und Cosinusreihen", *Repertorium der Physik*, 1837, *1*:152-174, on p. 152.

[32] Ibid., p. 153.

physicists, this meant that if any such curve could be obtained empirically, say as data from an experiment, it constituted a valid mathematical function (e.g., displacement of an elastic string, temperature distribution in a bar). Secondly (figure 15 – down), such curves could be analyzed mathematically by representing them as Fourier series, as sums of simple waves with different wavelengths and amplitudes. Thereby, the most non-lawlike looking curve could be analyzed into the simplest of harmonic laws, often taken to represent the underlying rhythms of nature.

It is difficult to overemphasize the importance of this result for the history of physics at the time. In a most lucid and accessible way, it turned a whole range of purely experimental physics into mathematical physics through the curve, at least in principle. So enthusiastic was Bernhard Riemann, who studied with Dirichlet in Berlin from1847 to 1849 and wrote his *Habilitationschrift* of 1854 on Fourier analysis, that he claimed Dirichlet's results covered „all cases in nature . . . for however great our uncertainty concerning how the forces and conditions of matter change in space and time in the realm of the infinitely small, we can nevertheless safely assume that the funtions to which Dirichlet's investigations do not reach, do not occur in nature."[33]

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33 Bernhard Riemann, "Ueber die Darstellbarkeit einer Function durch eine trigonometrische Reihe" (Habilitationschrift, 1854), *Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen, 13* (1854), in *Bernhard Riemann: Gesammelte mathematische Werke,* eds. Heinrich Weber u. Richard Dedikind (eds), reedited by Raghavan Narasimhan (Berlin; Springer, 1990), pp. 227-264, on p. 237; also quoted in H. Koch, "Gustav Peter Lejeune Dirichlet", in *Mathematics in Berlin,* eds. H. G. W. Begehr, *et. al.*, Berlin; Birkhauser, 1998), pp. 33-48, on p. 37.

A second person who brought Fourier analysis to the attention of a broad audience in Berlin was Georg Simon Ohm, who had actually taught Dirichlet as a Gymnasium student in Cologne. Ohm moved to Berlin in 1826 to complete his now classic book on the electric circuit and then took up a part-time position at the War College for five years, where Dirichlet was also teaching. Ohm is known today largely for Ohm's law, which says that the current I through any section of a circuit is proportional to the electrical tension E (potential difference) across the section divided by its resistance R, or $I = E/R$. Ohm himself expressed a more general time-dependent relation for the electric potential at any point, closely resembling Fourier's differential equation for the temperature in a bar conducting heat. Drawing on this analogy with heat conduction, Ohm solved the equation for electric potential with a Fourier series. Although Ohm himself supplied no illustrations of curves, his results showed once again the great power of the harmonic decomposition as an expression of physical processes.[34]

I will not pursue further either Fourier analysis or Ohm's work except to note that in the 1840's the members of the Berlin Physical Society would adopt Ohm, whose work had been only slowly recognized, as one of their heroes in the cause of rigorous experimental and mathematical science. His analysis of the physics of hearing, based on the assumeption that the ear behaves essentially like a Fourier analyzer, so that we hear only the harmonic components of any com-

34 Georg Simon Ohm, *Die galvanische Kette, mathematisch bearbeitet* (Berlin: Riemann, 1827), reprint with commentary by Lothar Dunsch (Berlin: Verlag der Wissenschaften, 1989), pp. 170-176.

plex sound wave, stimulated a long-standing debate over combination tones, including Helmholtz's well-known work from the mid-fifties on combination tones and on the sensations of tone.[35] Fourier analysis had by then become a pervasive tool of mathematical physics.

Return now to Dove, who had published Dirichlet's review article in his *Repertorium*. In the 1830s and 40s Dove was omnipresent in Berlin education. In addition to teaching physics at the University, where du Bois-Reymond attended his lectures, Dove taught at various times at the *Friedrich-Wilhelms-Institut* for army doctors, where he was among Helmholtz's teachers, the *Kriegschule* (where he lived with his family), the *Artillerie*- und *Ingenieur-Schule*, and at one or more *Gymnasia*, including the *Friedrich-Wilhelms-Gymnasium*, where his geometry course included exercises in geometrical drawing.[36] He was also one of the pioneers in Berlin of the use of curves to represent physical laws,

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[35] R. Steven Turner, "The Ohm-Seebeck Dispute, Hermann von Helmholtz, and the Origins of Physiological Acoustics", *British Journal for the History of Science*, 1977, *10*:1-24. Myles Jackson, *Harmonious Triads: Physicists, Musicians, and Instrument Makers in Nineteenth-Century Germany* (Cambridge, MA: MIT Press, 2006), ch. 6. Georg Simon Ohm, "Ueber die Definition des Tones, nebst daran geknüpfter Theorie der Sirene und ähnlicher tonbildender Vorrichtungen", *Annalen der Physik und Chemie*, 1843, *59*:513-65; and "Noch ein Paar Worte über die Definition des Tones", *Annalen der Physik und Chemie*, 1844, *62*:1-18; both in *Gesammelte Abhandlungen von Georg Simon Ohm*, ed. E. Lommel, (Leipzig, 1892), 587-633, 634-649. Hermann von Helmholtz, "Ueber Combinationstöne," *Annalen der Physik und Chemie*, 1856, *99*:497-540; in *Wissenschaftliche Abhandlungen von Hermann Helmholtz*, 3 vols (Leipzig: Barth, 1882), Vol. I: 263-302.

[36] Hans Neumann, *Heinrich Wilhelm Dove: Eine Naturforscher-Biographie* (Liegnitz; Krumbhaar, 1925), pp. 13-14. Gymnasium courses in *Programmschrift, Königlichen Friedrich-Wilhelms-Gymnasium* (Berlin, 1838), pp. 53-60.

especially laws that seemed to defy mathematical expression. This work connected his interests directly to Dirichlet's.

Already in his first publication as a newly habilitated *Privatdocent* in Berlin, „Meteorological Investigations of the Wind" (1827), Dove sought to show that the direction of the wind, which appeared to change so arbitrarily „that people had given up trying to discover anything lawlike in it," actually obeyed a regular law that could be revealed by barometric observations. On the basis of published measureements taken over 10 years in Paris, he succeeded in representing the average yearly barometric pressure (and temperature and humidity) as a periodic function *b(x)* of the direction of the wind *x*, from 0° to 360° around the compass,[37]

$$b(x) = a - c \sin (x + a),$$

where *a* and *c* are constants and a is a phase angle. Although Dove did not publish the curves for his laws, he suggested that the reader should construct them from his tables to actually see the cycles of pressure, temperature, and humidity as the wind moved around the compass.[38] It will be apparent why Dove would have been interested in publishing Dirichlet's proof of the validity of Fourier analysis of empirical curves.

These examples from Dirichlet, Ohm, and Dove, and the importance they took on for the members of the Berlin Physical Society, might be thought of simply in terms of the

[37] Heinrich Wilhelm Dove, "Einige meteorologische Untersuchungen über den Wind", *Annalen der Physik und Chemie,* 1827, *11*:545-590, on 545, 550. Revised version in H.W. Dove, *Meteorologische Untersuchungen* (Berlin; Sander'schen Buchhandlung, 1837), pp. 97-120.

[38] Dove, "Einige meteorologische Untersuchungen", pp. 585, 590.

practical utility of harmonic decomposition of processes occurring in nature. But when correlated with the related practices in projective geometry and neo-classical art, they suggest again that the anschaulich representation of laws in terms of lines and curves had rather broad circulation in Berlin culture.

Alexander von Humboldt: Patron of the Curve

If by 1840 Dove and Dirichlet represented the pinnacle of current practice in the physical and mathematical use of curves, there stood behind them, both intellectually and politically, a patron of enormous prestige, Alexander von Humboldt. As noted previously, Humboldt had returned to his native Berlin in 1827 after twenty years in Paris, where he published the grand volumes that contain the scientific account of his travels in South America and Mexico with Aimé Bonpland from 1799 to 1803. A favorite of King Friedrich Wilhelm III, Humboldt had officially held the title of Chamberlain since 1805 and returned to Berlin at the king's insistence to take up his duties, with an enhanced salary of 5000 thaler. He returned like a modern Columbus. His lectures at the University and at the *Singakademie* in 1827-28 — overlapping with the Dürerfest, also at the *Singakademie* — made him a sensation in Berlin society and laid the foundation for perhaps the most popular scientific book of the 19th century, his five-volume *Kosmos* (1845-1862).[39]

Not so well known is that images of lush tropical landscapes from his Vues des *Cordillieres* (1810) and of mysterious peoples associated with them had already become familiar to Berlin opera-goers in the scenery that Schinkel designed for Goethe's *Magic Flute* (1816) and for a series of other operas: Handel's *Athalia* (1817), Spontini's *Fernand Cortez* (1818), Rossini's *Armida* (1820) and especially Spontini's *Nurmahal*, which complemented Humboldt's popular lectures of 1828.[40] Images of exotic lands and peoples thus surrounded Humboldt's popular persona as he went about establishing his scientific presence. The famous lectures at the *Singakademie* were followed by an epochal meeting in Berlin of the Union of German Scientists and Doctors (*Verein deutscher Naturforscher und Ärzte*), which Humboldt organized with his longtime friend, the professor of zoology Heinrich Lichtenstein. Since they aimed to instill a new sense of pride and confidence among German scientists, staging was important. With Schinkel's help, he employed some of the same sort of operatic scenery that already carried his

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39 Publication details in Hanno Beck, ed., "Zu dieser Ausgabe des *Kosmos*,“ in Alexander von Humboldt, "*Kosmos“: Entwurf einer physischen Weltbeschreibung*, vol 7(2) of *Alexander von Humboldt: Studienausgabe,* ed. Hanno Beck (Darmstadt: Wissenschaftliche Buchgesellschaft, 1993), p. 355.

40 Humboldt, *Vues des cordillières,* e.g, plates 31, 33, 41-42, 63. Ulrike Harten, ed., *Die Bühnenentwürfe*, vol. 17 of *Karl Friedrich Schinkel, Lebenswerk*, eds. Helmut Börsch-Supan u. Gottfried Riemann (Munich & Berlin: Deutscher Kunstverlag, 2000), pp. 132-135, 228, 233-35, 237, 266, 271, 274, 340. Friedrich Muthmann, *Alexander von Humboldt und sein Naturbild im Spiegel der Goethezeit* (Zürich; Artemis, 1955), pp. 91-102. See also M. Norton Wise and Elaine M. Wise, "Staging an Empire", in *Things that Talk,* ed. Lorraine Daston (Cambridge; Zone Books, 2003), pp. 100-145, esp. 137-144.

popular image. For a celebratory evening session, held in one of Schinkel's greatest buildings, the *Schauspielhaus*, with Humboldt himself as the featured speaker and with King Friedrich Wilhelm III in attendance, Schinkel adapted his earlier Queen-of-the-Night scene from The Magic Flute for a backdrop. Like stars in the heavens above Zoroaster's temple, the names of famous Germanic scientists shined down on their earthly heirs. Music too enhanced the unifying spirit of the evening, including a choral piece composed at Humboldt's request by the precocious young Felix Mendelssohn-Bartholdy, one of the talented family of Abraham Mendelssohn-Bartholdy, at whose home Humboldt was a welcome guest.[41]

As the cultural life of the city shaded seamlessly into the life of science, Humboldt went about promoting the first-class research structures that he envisaged for Berlin, drawing heavily on his personal relationship with the King, with several of his Ministers, and with numerous friends throughout Berlin society.[42] He recruited young talent where-

41 A. v. Humboldt and H. Lichtenstein, *Amtlicher Bericht über die Versammlung deutscher Naturforscher und Ärzte zu Berlin im September 1828* (Berlin; Trautwein, 1829), 19 (schematic order of names for the backdrop). Paul Ortwin Rave, *Karl Friedrich Schinkel. Berlin, dritter Teil: Bauten für Wissenschaft, Verwaltung, Heer, Wohnbau und Denkmäler* (Berlin; Deutscher Kunstverlag, 1962), 363 (drawing of the hall with backdrop in the *Schauspielhaus*). See also Myles W. Jackson, "Harmonious Investigators of Nature: Music and the Persona of the German *Naturforscher* in the Nineteenth Century", *Science in Context*, 2003, *16*:121-145, who gives a fascinating account of the role of music among the *Naturforscher*, especially at the Berlin meeting, and whom I thank for very helpful discussions. We differ on whether the Schinkel backdrop was at the *Singakademie* or the *Schauspielhaus*.

42 Humboldt's promotional efforts are best captured in the collections of his letters published by the Akademie der Wissenschaften, e.g., Kurt-R. Biermann, ed., *Alexander von Humboldt. Vier Jahrzehnte*

ver he saw it, including the newly arrived Dirichlet and Dove. Almost immediately he set up a magnetic observatory to extend earlier work from 1806-7, recording hourly and daily variations in the direction of the earth's magnetic field. For the purpose, Abraham Mendelssohn-Bartholdy offered the large garden of the family home, while the ubiquitous Schinkel contributed the design for a small iron-free observing house. Around this small observatory, linked through Humboldt's promotional activities into an international network of similar sites taking corresponding observations, the charismatic organizer attracted the young physicists and mathematicians of Berlin: Dirichlet, Dove, Magnus, Encke, and Poggendorf, among others. It was Dove who proudly took charge of publishing their results of 1829-30, represented graphically in sixteen plates of curves of magnetic declination, comparing the Berlin observations with simultaneous readings from the string of observatories from South America to Russia.[43]

Humboldt's own use of curves was already well-established. Famous are his „physiognomic“ projections of landscapes in South America and Mexico. In their simplest form they were vertical cuts, yielding a silhouette of rising and falling elevations over mountains, plateaus, and valleys,

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Wissenschaftsförderung. Briefe an das preußische Kultusministerium, 1818-1859 (Berlin; Akademie-Verlag, 1985).

43 Alexander von Humboldt, "Ueber die Mittel, die Ergründung einiger Phänomene des tellurischen Magnetismus zu erleichtern", *Annalen der Physik und Chemie*, 1829, *91*:319-336, on p. 333. H. W. Dove, with a forward by A. v. Humboldt, "Korespondierende Beobachtungen über die regelmässigen stündlichen Veränderungen und über die Perturbationen der magnetischen Abweichung im mittl. und östl. Europa“ *Annalen der Physik und Chemie*, 1830, *19*:357-391. H. W. Dove, *Gedächtnissrede auf Alexander von Humboldt* (Berlin; F. Dümmler, 1869), pp. 22-23.

from which much could be read about the character of the landscape and the culture that inhabited it.[44] In the more elaborate form of the „physiognomy of plants" Humboldt inscribed characteristic species on his vertical projections as well as on the more usual surface projections, yielding changing zones of vegetation with changing elevation, latitude, and longitude. Through physiognomy, he sought not a botanist's taxonomic classification of the vegetation but rather "that through which its mass individualizes the total impression of a region."[45] From this painterly analysis he identified eighteen main forms of plants characteristic of different climate zones, from the tropics to northern latitudes and from sea level to the tops of mountains.

Importantly for the present discussion, and as Michael Dettelbach has persuasively argued, Humboldt's aesthetically inspired physiognomy of plant zones cannot be split off from his equal emphasis on precision measurement of physical quantities: temperature, pressure, altitude, and magnetic parameters. In fact, for Humboldt, quantitative mapping was precisely what would reveal the qualitative landscape. This passage between quantitative and qualitative is particularly

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44 On Humboldt's physiognomic vision see Michael Dettelbach, "The Face of Nature: Precise Measurement, Mapping, and Sensibility in the Work of Alexander von Humboldt," *Studies in History and Philosophy of Biological and Biomedical Sciences*, 1999, *30*:473-504.

45 Alexander von Humboldt, *Ideen zu einer Physiognomik der Gewächse* (1806), republished (with extensive notes) in Humboldt's *Ansichten der Natur*, 3rd ed. (1849), reprinted in Beck, *Studienausgabe*, vol. 5: *Ansichten der Natur* (1987), (cit. n. 40), p. 184. Humboldt's physiognomic perspective attained its most extensive form in A. v. Humboldt and A. Bonpland, *Ideen zu einer Geographie der Pflanzen nebst einem Naturgemälde der Tropenländer* (1805-1807), in Beck, *Studienausgabe*, vol. 1: *Schriften zur Geographie der Pflanzen* (1989), (cit. n. 40), 43-161.

apparent in the curves with which he attempted rigorously to define the distribution of climatic zones over the surface of the earth. His pathbreaking „isothermal lines“ of 1817 were curves of constant annual mean temperature mapped over the northern hemisphere for both surface position and mountain elevation (figure 16).[46] For Humboldt the isothermal lines continued to express the physiognomy of nature, a concept that included both art and science, somewhat like projective geometry.

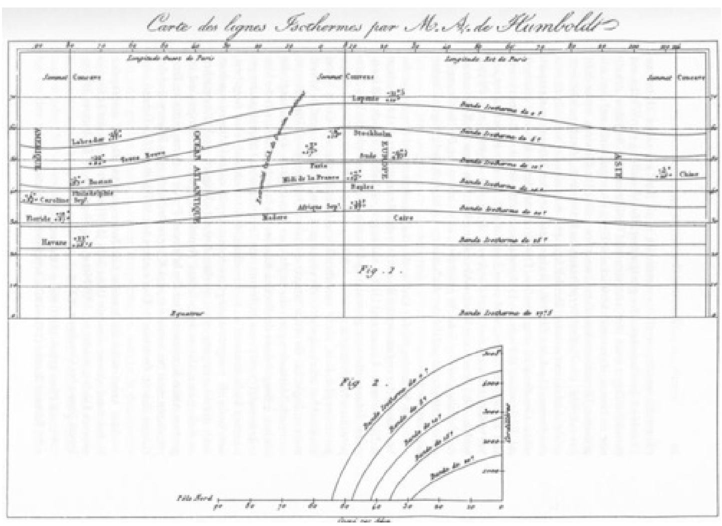

Figure 16. Alexander von Humboldt, Isothermal Lines, 1817.

By the time he arrived in Berlin, Humboldt envisaged a much broader program to incorporate variations over time

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[46] Dettelbach, "The Face of Nature," pp. 473-487. A. von Humboldt, "Des lignes isotherme et de la distribution de la chaleur sur le globe", *Mémoires de physique et de chimie de la Société d' Arcueil*, 1817, *3*:462-602; strangely, the chart appeared only in a separate publication (Paris: Perronneau, 1817); German in Beck, *Studienausgabe*, vol. 6: *Schriften zur physikalischen Geographie* (1989), pp. 18-97, chart on 19.

into the curves of nature, as in the variations of magnetic lines, and to extend his method to a whole range of meteorological measurements. The time had come to discover whether „the pressure of the atmosphere, the quantities of rain falling from the air, the relative frequency of prevailing winds, and the direction of isothermal lines, like the distribution of magnetism over the earth, are subject to secular variations“.[47] This is the program that Dove made into his life's work, adapting Humboldt's method of curves to reveal the laws of meteorology. Indeed, Dove's description of the relation of average barometric pressure to the direction of the wind was inspired in part by Humboldt's isothermal lines and by his extensive observations on climate. Dove had just completed his *Habilitationsschrift* on the distribution of heat over the earth, the distribution that Humboldt had depicted with his isothermal lines.[48]

The isothermal lines inevitably recall also Humboldt's personal acquaintance with Joseph Fourier in the Paris Academy of Sciences and with his *Analytical Theory of Heat* of 1822. On the basis of calculations dependent on the mathematical theory of the diffusion and radiation of heat, Fourier had become a leading proponent of the view that the earth was a cooling body, most likely having been formed originally as a molten mass. That view, which informed all of Humboldt's work in physical geography, had major impli-

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47 Humboldt, "Ueber die Mittel . . . tellurischen Magnetismus", 319.

48 H. W. Dove, "Einige meteorologische Untersuchungen", 578. *Idem*, *De barometri mutationibus*, Dissertation, Berlin, 1826; *De distributione caloris per tellurem*, Habilitations-Schrift, Königsberg, 1826 (not published).

cations for the isothermal lines at the surface of the earth as well as for the internal temperatures that Humboldt and others had measured deep in mines and in the water issuing from springs. He looked forward in 1817 to the „beautiful analytical work with which Fourier will soon enrich general physics“.[49]

Humboldt knew Fourier well by the time the young Dirichlet joined Fourier's circle in 1825. And it was at Fourier's instigation that Humboldt arranged for Dirichlet to obtain his appointments in Prussia, first at the University of Breslau in 1827 and then from 1828 successively at the *Kriegschule*, the University, and the Academy of Sciences in Berlin. Humboldt's loyal friendship smoothed Dirichlet's entire career, including even his marriage in 1832 to Rebecca Mendelssohn-Bartholdy (daughter of Abraham), after Humboldt introducted him to the family.[50]

1828 was a great year for curves. As though in a stellar conjunction, the revived Dürer, Humboldt, Dirichlet, and Dove arrived together in Berlin. In their different ways, they all treated the curve as revealing the essence of nature's forms and processes, and in this they joined an already flourishing culture represented by people like Schinkel, Beuth, and Hummel. It is this culture and the technical practices circulating through it that supplied the inspiration and the

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49 Humboldt, "Des lignes isotherme", p. 94.

50 Kurt-R. Biermann, ed., *Briefwechsel zwischen Alexander von Humboldt und Peter Gustav Lejeune Dirichlet* (Berlin; Akademie-Verlag, 1982), see the Introduction and early letters from 1825. *Idem*, *Johann Peter Gustav Lejeune Dirichlet, Dokumente für sein Leben und Wirken* (Berlin; Akademie-Verlag, 1959), p. 12. E. E. Kummer, "Gedächtnissrede auf Gustav Peter Lejeune Dirichlet", in *G. Jejeune Dirichlet's Werke*, 2 vols (Berlin; Reimer, 1897), pp. 310-344, esp. 314-324.

resources available to the members of Berlin Physical Society for their own curve-drawing activities.

Laws as Curves in the Berlin Physical Society

In people like Du Bois-Reymond and Helmholtz we see how the Humboldt-Dove-Dirichlet nexus of curve production became a part of the scientific literacy of a new generation that sought to make physical science the basis of all natural science, using curves to capture the lawlike character of apparently non-lawlike phenomena in nature. We see too how crucial was Dove's role both as a ubiquitous teacher in the Berlin educational network and as editor of the *Repertorium der Physik*. Dove taught physics to Du Bois at the University and to Helmholtz at the Friedrich Wilhelm's Institute for military doctors. And while he no doubt exposed them to the virtues of graphic representation, he also brought to their attention the latest works on electricity by Ohm and by Faraday, whose lines of electric and magnetic force were already capturing attention. Du Bois carried both the electricity and the lines into physiology in the early 40s, when he began to study the electrical stimulation of nerves and muscles, culminating in his *Untersuchungen über thierische Electricität* of 1848-49. His usual source of experimental material was the frog.

Figure 17 depicts his first major discovery, the law of the frog current. The diagram shows a rectangular section of freshly prepared muscle, with fibres running longitudinally, and a curve of current strength, which surrounds the rectangle. This curve of current (e.g., the top left portion) results from placing two electrodes a short distance apart and moving them in steps between the *x*'s along the longitudinal surface and down the cross-section. Du Bois-Reymond's sensitive galvanometer showed that a current will always flow between the electrodes in the direction of the arrow around the corners, with a strength increasing to the corner (5) and then decreasing to the mid-point on the cross section (7). The ordinates of the curve are the dashed lines parallel to the bisecting line of the corner. No current flows with the electrodes placed symmetrically on two sides of the mid-points at I and 7. This inventive if complicated representation, with the curve superposed on the muscle section and showing all of the symmetries of the phenomenon, suggests Du Bois-Reymond's fascination with laws as curves.[51]

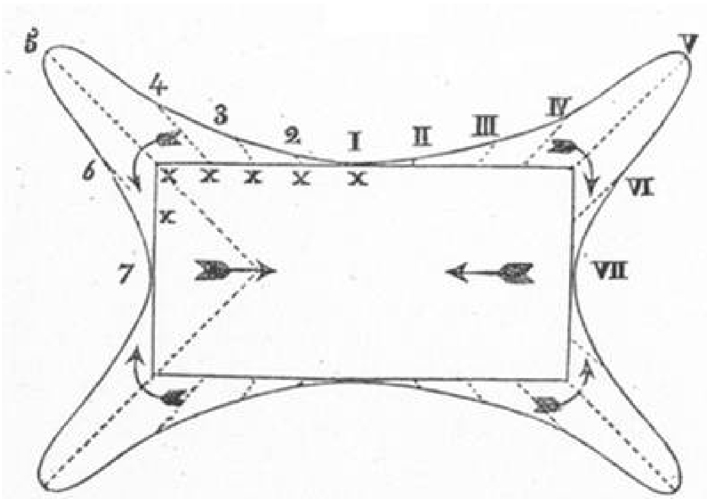

Figure 17. Emil Du Bois-Reymond, Muscle-current diagram, 1848-49

Frogs, however, were not his only experimental animal. In figure 18 he has drawn himself with the youthful beauty of a Greek athlete. He is measuring the current that passes over his body when his right bicep is strongly

[51] Emil du Bois-Reymond, *Untersuchungen über thierische Electricität* , 2 vols (Berlin: Reimer, 1848-49), vol. 1.

contracted and the left remains relaxed. Du Bois-Reymond's ability consistently to produce deflections of his galvanometer actually resulted from a highly skilled performance, mastered only after extensive practice in controlling his own body. As Sven Dierig has emphasized, this bodily control as experimenter mirrors Du Bois's bodily control as a gymnast, attained through many years of exercise on the bar, beam, and horse.[52]

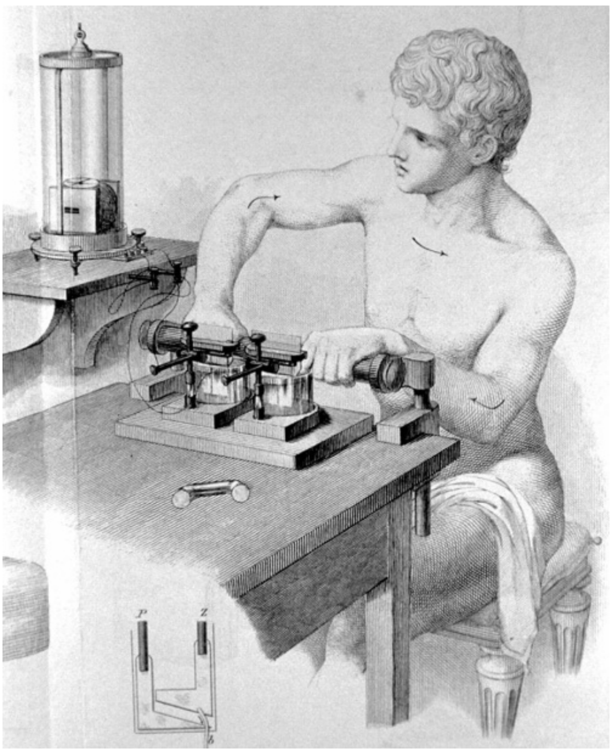

Figure 18. Emil Du Bois-Reymond as experimenting Apollo, 1848-49.

Dierig suggests that in his classical self-representation, Du Bois intended to portray himself as an Apollonian figure. Within the pervasive neo-humanist value structure of the *Bildungsburgertum*, Apollo epitomized manly beauty and the virtues of athletic excercise, particularly gymnastics, as a component of *Bildung*. This interpretation of Du Bois's self-image is thoroughly consistent also with the idealist conception of beauty that his closest collaborator in founding the Physical Society, Ernst Brücke, held throughout his life,

52 Dierig, "Apollo's Tragedy," (cit. n. 7). Du Bois-Reymond, *Thierische Elektricität*, vol. 2, pp. 276-288.

reflecting the neo-classical aesthetics that he had learned from his artist father and uncles and that he recognized in the smoothly muscled bodies of trained gymnasts and acrobats.[53]

As the values attached to instruments and aesthetics circulated among the members of the Physical Society, their attempts to represent laws as curves aimed less at employing the disciplined self as a recording instrument than at developing the skills to use mechanical and electrical instruments that would draw the curves directly, thus „self-recording“ or „self-registering“ instruments. These instruments were aids in the effort to reveal the essences of nature in the form of curves. They sought ideal forms, not photographic realism and not the confused and contingent appearances of particular events.[54] Du Bois, Brücke, and Helmholtz all maintained the classicizing aethetics of their youth throughout their lives. Although this simultaneous commitment to mechanics and aesthetics could be developed at length for several members of the Physical Society, I will indicate briefly only how it played out for Helmholtz.

Important sources in mechanics for the proliferation of self-recording instruments in the 1830s and 40s were the dynamometers and indicators developed by engineers to record the work being done by any working machine, whe-

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53 E. T. Brücke, *Ernst Brücke*, pp.139-146.

54 For this reason, the term "mechanical objectivity" employed for atlas makers of the 19th century by Lorraine Daston and Peter Galison, "The Image of Objectivity", *Representations*, 1992, *40*:81-128, does not seem appropriate to the aims of the Physical Society. More generally, while they make a very persuasive case for the atlases, which belong to the tradition of natural history, I am skeptical about its extension to natural philosophy, primarily because of the strongly idealizing practices of both mathematical and experimental physics.

ther powered by muscle, wind, water, or steam. The indicator for a steam engine, because it responded to the pressure inside the cylinder, was sometimes said to take its pulse, like a stethoscope.[55] Figure 19a shows how an indicator from the 1840s was screwed into the top of the cylinder of a steam engine.[56] The string attached to the connecting mechanism of the engine's main beam produces one revolution of the recording cylinder of the indicator (figure 19b) for each cycle of the engine's piston, while a stylus rises and falls with the pressure in the cylinder. Although originally invented (in a much simpler form) by James Watt and his master mechanic John Southern in 1796, the indicator remained almost unknown until the 1820s and received rapid development only in the 1830s and 40s, when various versions of the rotating drum were introduced.[57] Since the recording drum rotates with the motion of the piston, and thus in proportion to the volume of the cylinder, while the stylus records the rise and fall of pressure in the cylinder, the indicator effectively traces a curve of pressure vs. volume. Consequently, the area enclosed by the resulting „indicator diagram" (figure 19c)

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55 Thomas John Main and Thomas Brown, *The Indicator and Dynamometer, with their Practical Applications* (London; Hebert, 1847), p. 5.

56 Joseph Hopkinson, *The Working of the Steam Engine Explained by the Use of the Indicator: With a Description of that Instrument and Instructions How to Use It* (London; Simpkin, Marshall, & Co., 1854), title page.

57 H. W. Dickinson and Rhys Jenkins, *James Watt and the Steam Engine* (1927), reprint (Derbyshire; Moorland, 1981), pp. 228-233. R. L. Hills and A. J. Pacey, "The Measurement of Power in Early Steam-driven Textile Mills", *Technology and Culture*, 1972, *13*:25-43. Indicators were described in Berlin for Beuth's Gewerbefleiss-Verein in *Verhandlungen*, (1830), 72, 228. For the Physical Society, Werner Siemens provided an obvious source.

measures the work done by the engine in one cycle: i.e., the integral of pressure times change of volume over one revolution.

Helmholtz was familiar with the use of these diagrams for steam engines by mechanics and with their transformation into the idealized Carnot diagrams for generalized heat engines by mathematical engineers and physicists. He was equally familiar with the physiological instruments derived from them,[58] especially the "kymograph" invented by his friend Carl Ludwig in 1847, which produced a graphical recording of blood pressure or respiration. The instrument of present interest, however, is the frog-drawing-machine (*Froschzeichenmaschine*, or myograph) of figure 20, which Helmholtz developed between 1848 and 1852.[59]

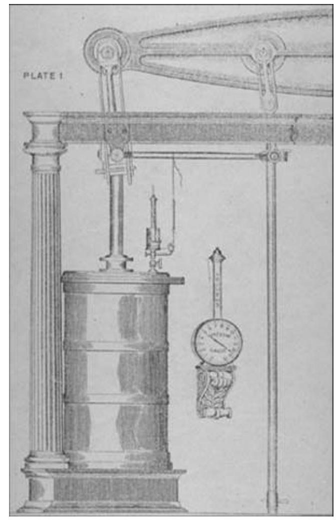

Figure 19a. Joseph Hopkinson, The Working of the Steam Engine Explained

[58] Soraya de Chadarevian, “Graphical Method and Discipline: Self-Recording Instruments in Nineteenth-Century Physiology,“ *Studies in History and Philosophy of Science*, 1993, *24*:267-291; and “Die 'Methode der Kurven' in der Physiologie zwischen 1850 und 1900,” in *Die Experimentalisierung des Lebens: Experimentalsysteme in den biologischen Wissenschaften 1850/1950,* eds. Hans-Jorg Rheinberger und Michael Hagner (Berlin : Akademie Verlag, 1993), pp. 28-49.

[59] I give a reinterpretation of this work, focusing on its relation to Helmholtz's conservation principle and his aesthetics, in *Bourgeois Berlin and Laboratory Science* (in preparation), ch. 8, “Ein Schauspiel für Götter.“ This account builds on the papers of Olesko and Holmes cited below. The main primary sources are Hermann Helmholtz, “Messungen über den zeitlichen Verlauf der Zuckung animalischer Muskeln und die Fortpflanzungsgeschwindigkeit der Reizung in den Nerven” (1850); “Messungen über die Fortpflanzungsgeschwindigkeit der Reizung in den Nerven. Zweite Reihe,” (1852); “Ueber die Methoden, kleinste Zeittheile zu messen, und ihre Anwendung für physiologische Zwecke (1850), all in Wissenschaftliche Abhandlungen, 3 vols (Leipzig; Barth, 1882-95), vol. 2: 764-843; 844-861; 862-880.

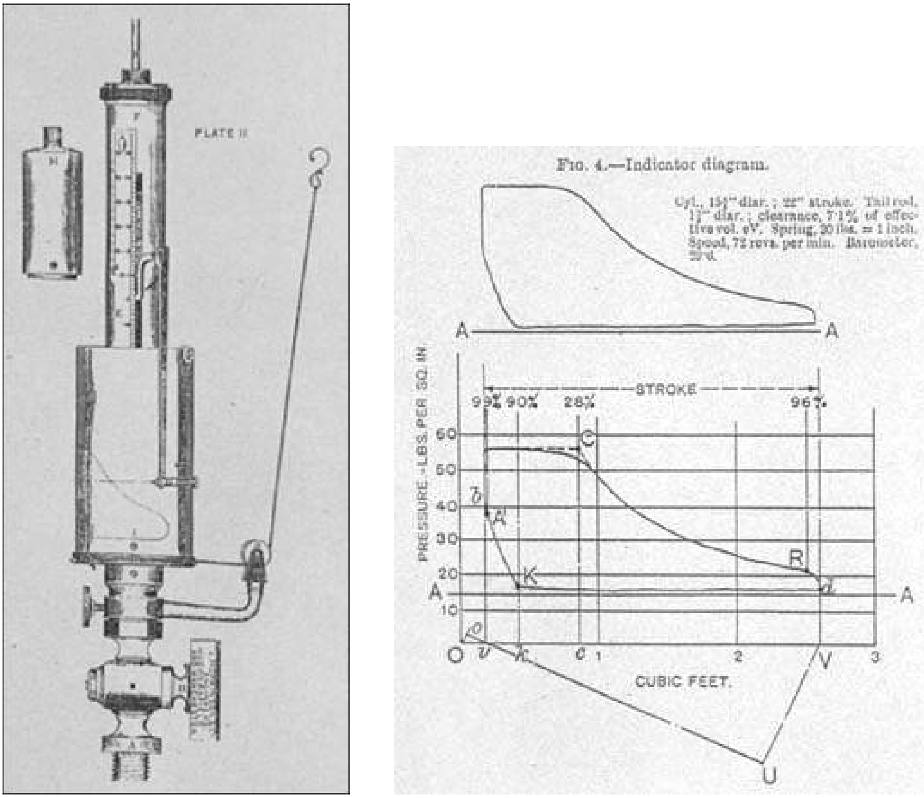

Figure 19b and 19c. Recording cylinder and indicator diagram, 1854.

According to Ludwig, both his own and Helmholtz's instruments derived directly from the indicator. Helmholtz's device treats the contracting and relaxing frog muscle quite literally like an engine burning fuel to produce work. The frog muscle (not shown) pulls on the hook at top center in the main drawing. When contracting, it lifts a frame (top view on the right) which carries a stylus on its left end. The stylus draws a curve on the rotating drum to the left of one cycle of contraction and extension of the muscle, like an indicator curve, but here representing at any point the net work that has been done by the muscle.[60] The conical pendulum on the bottom left, originally intended as a regulator of rotational speed, may well have derived from a differential governor for steam engines developed by Siemens. Finally, the timing scheme for triggering the electrical stimulus to the frog's nerve at a definite point in the drum's rotation (detailed at bottom left), was adapted from a precision technique that Siemens had developed for measuring the muzzle velocity of cannon balls and which Du Bois, at one of the first meetings of the Physical Society in 1845, suggested might be adapted for muscle contraction. In realizing this idea, Helmholtz obtained a fairly precise measure of the temporal process of muscle contraction following a stimulus.[61]

Helmholtz's results for what he called the curve of *Energie* of the frog muscle, appear on the right. The curves write out the muscle's action in the language of engines. His Fig.'s 5 and 6 show results for fresh and slightly tired muscles while Fig.'s 4 and 7 are controls, for tiredness and irritability.

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60 Carl Ludwig, *Physiologie des Menschens*, 2 vols (Heidelberg: Winter, 1852), vol. 1: 333. Robert M. Brain and M. Norton Wise, "Muscles and Engines: Indicator Diagrams in Helmholtz's Physiology," in *Universalgenie Helmholtz: Ruckblick nach 100 Jahren*, ed. Lorenz Krüger (Berlin: Akademie Verlag, 1994), pp. 124-145; reprinted in Mario Biagioli, ed., *The Science Studies Reader* (New York: Routledge, 1999), pp. 51-66.

61 Werner Siemens, "Beschreibung des Differenz-Regulators der Gebrüder Werner und Wilhelm Siemens," *Dingler's polytechnisches Journal*, 1845, *98*:81, in *Wissenschaftliche und technische Arbeiten von Werner Siemens*, 2 vols (Berlin: Springer, 1891), pp. 2-11. Siemens, "Anwendug des elektrischen Funkens zur Geschwindigkeitsmessung," *Poggendorff's Annalen der Physik und Chemie*, 1845, *66*:435-445; in Siemens, *Wiss. u. Tech. Arbeiten*, 8-14. Siemens, "Ueber Geschwindigkeitsmessung," *Fortschritte der Physik im Jahre 1845*, 1847, *1*:46-72. "Protcoll der Physikalischen Gesellschaft zu Berlin: 1845," Archiv der Deutschen Physikalischen Gesellschaft, Nr. 10001, 7 March 1845.

Fig. 4 may be taken as the iconic result. Its two curves demonstrate two things in a perspicuous manner.[62] First, the muscle only develops its *Energie* over time (about 0.15 seconds to raise the weight to maximum height).

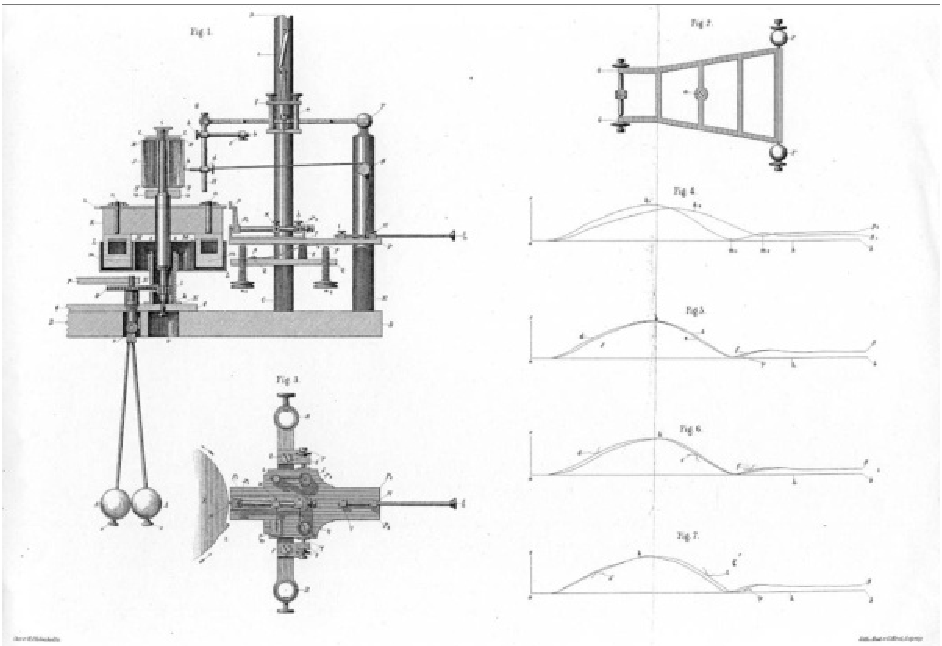

Figure 20. Helmholtz's frog-drawing machine (myograph).

This was a surprising result for physiologists when Helmholtz first announced it in 1850, although he fully expected it on the assumption that the *Energie* resulted from purely physical-chemical processes going on in the muscle.

62 Helmholtz, "Messungen über Fortpflanzungsgeschwindigkeit," W.A., plate II. A nice analysis focusing on „qualitative precision" is Frederic L. Holmes and Kathryn M. Olesko, "The Images of Precision: Helmholtz and the Graphical Method in Physiology," in *The Values of Precision,* ed. M. Norton Wise (Princeton: Princeton University Press, 1995), pp. 198-221.

The result served to confirm the thesis of conservation of force that he had developed at length in his (not yet) classic paper of 1847, *Ueber die Erhaltung der Kraft*. Secondly, the observeable delay time suggested to Helmholtz that he might actually measure the time it took for a stimulus to reach the muscle when propagated along the nerve. The two curves of Fig. 4 depict Helmholtz's famous demonstration that the nerve impulse requires time for propagation. They are displaced relative to one another because they are stimulated from different points on the nerve. Dividing the distance between the stimulation points by the time represented by the displacement, shows that the nerve impulse travels at the relatively slow speed of 27 meters per second, less than 1/10th the speed of sound in air, again confirming the assumption of ordinary physical processes.

So far we have seen only Helmholtz's mechanics. But he had had five years of training in drawing at the Potsdam Gymnasium and when he began his work on the *Froschzeichenmaschine* in 1848 he had just taken up a position at the Academy of Art in Berlin teaching anatomy to art students, a position in which Brücke had preceded him and Du Bois-Reymond would follow. The relation between these two activities can be symbolized by the fact that he made the drawing of the machine himself, entering *Gez. v. H. Helmholtz* (drawn by H. Helmholtz) on the lower left, in the manner of artists, with the lithographer on the bottom right. More deeply, his aesthetic values can be seen in his usage of Form, in both contexts. In his *Probevortrag* for the Academy of Art, his conception of Form appears in the adjectives he regularly associates with the term — *lebendig*; ideal; *harmo-*

nisch; *geistig* — and with the artist's capacity to express it — *Anschauung der Form*; *künstlerischen Schönheitssinn*; *künstlerischen Geist*. Unlike the closely related term *Gestalt*, Form refers in Helmholtz's usage not to the particular shape that a muscle may have on a specific body but to its type and especially to its Idea. The artist must be able to perceive this Form in an immediate, intuitive, and lively *Anschauung*. Training in anatomy is crucial to recognizing the Form and its causes and to differentiating essential from non-essential features of a particular shape (*Gestalt*), although it can never replace the *künstlerische Geist*.

> It is a means which facilitates for the artist his spiritual victory over the ever-changing variety of his earthly object, the human Form, which should sharpen his view of the essential in the *Gestalt*, which should equally make transparent to him the entire *Gestalt*. . . . But art, I would like to say, begins only beyond anatomy. The artistic spirit reveals itself first in the wise application of the Forms whose interconnection and elementary features anatomy has taught; it reveals itself in the differentiating characteristic of the *Gestalt*.[63]

Thus it is through the realization of the Form that an artist produces the beauty of a particular *Gestalt*. And just because it is the *Form* and not the *Gestalt* that is of primary interest, the artist's task is not to copy nature but to capture ideal beauty, to awaken in the viewer "*das Gefühl harmonischer und lebendiger Schönheit*."

> The artist should never attempt to imitate in the truest possible way, because his model is always only a person grown up in earthly imperfection, never corresponding to

[63] Hermann Helmholtz, "Probevortrag," in Leo Koenigsberger, *Hermann von Helmholtz*, 3 vols (Braunschweig: Vieweg, 1902-1903), Vol. I: 95-105, on 102-105.

> the Ideal; rather, he should modify the individual Gestalt until it is the perfected impression of its spiritual content.[64]

To reveal the *Ideal* of the curve of *Energie* as opposed to any individual *Gestalt*, was precisely Helmholtz's aim in his four years of work on the frog-drawing-machine. His entire argument, in fact, rested on establishing this *Form* as a constant of the natural process of contraction. For example, the measurement of propagation speed from his Fig. 4, as he fully elaborated, depends on the two curves being congruent throughout their length, so that the displacement is uniform throughout and therefore dependent only on propagation time, not on such contingencies as state of tiredness or intensity of stimulation.[65]

The frog-drawing-machine represents the pinnacle of self-recording instruments in the early days of the Berlin Physical Society. But it was only one of a considerable number of curve-producing techniques and instruments that the members of the Society developed in the 1840s, the conditions for which I have attempted to draw out of the artistic, scientific, and industrial life of the city. Indeed, their work as a whole should be seen as a subset of many forms of curve production in Berlin.

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64 Helmholtz, "Probevortrag," 101.

65 Helmholtz, "Messungen über den Zeitlichen Verlauf"; usages of *Gestalt* and *Form* appear at 768, 770, 791-794, 820. Kathryn M Olesko and Frederic L. Holmes, *Experiment, Quantification, and Discovery: Helmholtz's Early Physiological Researches, 1843-1850*," in *Hermann von Helmholtz and the Foundations of Nineteenth-Century Science*, ed. David Cahan, (Berkeley: University of California Press, 1993), pp. 50-109, analyze especially Helmholtz's accounting procedures using the method of least squares.

Conclusion

Return now to Du Bois's certificate of membership, and particularly to the lush tropical tree (figure 21) on which the modernizing scientists perform their feats. It is a tree of knowledge, to whose fruiting and flowering higher branches one of the heroes of enlightenment has tied the banner of the Physical Society. Unlike the pudgy cherubs or Putti familiar in many other such fanciful images at the time, the analogous figures here are athletic youths. They conspicuously employ physical instruments to carry out analytic experiments in the various „branches“ of physics, which the group had begun to review in its new journal, *Progress in Physics* (*Fortschritte der Physik*). From his perch in the higher branches, a young astronomer aims his telescope to reveal the line of epicyclic motions of a comet, now tied to the tree of knowledge, while a symbolic Newton with a large prism similarly analyzes the spectrum of sunlight, symbolized as an arabesque of harmonic loops, reminiscent of both Dürer and Fourier. A new Galileo on the right demonstrates the law of falling bodies, showing that the distance increases with the square of the time. The gymnast on the left, surely representing Du Bois himself, performs his exercises on an electromagnet. His neighbor attempts to fathom the watery depths with a perfectly straight plumbline, unaware that the deceitful nymphs below are busy making a tangle of it. Of the performers at the base of the tree, one investigates the lines of Chladni figures (produced by bowing a metal plate covered with dust)[66], another carries out a geometrical analysis, a third draws electrical sparks from a Leyden jar, and a fourth tests the laws of hydrodynamics with a curiously phallic pump. The prominence in this scene of physical instruments and of curves is everywhere apparent.

Equally apparent, the curves are conceived as inscribed by the instruments, which read out the ideal forms of nature. The heroes themselves, in their classical beauty, seem to play much the same role as Du Bois's Apollonian experimenter. If so, their activities should be seen as disciplined performances on their instruments of analysis to reveal nature's true Forms. Thus Du Bois's iconography states my central theme, that curves, especially harmonic or rhythmic curves, conceived as representing the essence of natural objects and processes, played an extraordinarily important role in the view of knowledge held by the members of the Physical Society, a view that carried across the boundaries of art, science, and technology. As Du Bois himself expressed it in the introduction to his *Animal Electricity*,

[66] On Chladni's figures and their fundamental significance for music and science, see Jackson, *Harmonious Triads*, (cit. n. 36), especially ch. 2.

even though one could only rarely obtain knowledge of cause-effect relations in a mathematically expressible form, ”The dependence of the effect on each circumstance presents itself in the form of a curve . . . whose exact law remains . . . unknown, but whose general character one will in most cases be able to trace."[67] This is a view of the relation between laws and curves that Hummel, Burg, Humboldt, Dirichlet, and Dove had all expressed in their own ways and that Helmholtz realized with his frog-drawing-machine. It carries Dürer's Platonism into the 19th century, but with the crucial addition of Fourier analysis, precision instruments, and graphical representation, which seemed finally to provide the tools to put Dürer's idealist vision of knowledge into a realist form.

Looking once again at Du Bois's allegory, if we follow the vertical display downward, we leave the light of day and the scenes of rational analysis above ground and move under ground, where the roots of the tree of knowledge lie buried in the mythological past. This underworld recalls Du Bois's well-known polemic, immediately following his extended discussion of mathematical-physical methods and the use of curves, launched against the dark and vitalistic notion of a *Lebenskraft*, which he ascribed to the speculative romanticism of contemporary physiologists and to their ignorance of physical methods.[68] Here Mephistopheles steps out of the flames of hell to observe the searching figure in the cave, from Plato's Republic, who with book in hand is vainly attempting to decipher dim shadows on the wall, imprisoned in his own

[67] Du Bois-Reymond, *Thierische Elektricität*, vol. 1: 26-27.
[68] Ibid., pp.xxxiv-xl.

imaginings. Apparently he lacks the instruments of enlightenment that the new physicists regard as necessary for ascending the Platonic scale from the visible to the intelligible. Outside, bearded giants with torch and urn evoke the powers of fire and water while plucking grapes to share with another of the voluptuous water nymphs.

Finally, as the roots of knowledge descend to their primordial source in the world of the nymphs, the aesclepius, ancient symbol of medical art, entwines itself on a root. The serpent is ironically juxtaposed with the lowly frog, whose muscles and nerves provided the primary material for the new electro-physiology of Du Bois and Helmholtz. Down in this watery romantic domain, the rationalized curves of nature — cometary trajectory, spectrum of sunlight, Chladni figures, geometrical diagram, and the pronounced black plumb line — become an inaccessible tangle. If Du Bois's athletic heroes feel the attractions of the vital force, their machines of objectivity elevate them beyond its seductive grasp.

For interpreting the cultural location of Du Bois's playful but intense promontory of science, its horizontally arrayed background is significant. The lush tropical growth emerges out of scenes of both classical purity and industrial progress. From a galley nearly lost in the distance on the left, classicism proceeds through the Egyptian obelisks, sphinx, and pyramid, to the Parthenon of Athens, and up to an 18th century scene of academic learning, with a professor in wig and frock coat lecturing to the passively assembled students outside his temple. Only in the present of the mid-19th century do the students themselves, freed from temples and priests, take over the task of making knowledge through experimental research. From the right, their new mode of action has emerged from the era of sailing ships and stands before those newly domesticated powers of Neptune and Vulcan, the steamship and the railroad, which appear on the Bay of Naples before a gently smoking Vesuvius.

The background panorama thus carries forward to the viewer dual ideals of knowledge-making, or *Wissenschaft* — namely, classical learning and material progress — which were continually circulating through the culture in which the members of the Berlin Physical Society formed their identities. Du Bois's imagery, in brief, places the young heroes wielding their implements of progress at the juncture of a vertical history leading upwards from mythology to truth and a horizontal history projecting forwards both from classical education on the left and from industrial drive on the right, uniting those forces in the movement to the future. That movement is carried by the instruments that draw the curves of nature’s laws.

Creole technologies and global histories:

rethinking how things travel in space and time

By David Edgerton[*]

The Uruguayan writer Eduardo Galeano once wrote: 'la diosa tecnología no habla español' [the Goddess Technology does not speak Spanish].[1] Indeed historians of technology in many parts of the world are told the equivalent. Most of us, it is claimed, don't speak technology; don't have technology to speak of.[2] As I have argued elsewhere, in order to be able to write a history of technology which is both global and historical, and which engages directly with more

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[*] Imperial College London. I am most grateful to participants at the Lisbon workshop on "The Circulation of Science and Technology: Places Travels and Landscapes" for their comments, as well as to Waqar Zaidi, anonymous referees, Tiago Saraiva, and especially to Eric Schatzberg.

[1] Eduardo Galeano, *Las Venas abiertas de America Latina* (Buenos Aires/México, D. F.: Siglo XXI, 1978), first published 1971, p. 381.

[2] This point has been made to me by many colleagues from around the world, and also by an American historian of technology, Pauline Kusiak, who noted that in Senegal, the Senegalese were astonished to find her studying 'technology' in their country.

than a tiny minority of white males, we need to break the unfortunate association, indeed conflation, that exists between invention and innovation on the one hand, and technology on the other. [3] In this paper, which draws on a chapter in a forthcoming book, I focus on twentieth-century horse transport in the rich world, and explore the new technologies of the poor world, and especially of its megacities.[4] By looking at these cases I show the continued vitality of what is taken to be a technology of previous centuries, and demonstrate how its twentieth growth and survival cannot be understood as persistence. Secondly, I show how the spectacular growth of the poor city depended on new technologies of poverty, which had origins elsewhere. I use this case to explore what I call *creole* technologies.

Conflating use/innovation and past/present

The vast majority of accounts of technology (academic and popular) conflate technology with technological

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3 See my "De l'innovation aux usages. Dix thèses éclectiques sur l'histoire des techniques", *Annales H.S.S.*, 1998, 53:815-837 (the English version is "From innovation to use: ten (eclectic) theses on the history of technology", *History and Technology*, 1999, 16:1-26) and Svante Lindqvist, "Changes in the Technological Landscape: The Temporal Dimension in the Growth and Decline of Large Technological Systems", in Economics of Technology, ed. O. Granstrand (Amsterdam: Elsevier, 1994), pp. 271-288.

4 David Edgerton, *The Shock of the Old: technology and global history since 1900* (London: Profile; New York: Oxford University Press, 2007), translated as *Innovación y tradición: historia de la tecnología moderna* (Barcelona: Crítica, 2007), and into Portuguese by Editora Zahar, Rio de Janeiro. The book contains chapters on Significance, Time (which is drawn on here), Production, Maintenance, Nations, War, Killing, and, Invention.

novelty (invention/innovation/creativity). Such studies cannot usefully contribute to a rethinking of standard accounts of technology and society, for they are concerned neither with what technologies actors had available to them, nor indeed what was invented. Rather they focus on the early history of *some* technologies which later became important. Yet despite such limitations, such studies, implicitly and explicitly, do seek to say something about both invention/innovation and the relations of technology and society. Yet if we do want to examine these we need studies of technology-in-use on the one hand, and of inventtion/innovation on the other. This will yield a dramatically different picture to the one implicit in most existing accounts, and will allow us furthermore, to engage with and challenge, standard general historical accounts.

As well as conflating invention/innovation and use, most writing about past technology is not concerned with the place of technology in history, but with something subtly but significantly different. Its aim is to illustrate with examples from the past, what one historian calls, after Martin Heidegger, 'the question of technology'.[5] That is, the main concern is with exploring the nature of technology, its malleability, relation to culture, and so on. This helps us to understand more why so little work set in the past is concerned with historical arguments about technology, let alone challenging existing historical pictures. Its concerns are elsewhere.

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5 Thomas J. Misa, Leonardo to the *Internet: technology and culture from the Renaissance to the present* (Baltimore: Johns Hopkins University Press, 2004).

The conflation of invention/innovation and technology is deep-seated. It is found not only in older studies, but is central to most work in the social construction of technology (SCOT) and actor-network theory (ANT) traditions.[6] It is also there, despite immediate appearances, in Ruth Schwartz Cowan's call for the study of the 'consumption junction', and in Ruth Oldenzeil's subsequent arguments that studying users shows women active in the *shaping* of technology.[7] Studies of *users* and innovation, going back to the 1970s, and later developed under the SCOT tradition, and recently extended, are similarly primarily concerned with users and changing technologies.[8] It is revealing too that the key concept of 'technological determinism' has been routinely defined as something along the lines of 'technical change causing social change' rather than the older definition of technology shaping society. It is also significant that in STS and history of technology circles it was primarily criticised as a theory of technology, rather than what it classically was: a theory of society and history.[9]

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[6] A criticism made by Langdon Winner, who had long been concerned with use, in "Upon Opening the Black Box and Finding it Empty: Social Constructivism and the Philosophy of Technology", *Science Technology & Human Values*, 1993, 18: 362-378.

[7] Ruth Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in *The Social Construction of Technological Systems*, ed. Wiebe E. Bijker, et al. (Cambridge: MIT Press, 1987), pp. 261-280.

[8] Ruth Oldenziel, "Man the Maker, Woman the Consumer: The Consumption Junction Revisited" in *Feminism in the Twentieth Century. Science, Technology and Medicine*, ed. Angela N. H. Creager, Elizabeth Lunbeck, Londa Schiebinger (Chicago: Chicago University Press, 2001), pp. 128-148; Trevor Pinch and Nelly Oudshoorn eds., *How Users Matter: the Co-Construction of Users and Technologies* (Cambridge, MA: MIT Press, 2003).

[9] For examples see Edgerton, "From innovation to use".

In recent years there have been serious and rewarding efforts by historians of technology to engage with general histories of the nation and the world. Yet here too and innovation-centric picture of technology has been central. Thomas Hughes has written just such a book, explicitly committed to a providing a history of America. It is called, appropriately and revealingly, *American Genesis: a century of invention and technological enthusiasm*.[10] More recently Pauline Maier, Merritt Roe Smith, Alexander Kayssar and Daniel Kevles have written a textbook of American history which includes much material on innovation in science, technology and medicine: the book is called, *Inventing America: a history of the United States*.[11] Global histories of technology too are innovation-centric. One very recent world history of technology illustrates this. The period 1870-1930 is discussed in terms of research and invention in electricity and chemicals; 1936-1990 in terms of the *war time* history of the atomic bomb, electronics and computing; and 1970-2001 in terms of the fax, hamburgers and the internet.[12] Such a list of technologies, in this chronological form is, apart from the hamburger, far from idiosyncratic. It is very similar to the choice of technology in works on the history of US technology in their coverage of the twentieth century: the interwar period tends to have electricity, motor cars, and aviation, and the period of Second World War and

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[10] Thomas Hughes, *American Genesis: a century of invention and technological enthusiasm* (New York: Viking 1989).

[11] Pauline Maier et al., *Inventing America: a History of the United States* (New York: Norton, 2003), 2 vols.

[12] In Misa, *Leonardo to the Internet*, 1900-1950 is also dealt with in terms of modern architecture.

later is deemed to be the age of nuclear power, computers, space rockets, and the internet.[13] One historian of the United States claims explicitly that 'four technological systems have dominated twentieth century history: automobiles, and their attendant roads and fuel sources; aircraft, spacecraft and also rockets; electronic communication devices; from wireless telegraphy to personal computers; and finally, biotechnologies, new foodstuffs, medications, and contraceptives', an argument which has the virtue of insisting on the simultaneous existence of these systems.[14]

Innovation-centredness is also found in the global histories of writers other than professional historians of technology. So-called 'long-wave' theories, which see the world economy going through fifty year cycles of activity, driven by innovation, are a good example.[15] The Schumpeterian focus on innovation is also central to the global historical work of David Landes and Joel Mokyr: for

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[13] This is my reading of Thomas Hughes' *American Genesis*, and recent textbooks namely Carroll Pursell, *The Machine in America: a social history of technology* (Baltimore: Johns Hopkins University Press, 1995), Ruth Schwartz Cowan, *A Social History of American Technology* (New York: Oxford University Press, 1997); and Thomas J. Misa, *Leonardo to the Internet.*

[14] Schwartz Cowan, *A Social History of American Technology*, p. 221.

[15] Chris Freeman and Francisco Louçã, *As Time goes by: from the industrial revolutions to the information revolution* (Oxford: Oxford University Press, 2002); Carlota Perez, *Technological Revolutions and Financial Capital: the dynamics of Bubbles and Golden Ages* (Cheltenham: Edward Elgar, 2002). Nathan Rosenberg and Claudio Frischtak wrote a devastating critique of such writings as they first appeared. See their "Technological Innovation and Long Waves", *Cambridge Journal of Economics* (1984); reprinted in Nathan Rosenberg, *Exploring the Black Box* (Cambridge: Cambridge University Press, 1994). Of course it did not stop production of such work. The key long-wave innovator was the East German Gerhard Mensch, who published in German in 1975, *Das technologische Patt: Innovationen überwinden die Depression* (Frankfurt: Umschau Verlag, 1975).

them a few innovations are of crucial importance, and are discussed mainly around the time of innovation.[16] Many global histories show a Smithian focus on technologies of communication, with, again, a strong innovation-centric bias.[17] We need to stress that these are not studies *of* innovation, but rather of studies of the economy, *focussed on* innovation.

Our understanding of the technology (and science) of the twentieth century is thus, I suggest, nowhere near as securely based as we routinely assume; our mental maps need redrawing. Our shared accounts of rich-world technology are systematically biased by a conflation of stories of innovation and use, and the focus on technologies and sciences of high cultural resonance at the early stages of diffusion. We have many critiques of what is taken to be old-fashioned history of technology – it is taken to be masculine-oriented, production-oriented, materialistic, determinist, internal etc which is to be countered by new approaches. But we don't in fact have even a coherent productionist, masculine, materialist account of technology (either of technology-in-use or invention) and history in the twentieth century.[18]

To produce a full account of technology we need a new approach. It needs to distinguish clearly between use and invention/innovation, and to focus on each. It should not be concerned with replacing the study of innovation with

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[16] David S Landes, *The Unbound Prometheus: technological change and industrial development in Western Europe from 1750 to the present* (Cambridge: Cambridge University Press, 1969); Joel Mokyr, *The Gifts of Athena: historical origins of the knowledge economy* (Princeton University Press, 2002).

[17] For example, J.R. McNeill and William H. McNeill, *The Human Web: a bird's-eye view of World History* (New York: Norton, 2003).

[18] Thanks to Eric Schatzberg for helping me formulate this point.

the study of use but rather needs to recognise the significance of the distinction for the study of each. In its focus on technologies-in-use it has distinguished predecessors, including the work of feminist historians like Ruth Schwartz Cowan,[19] historians concerned with the environment, and historians of technology, above all Svante Lindqvist.[20] In the history of invention, oddly enough, it has fewer recent works of note to draw on, especially for the twentieth century.[21] The shift away from the conflation of technology and innovation is just the beginning. We need to be concerned with all kinds of technologies. Rather than seeking to replace a history focussed on high-tech, masculine, industrial technologies with low-tech, the feminine and the domestic, we need to deal with both, with the aim of getting a sense of the material basis of human existence. We need also, I would argue, to engage with history, and not just the question of technology,

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[19] Siegfried Giedion, *Mechanization takes command: a contribution to anonymous history* (Oxford University Press, 1948); Ruth Schwartz Cowan, *More work for mother: the ironies of household technology from the open hearth to the microwave* (New York: Basic Books, 1983); Cynthia Cockburn and Susan Ormrod, *Gender and Technology in the Making* (London: Sage, 1993); Stewart Brand, *How buildings learn : what happens after they're built* (London: Viking, 1994). See also Carroll Pursell, "Seeing the invisible: new perceptions in the history of technology", *ICON*, 1995, 1:9-15.

[20] Svante Lindqvist, "Changes in the Technological Landscape" (cit. n. 3); John McNeill, *Something New under the sun: an environmental history of the twentieth century* (London: Penguin, 2000); Vaclav Smil, *Energy in World History* (Boulder: Westview Press, 1994); Paul Josephson, *Industrialized nature : brute force technology and the transformation of the natural world* (Washington, DC: Island Press, 2002); Andrea Tone, *Devices and desires: a history of contraceptives in America* (New York: Hill and Wang, 2001); Ronald Kline, *Consumers in the country: technology and social change in rural America* (Baltimore, MD / London: Johns Hopkins University Press, 2000).

[21] Though see Kees Gispen, *Poems in Steel: the politics of invention from Weimar to Bonn* (Oxford: Berghahn, 2001).

and to do it in a particular way, offering a new kind of post-contextualist history to those already available.

This point requires a brief elaboration. One of the great aims of historians of technology has been to write contextual histories of technology/innovation, that is to say histories which locate their subject matter within their historical context. Historians of technology/innovation have become experts not just in particular technologies but in particular contexts.[22] But what is the context? Is it the conclusions of other historians? If so, which? Histories are as contested as we want technologies to be. There are deeper problems still: contextualism assumes that technology was not present in the literature on the context, and explicitly that was often the case. But there is a great difficulty here, which is that existing historical work, and indeed contemporary sources, already have a particular account of technology in them. No history of the USA, or of Britain, or anywhere, in the twentieth century, especially, does not already have an implicit history of science and technology in it. There is a problem of circularity.

One way out of all these problems is write the 'history of content and context together', to write a history from all the materials to hand.[23] This leads to the use of concepts like

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[22] Those contexts have often been national, just as most histories are national, which raises problems in itself.

[23] Andy Pickering calls for histories 'without regard for traditional distinctions between history of science and history more generally, and especially without centering research upon an archive demarcated by such distinctions. Such an approach would blur the disciplinary identity of historians of science, of course, but no one is better placed than historians of science to speak of the *truly* integral place of science in global history, and the end result might be a clearer view of global

co-production and mutual constitution of technology, politics, history. They are useful not least because they get us away from bashing at technological determinism.[24] But there is a real risk in using this approach of falling for the Latourian temptation of seeing the world being recreated from scratch in the laboratory, and of following the scientists and engineers a little too closely. The danger is that we end up reproducing (yet again, I would argue) their accounts of national and world history, even if it is with a different gloss and in new language.[25]

A different kind of post-contextual history is possible, and I think necessary. It needs to get away from its focus on scientists and engineers, and their originality, and to examine the extent to which, for example, the ideas of scientists and engineers, about science and technology to politics, are derivative rather than original.[26] It needs to examine carefully the assumptions that are made in accounts of technology, and the context. That means understanding the standard narratives, often derived from popular sources, that

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history itself.' Andrew Pickering, "The Rad lab and the World", *British Journal of the History of Science* , 1992, 25: 247-251, p. 251.

[24] Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, MA: MIT Press, 1998) is an example, in part, of this approach. See also Michael Allen and Gabrielle Hecht eds., *Technologies of Power: essays in honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: MIT Press, 2001).

[25] See for example, Bruno Latour, "Give me a laboratory and I will raise the world", in *Science Observed*, ed. K. Knorr-Cetina and M. Mulkay (London: Sage, 1983), pp.141-170 and *Aramis: The Love of Technology* (Cambridge: MA, Harvard University Press, 1996).

[26] For elaboration of these points see my "British Scientific intellectuals and the relations of Science and War in Twentieth Century Britain", in *National Military Establishments and the Advancement of Science: Studies in Twentieth Century History*, eds. Paul Forman and J.M. Sanchez Ron (Dordrecht: Kluwer, 1996), pp. 1-35.

shape our accounts (for example, in making them so innovation-centric). The point of a post-contextual picture is to give us a different account of the national and global historical context, and the place of technology in it, not merely adding technology to accounts.[27]

Thinking about twentieth-century horsepower, and technology and poor world is a good example of the need to rethink object and context, and the underlying assumptions made in our accounts of both. Let us start with the poor world: rarely taken seriously by sociologists or historians, it hardly figures in global histories.[28] Some explanation of the term is required: I use it to mean that majority of places in the world, where the great majority of the population are and have been, by the standards of western Europe and north America, very poor. In other words, I am referring to those places we more usually study under labels like 'colonial', 'post-colonial', 'developing', and 'third world', none of which ever applied to all poor countries of the twentieth century.

In relation to technology the poor world is especially invisible. For innovation-centric history of technology the poor world does not exist as it has not been a significant technical innovator in recent centuries.[29] Thus a key built-in assumption in many kinds of treatments is that the poor

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[27] For examples see my *Warfare State: Britain 1920-1970* (Cambridge: Cambridge University Press, 2005), and *The Shock of the Old* which attempts to rethink standard accounts of production, war, nations, killing and invention, by focussing on what technologies were in use.

[28] Peter Worsley, *The Three Worlds: culture and world development* (London: Weidenfeld and Nicolson, 1984) is a rare case.

[29] An important and honourable exception is Arnold Pacey, *Technology in World Civilisation: a thousand year history* (Oxford: Blackwell, 1990) which has a fair amount on poor countries in twentieth century.

world, with some notable exceptions (which I discuss further below), *lacks* modern technology. This rule is proved by the exceptions to it. Many general texts on technology will mention the 'green revolution' of the 1960s and 1970s in poor parts of Asia. This is also interesting in that it is illustrative of the deep association between agriculture and poverty: it is rare to find other references to agriculture after 1945, even 1900, in histories of technology. That should be a matter of surprise, since there was a radical transformation in agriculture in the rich world, particularly after the mid-twentieth century, when agriculture saw much greater rates of productivity change than industry, and at much greater rates than before. This green revolution made a huge impact on patterns of world trade, belying the standard image of a poor agricultural world exporting food to a rich industrial world. The USA exported wheat to the USSR in the 1970s and 1980s and on a huge scale, and continues to export raw cotton to the whole world, including China.

The neglect of even the most modern agriculture goes along with a much wider neglect of non-industrial technologies in studies of the twentieth century: the horse, the camel, the donkey cart, the wooden plough or the handloom, are seen as technologies of previous historical eras, not to be considered as part of the twentieth century. That they are primarily associated with a poor world, makes them even more invisible as technologies, even in the poor world. Yet they, just like the aeroplane and the motorcar, were made, maintained, and used, and changed throughout the last century. They existed in the same, interconnected world. Our conceptualisation of these technologies reveals a deeply embedded assumption of how technological space and time works, one in which spatially separated rich and poor are put on a temporal scale, as 'developed' and 'developing', and in which we date technologies by invention. We may scoff at such naiveté, but we should not fall for the idea that we have an adequate account of the technology of the rich world, which we have to 'decentre' to get a decent account of the poor world. We have to decentre that account to get a good account of the technology of both.[30]

Twentieth-century animal power in the rich world

The history of twentieth century technology in rich countries, as well as poor countries, usefully starts with technology usually seen as old, perhaps even obsolete, merely persisting anachronistically, like horse-power.[31] If we were to date the age of horsepower by its maximum use, rather than by its innovation, it would be much more recent than the history books allow. Twentieth-century horsepower was not a left-over from a pre-mechanical era; for example, the gigantic horse-drawn metropolis of 1900 was new. In Britain, the most industrialised nation in the world in 1900, the use of horses for transportation peaked not in the early

[30] David Arnold, "Europe, Technology and Colonialism", *History and Technology*, 2005, 21:85-106, argues for the significance to the study of European technology of studying colonial technologies. My point here is more general.

[31] See, again, the seminal paper by Svante Lindqvist, "Changes in the Technological Landscape" (cit. n. 3).

nineteenth century but in the early years of the twentieth. How could it be that horse transport expanded at the same time as trains pulled by 'iron horses'? The answer is that economic development and urbanisation went hand-in-hand with more horse-buses, horse-trams, and horse carriages. In addition, while train and ship carried goods over long distances, over shorter distances horse-drawn vehicles became ever more necessary. Thus visitors to London's Camden Market, on the site of a huge railway yard and interchange with the canal system, will note that many of the old buildings were stables.[32] These were not there to house animals used for riding in nearby Regent's Park, but for draught animals. In 1924 the largest and most progressive British railway company, the London, Midland and Scottish railway had as many horses as it had locomotives – 10,000. By contrast it had just over a thousand motor vehicles. In 1930 the LNER railway had 7,000 steam locomotives and 5,000 horses, and only about 800 motor vehicles.[33] There is no doubt though, that by 1914 in the great rich cities of the world, horse transport was giving way to the motor-powered buses, lorries and cars, and electric-powered trams.

In agriculture, the horsepower peak was to come later. For example, in Finland the horse population peaked in the 1950s because they were used in logging. The United States provides the most graphic example. Agricultural

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[32] 60% of Britain's capital stock in railways as it stood in 1961 was constructed before 1920, and 54% of harbours, docks and canals. See Geoffrey Dean, "The Stock of Fixed Capital in the United Kingdom in 1961", *Journal of the Royal Statistical Society* A, 1964, 127:327-351.

[33] E.J. Larkin and J.G. Larkin, *The Railway Workshops of Britain 1823-1986* (London: Macmillan 1988), pp. 230-233.

horsepower peaked in 1915 with more than 21m on American farms, up from 11m in 1880, a level to which it had returned by the mid-1930s.[34] The US case is particularly interesting because at the beginning of the twentieth century it had highly mechanised agriculture, but this was horse-powered agriculture. We are apt to underestimate the implications of relying on horsepower in the country-side. At the peak of agricultural horse use in Britain and the USA, about one-third of agricultural land was devoted to their upkeep: horses were large consumers of grass, hay and grain.[35] Mechanised agriculture helped the USA become the richest large nation in the world, and one that by the 1910s was by far and away the largest producer of motor-vehicles.

In one area of twentieth-century life, the use of horses for transport was particularly remarkable. The Great War and the Second World War are seen as industrial wars, as feats of engineering and science and organisation. And so they were. Because of this both involved huge numbers of horses, which, like men, were conscripted. Every belligerent depended on them, as well as on mules, and other beasts of burden. Before the Great War, the small British army had 25,000 horses but by the middle of 1917 the great new mass British armies had 591,000 horses, 213,000 mules, 47,000 camels and 11,000 oxen. In late 1917 there were 368,000 British horses and 82,000 British mules on the Western Front alone, hugely outnumbering British motor vehicles.

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34 *Historical Statistics of the United States: Colonial Times to 1957* (Washington: US Bureau of the Census, 1960), pp. 289-290.

35 Colin Tudge, *So shall we Reap* (London: Allen Lane, 2003), p. 69.

This was not a question of a deluded commitment to cavalry. Only one third of the British horses on the Western Front were for riding (and only some of these were in cavalry units) – the great majority transported the vast quantities of *materiel* required in modern war, particularly from the railheads to the front. The use of horses was not an exceptional emergency measure to make use of Britain's existing horses. Horses were desperately needed, and Britain bought 429,000 horses, and 275,000 mules from North America, and imported vast quantities of fodder too. Britain's ability to exploit world horse markets was crucial to its military power.[36] In any case the British were not unique. The vast American armies pouring into Europe in 1918 equipped each of their very large infantry divisions with 2,000 draught horses, another 2,000 riding horses, and no fewer than 2,700 mules: one horse or mule for every four men.

An even starker example of the continuing importance of the horse is provided by the Second World War. The German army, so often portrayed as centred on armoured formations, had even more horses in the Second World War than the British army had in the Great War. The horse was the 'basic means of transport in the Germany Army'. German rearmament in the 1930s involved mass purchase of horses such that by 1939 the army had 590,000, leaving 3m others in the rest of the country. Each infantry division needed around 5,000 horses to move itself. For the invasion of the Soviet Union in 1941, 625,000 horses were assembled. As

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[36] John Singleton, "Britain's Military Use of Horses 1914-1918", *Past and Present* , 1993, 139:178-203

the war progressed the German horse army got ever larger as the Wehrmacht pillaged the agricultural horses of the nations it conquered. At the beginning of 1945 it had 1.2 million horses; the total losses of horses in the war are estimated at 1.5m.[37] Could it be that the Great War and the Second World War saw more horses in battle than any previous war? Could it be that the draught-horse to soldier ratio also increased, despite the use of other forms of transport?[38] Certainly the Wehrmacht embarked on its march to Moscow with many times more horses than Napoleon's *Grand Armée*.

There is no doubt that the global horse and mule population dropped from the early decades of the twentieth century. Horses disappeared from rich cities and from the fields of rich countries. Yet in some parts of the world not only did animal traction remain important, but became more important as animals replaced human power. In one dramatic case, animal power replaced tractors. Cuban agriculture was transformed from the early 1960s with Soviet and east European agricultural machinery and supplies, leading to a downgrading of animal traction. But the collapse of the Soviet bloc in 1989 led the Cuban government to develop an animal traction programme. The agricultural horse population recovered, but the main focus was on oxen. They were

37 R. L. DiNardo and A. Bay, "Horse-Drawn Transport in the German Army," *Journal of Contemporary History* , 1988, 23:129-41

38 This compares with 300 draught horses in a Saxon division in the Napoleonic wars (a 1:20 draught horse:man ratio). http://www.napoleon-series.org/military/ organization/c_saxon11.html. I have seen estimates for the grand armée of around 50,000 draught horses for an invading army of around 400,000.

bred and trained in large numbers, and the technical infrastructure needed to use them was built up. The recovery in the number of oxen was spectacular. Numbers had fallen from 500,000 in 1960 to 163,000 in 1990 but increased to 380,000 in the late 1990s. These huge numbers of oxen replaced 40,000 tractors. [39]

Not Alphaville but bidonville: technology and the poor megacity

The story of the poor world and technology if it is told at all is one of transfer, resistance, incompetence, lack of maintenance, and enforced dependence on rich-world technology. Imperialism, colonialism, and dependence were the key concepts, and the *transfer* of technology from rich to poor, the main process.[40] There have been calls for the decentring of the standard 'western' account of technology, and thus for example, not to judge Chinese technology of the 18th century, say, by the standard of standard stories of British technology: different technologies were central.[41]

39 M. Henriksson and E. Lindholm, "The use and role of animal draught power in Cuban Agriculture: a field study in Havana Province", *Minor Field Studies 100*. (Uppsala: Swedish University of Agricultural Sciences, 2000), citing Arcadio Ríos, *Improving animal traction technology in Cuba* (Havana: Instituto de Investigación Agropecuaria 1998).

40 For an excellent review which parallels many of the arguments developed here see David Arnold, 'Europe, Technology and Colonialism' (cit. n. 30)

41 Francesca Bray, "Technics and Civilisation in late Imperial China: an essay in the cultural history of technology", *Osiris* second series, 1998, 13:11-33. I would make the additional point that we should not believe that the standard story applies to the industrialised 'west' either. Bray does not challenge the innovation-centredness of most accounts of western technology. Indeed, while one would expect anthropologists,

That is a crucial point, yet studies of technology in the poor world in the nineteenth and twentieth centuries, even by post-colonial historians, focus precisely on (some) technologies brought from the rich world. The case of the 'green revolution' has been mentioned. But the list is longer. Thus Gyan Prakash notes that to 'speak of India is to call attention to the structures in which the lives of its people are enmeshed – railroads, steel plants, mining, irrigation, hydro-electric projects … and now, the bomb'. [42] The long list he produces hardly includes anything which did not come from outside India, and was not central to Western accounts of modernity. This is far from unusual, for most studies of that well-studied case of India, when dealing with 'technology', take this to mean railways, dams, does not include, to anything like the extent merited, the technologies most Indians used (though one should not underestimate indeed the importance of such things as railways in India). The interest is not primarily in the material basis of Indian life, but in technology, which almost by definition it seems, comes from the West, and is defined by what counts as technology in the histories.[43] This is not to say we should not study railways,

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archaeologists and so on to concentrate on use of established technologies, nevertheless in practice, innovation becomes central when 'technology' comes into the frame. Thus Pierre Lemonnier's notes of his own collection of essays that 'most papers are concerned [not with invention but] with a subsequent step of the process of innovation, that of "choosing" what to do with a new technical element, whether it has been contrived locally or not'. Pierre Lemonnier ed., *Technological Choices: transformation in material cultures since the Neolithic* (London: Routledge, 1993), p. 21.

[42] Gyan Prakash, *Another Reason: science and the imagination of modern India* (Princeton: Princeton University Press, 1999), p. 3.

[43] See for example the papers covering the 20th century in Morris Low (ed.), *Beyond Joseph Needham: Science, technology and medicine in*

dams, or nuclear weapons in the poor world – far from it. It is to say that they do not exhaust the category 'technology' in the poor world (just as it does not in the rich world), even that which originated in the rich world. Whatever the view taken of what technology has done in the poor world, what 'technology' is has not been seriously debated.[44]

We don't have a good account of the distinctiveness of the new poor world as it emerged in the twentieth century. We have neither an appreciation of the significance of 'traditional' technologies – whether the crucial agricultural ones or any others – nor those brought by colonising states, nor indeed that came in from the rich world through to native populations though trade, like the neglected cases of consumer durables like the bicycle and the sewing machine.[45] Yet we need to go further and see the poor world as a distinctive *technological* world, not merely a derivative one, or one which was a hybrid of rich and poor worlds. The poor world was particularly fast-growing and changing in the twentieth century. It depended on a complex, original and changing technological landscape which included, importantly, mass

East and South East Asia, *Osiris* second series, 1998, 13; Roy MacLeod and Deepak Kumar eds., *Technology and the Raj: Western Technology and Technical Transfers to India*, 1700-1947 (New Delhi: Sage 1995); David Arnold, *Science, Technology and Medicine in Colonial India* (Cambridge: Cambridge University Press, 2000).

44 For some white European intellectuals in the interwar years, a critique of western industrial civilisation was built on celebration, often with noble savage overtones, of the ancient less corrupted cultures of Africa and Asia. A very few non-white intellectuals, and fewer African and Asians were themselves putting this forward, among them Rabindranath Tagore and Mahatma Gandhi. See Michael Adas, *Machines as the Measure of Men: Science, Technology and ideologies of western dominance* (Ithaca: Cornell University Press, 1989), pp. 380-401.

45 A point also well made by David Arnold, "Europe, Technology and Colonialism" (cit. n. 30).

technologies first developed elsewhere but used in distinctive ways. The technologies of the poor megacity, and particularly the materials from which is has been made, are a key case: they represent, today, a distinctive, new technology of poverty.[46]

It is easy to underestimate the importance of the poor city in the twentieth century. Through the twentieth century they have growth at remarkable rates, as the poor world grew in population much faster than the rich world, and urbanised quickly too. By the end of the century (in stark contrast to the beginning) most of the largest cities of the world were poor places: where once Paris, London, and New York led in scale and opulence, the largest cities of 2000 were places few would seek to emulate: São Paolo, Jakarta, Karachi, Mumbai (Bombay) Dhaka, Lagos, and Mexico City. These cities did not replicate the earlier experience of Berlin or Manchester. These were not cities of horses, or of trains, or spinning mules, or great electrical or chemical industries. They do not conform to the standard story of modernity.

Central to this new urbanisation was the growth of the slum, or shanty town, though we must beware this language, for the terms used describe many different types of housing. For example the *favelas* of Rio de Janeiro are connected to electricity and water while the *asentamientos* (settlements) of Guatemala City are dark at night. At first sight, the term slum might refer, as it generally did in the rich world, and in many parts of the poor world, to decayed old

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46 Gustavo Riofrio and Jean-Claude Driant *¿Que Vivienda han construido? Nuevos Problemas en viejas barriadas*, (Lima: CIDAP/IFEA/TAREA 1987).

parts of cities where the poorest lived. But in the later twentieth century in particular a new kind of slum, a newly-built, one might say purpose-built one, arose. The optimistic term 'pueblos jovenes', or young towns, used to describe the slums of Lima says something important about them. Shanty towns were built without architects or engineers or building contractors, or according to building regulations; they were not made for cars or trains, let alone the information super-highway.

We need to be particularly wary of the characteristic definitions of slums in terms of the *lack* of facilities characteristic of rich cities, like permanent structures, particular forms of sanitation, or electricity. We need to ask not what technology the shanty town *lacks*, but what it has. For poor cities had particular and often novel systems of building, of sanitation, or supply of water, of food and all the other necessities of life, which were not traditional but new. They proved capable of sustaining a new kind of rapidly expanding urban existence on an enormous scale, even if usually a miserable one. One modern technology of the slum was the Kenyan 'flying toilet'. A plastic bag, that ubiquitous product of the post-Second World War chemical industry, was used not only to defaecate into, but to dispose of what was once quaintly called night soil: the bag was tied, taken outside, swung around, and hurled away as far as possible from one's patch.[47]

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[47] *Slums of the World*, p. 25 – quoted in Mike Davis, "Planet of Slums", *New Left Review*, second series, 2004, 26:5-34.

The modern materials from which many slums are built is sometimes inscribed in their very names. The early temporary slums of North Africa were known as *bidonvilles*, for the buildings were made from opened-up and flattened-out oil drums (‘*bidons*’). The term is now generic in French. The Arabic term for *bidonville* in Morocco is *mudun safi*, ‘metal towns’. The Durban slum dwellings are called *imijondolos* in Zulu, possibly derived from the use of wood from crates that had carried John Deer tractors in through the port in the 1970s.[48]

One material stands out in the development of the poor world, rural and urban, and that is ‘corrugated iron’, ‘galvanised iron’ used for making ‘tin roofs’. In the nineteenth century, it spread around the world to areas of British army operation as transportable housing. It also became a key material for building roofs and walls of white settler communities in Australia, New Zealand, and the Americas, where it is now of interest as a vernacular architecture. It was hugely important in the twentieth century as a truly global technology. Its cheapness, lightness, ease of use, and long life, made it an ubiquitous material in the poor world in a way it never had been in the rich world. A visitor to West Africa in the Second World War noted of ‘Ibadan, then the largest town in black Africa. … [it] had grown in less than a century from a local market into a city with nearly 100,000 inhabitants – though alas, as so often in Africa, the houses

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48 http://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/Durban.pdf *Understanding Slums: case studies for the Global Report on Human Settlements* Development and Planning Unit, UCL. See http://www.ucl.ac.uk/dpu-projects/Global_Report/

were mostly roofed with galvanized iron'.[49] Today Ibadan is at one end of a shanty-town corridor of 70 million people.[50] Its roofs, to judge from aerial photographs, are still rusted corrugated iron.

Corrugated iron was not just an urban technology. It was used to replace thatch roofs on traditional rural buildings as well. In Rwanda corrugated iron was first used by the Belgian colonizers for their public buildings. By the end of the twentieth century a lighter type was the standard roofing material of even the poorest homes. Farmers' houses build of adobe had corrugated iron roofs, and were called *terres-tôles* (earth-sheets). As the only part of the house villagers cannot make, the iron roof became a prized possession, it was looted from Tutsis homes in the genocide of 1994. As the tables turned, Hutu refugees trudged to the Congo bearing sheets on their backs, others buried them in their fields.[51]

As in other technologies, there has been innovation in corrugated iron, in both shapes and materials. It has become lighter and stronger, available in many more grades and types. New shapes of corrugations have been used, and new coating introduced. Yet the long-established sinusoidal corrugations still dominate the cheapest grades.

A second key cheap and new material was asbestos cement, especially corrugated asbestos-cement. Asbestos-

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[49] Julian Huxley, *Memories* (London: Allen & Unwin, 1970), Vol. 1, p. 269

[50] Mike Davis, "Planet of Slums", p. 15.

[51] Jean Hatzfield, *A Time for Machetes. The Rwandan genocides: the killers speak*. (London: Serpent's Tail, 2005), pp. 71-75 [First published in French, 2003].

cement was patented in 1901 by an Austro-Hungarian, Ludwig Hatschek, an asbestos producer. He called his invention ‘Eternit’, and the material and the name have both been long lasting. Production started by a Swiss company of the same name in 1903, which became a major multinational with branches all over the world. Eternit still means asbestos-cement in many places; in others it was called ‘Uralite’ or ‘Uralita’. Although this is not always clear, by far the main use of asbestos – a fibrous mineral – has been for the manufacture of asbestos-cement (also known as fibro-cement), and the main uses of this material were corrugated roofing, sheets for building work, and water and sewage pipes. It has been a key material in modern urbanisation. At the beginning of the century it was primarily used in North America; after the Second World War its use boomed in North America, and particularly in Europe, but growth took off in Asia, South America and Africa in the 1960s and 1970s.[52] Unfortunately asbestos was found to be a serious carcinogen, and its use was progressively banned in North America, Europe and elsewhere. As a result, world production fell from the mid-1970s. But at the end of the century production was still at the levels of the 1950s. Even in the

52 The ten largest consumers of asbestos 2000 were Russia 446,000 tons; China 410,000 tons; Brazil, 182,000 tons; India 125,000 tons; Thailand 120,000 tons; Japan 99,000 tons; Indonesia 55,000 tons; Korea 29,000 tons; Mexico 27,000 tons; Belarus 25,000 tons, and these countries accounted for 94% of the world total. Robert L. Virta *Worldwide Asbestos Supply and Consumption Trends from 1900 to 2000* (Reston , VA: U.S. Geological Survey), http://pubs.usgs.gov/of/2003/of03-083/of03-083-tagged.pdf

1990s in South Africa, 24% of new subsidized housing had asbestos-cement roofing.[53]

The Martinican/French writer Patrick Chamoiseau, in his novel *Texaco,* the great novel of the shanty town, reflected a new understanding of the poor city that was emerging in the 1960s and 1970s. In *Texaco* the history of Martinique is divided into the age of the ajoupas (shelters) and long-houses, the age of straw, the age of crate wood, the age of asbestos (fibro-cement), and the age of concrete, reflecting the key materials of the shanty towns.[54] In the age of asbestos, asbestos-cement sheet was used for walls; the roofs were of corrugated iron. Thereafter the people bought the occasional a bag of cement to make their world more stable and secure. One of the characters in the book is a new model urbanist who began to understand this novel kind of city. Indeed, 'self-help housing', and '*auto construcción'*, became terms of art in urban planning, recognising that houses were being built in vast numbers, well outside the standard networks of modernity.

Creole technologies

Corrugated iron, asbestos-cement, and cement were not invented in the poor world, they were first exported to it, and then locally-produced. The growth of the poor world went along with a massive increase in use of these 'old' tech-

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53 Appendix 8 of *The socio-economic impact of the phasing out of Asbestos in South Africa, a study undertaken for the Fund for Research into Industrial Development, Growth and Equity (FRIDGE), Final Report* http://www.nedlac.org.za/research/fridge/asbestos/

54 Patrick Chamoiseau, *Texaco* (London: Granta, 1997).

nologies from the rich world, and yet also, importantly, it was a story of the spread of distinctive uses of these technologies. One can usefully describe them as *creole* technologies, not least as a way of pointing to the fact that most technologies in use are to varying extents creole. By a creole technology I mean one which finds a distinctive set of uses outside the time and place where it was first used on a significant scale. Thus it is to be distinguished from transferred technologies, though I include the latter in cases where the transferred technology is essentially no longer in use in the originating territory. Often, but not necessarily, these technologies originating elsewhere combine in original ways with local technologies, forming hybrids, which not only combine creole technologies with local technologies, but also themselves become new creole technologies.

We can explore these points further by examining the meanings of the term creole (*criollo* in Spanish, whence the term comes). The original meaning of creole is local derivatives of something originally from elsewhere, used specifically to describe the locally-born white and black populations of the Americas – descendants of European settlers, *and* African slaves, in contradistinction to the indigenous population. Creole means derived from, but different to, the originating case. Thus the creole horse of the Americas, originating from beasts brought by the Spanish and Portuguese conquistadores, entered a horseless world, yet became different from the horses of the Old World. The term creole also carries the sense of earthy, local, genuine, vulgar, popular, in contrast to the sophistication of the metropolitan. These are the senses in which I use the term here. Yet I also allow into it elements of another sense from which it generally needs to be radically distinguished. In the United States in particular the term has come to be associated with hybridity, that is the mixing of traditions, races, cultures, and this is the sense in which it has found limited use in the history of science.[55]

The most straightforward sense of creole technology is that the basic imported technology got a new lease of life in the poor world. There were many cases of late adoption and long use in the poor world of rich-country technologies. A small example would be that carrier pigeons were introduced to the police services in Orissa (India) in 1946 and were only phased out in the 1990s. The Indian motor-vehicle industry provides some better-known examples. From the 1950s the 1955-model Royal Enfield Bullet motorcycle was manufactured in India. Production of the same model continues to this day at the rate of 10,000 a year in the original Madras factory, and with methods which still involve little assembly-line work. Hindustan Motors in Uttarpara, West Bengal still make the Ambassador, based on a mid –1950s Morris Oxford Series II motorcar. Production started in 1957 and to date 800,000 have been produced. The history of the Volkswagen Beetle is a particularly notable case given the

55 Stuart George McCook, *States of Nature: Science, Agriculture, and Environment in the Spanish Caribbean, 1760-1940* (Austin: University of Texas Press, 2002); Peter Galison, *Image and Logic: a material culture of microphysics* (Chicago: Chicago University Press, 1997). It is also used for languages – the languages of languages of the ex-slaves of the colonies, principally in the Caribbean that went from 'pidgin' simplified versions of English French, Portuguese, Spanish etc, to become separate 'creoles'. On language see Ronald Segal, *The Black Diaspora* (London Faber, 1995) chapter 34. The concept of 'hybridity' has been in vogue for a while in many fields, now including the study of technology. See Mikael Hård & Andrew Jamison, *Hubris and Hybrids: A Cultural History of Technology and Science* (London: Routledge, 2005).

scale of production of the car. By the early 1970s it had overtaken the Model T Ford as the car most widely produced in the world (15m), and it would continue to be produced, reaching a total of 21m. The end of production came in Mexico in 2003, where it had been in made since 1954. Brazilian production stopped in 1986 and restarted in 1993, and finally came to an end in 1996, long after finishing in Germany.

Communist China had its own distinctive attitude to old technologies of production, which provide examples like those above, and also an interesting variant. It pursued a 'walking on two legs' policy of industrialisation that has been called 'technological dualism'. The first leg was large-scale, urban, factory production, using models brought from the Soviet Union. This was a huge effort of transfer of technical skills, models, designs, and factories – China long remained a producer of Soviet technology. Till the end of the 1980s China was making Soviet trucks and steam locomotives from the 1950s. Steam train buffs flocked to the sidings and marshalling yards of China, for only in mid 1980s did diesel and electric locomotives overtake production of steam.

The second was locally run, small scale industry, reliant on local raw materials, and supplying local needs, usually the agricultural sector. These industries were based on centrally-supplied designs of technologies, usually themselves based on 'old' technologies that had gone out of use elsewhere in the world. From the late 1950s – 'backyard iron and steel' production, together with small-scale cement kilns, fertiliser plants, agricultural machinery workshops, food processing works, power generation, and mining, boomed under the Great Leap Forward. Fertiliser production was a rare example of a novel technology, for local fertiliser plants made a fertiliser used nowhere else in the world – ammonium bicarbonate.[56] The Great Leap cost the lives of millions and resulted in the waste of precious technical and natural resources. With its failure many local enterprises closed. But many did not, and survived till the next great expansion phase for these industries, the Cultural Revolution. By 1971 60% of fertiliser production came from small plants; 50% of cement; 16% of hydro generating capacity; overall around 10% of Chinese factory output.[57]

Varieties of creole transport technologies

Transport in the poor world provides rich examples of creole technologies of a kind which showed important elements of technical change. The poor megacities of the East had different transport patterns from the great rich cities of 1900, or even of 1930, but had transportation technologies which were in the most part derived from those common in these rich cities. Yet the patterns of development were differrent. Rich world cities never had, for example, the bicycle or motor-cycle densities of the megacities of late twentieth-century Asia. Indeed bicycle and motor bicycle production boomed in the world, particularly in the poor world, from the 1970s. For the first time in many decades bicycle produ-

56 Carl Riskin, "Intermediate Technology in China's rural industries", in *Appropriate Technologies for Third World Development*, ed. Austin Robinson (London: Macmillan, 1979), pp. 52-74.

57 Carl Riskin, "Intermediate Technology".

ction surged ahead of motor car production. In recent years around 100m bicycles were produced every year and only around 40 m cars. In 1950 there were around 10m of each, remaining about equal to 1970. The great change was the expansion in Chinese production to 40-50m bicycles from a few million in the early 1970s.[58] In addition Taiwan and India between them were, at the end of the century, making more bicycles than were produced in the world in 1950. Not only that but bicycle-derived technologies of the poor megacity provide an instance of a rich instance of creole technology.

In 2003 it was reported that the City of Calcutta was still trying to get rid of the hand-pulled rickshaw, long gone from most of the rest of Asia. These rickshaws were deemed old-fashioned even by the standards of long-gone hand-rickshaws: Calcutta's had spoked wheels, but not ones derived from bicycle technology: they were made of wood, and were rimmed with solid rubber rather than pneumatic tyres. Surely these were survivals from the distant past?

In fact the hand-pulled rickshaw, far from being an ancient invention, was apparently devised in Japan in the 1870s, though similar things had been in use in Europe on a small scale. The rickshaw replaced the palanquin/sedan chair. Use boomed from the very late nineteenth century, first in Japan, where numbers peaked around 1900. Use quickly spread in Asia. In Singapore their numbers peaked in the early 1920s, while Calcutta saw hand-rickshaw growth in

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58 See the statistics in World Watch Institute, *Vital Signs 2003-2004* (London: Earthscan, 2003) and earlier editions.

the 1920s and 30s. In most places the hand-rickshaw went out of use after the Second World War, condemned as a barbarous machine humiliating the poor pullers.

The cycle-rickshaw (sometime called a trishaw) was, as an invention, almost as old as the rickshaw; yet as a thing-in-use it peaked even more recently.[59] Developed in the 1880s, it found hardly any use until around 1929 in Singapore, where by 1935 they outnumbered hand-pulled rickshaws. They appeared in Calcutta around 1930, Dhaka around 1938; and Jakarta around 1936. By 1950 they were present in every country in south and east Asia. Japan had never had many. There were variations in design across countries but relatively little within countries. The most common was that with the passenger sitting behind the driver (India, Bangladesh, China, the Macao 'triciclo'). But the version with the passengers forward of the driver was also common, for example the Indonesian 'becak', Vietnamese 'cyclo', and the Malysian 'trishaw'. Others had the passenger to the side, as in the Philippines 'sidecar', the Burmese 'sai kaa', and the Singapore 'trishaw'.[60]

Far from disappearing after the Second World War, the number of cycle rickshaws continued to *expand* rapidly in the 1960s and 1970s. It was estimated in the late 1980s that there were 4 million in world, and that the number was still increasing overall though in some countries there were decreases. Dhaka was the capital of the cycle rickshaw with

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59 I am indebted to a marvellous book: Rob Gallagher, *The Rickshaws of Bangladesh* (Dhaka: The University Press, 1992).

60 See Tony Wheeler and Richard l'Anson, *Chasing Rickshaws* (London: Lonely Planet, 1998).

some 300,000 at the end of the twentieth century. A subsequent creole technology, unknown in the rich cities of the world is the scooter-based taxi. From the 1950s these 'auto-rickshaws', appeared in India, based on the scooter. Similar designs have spread all over Asia (for example the Thai 'tuk-tuk' and the Bangladeshi 'baby-taxi').

The cycle rickshaw was an urban, not a rural, machine. It followed, rather than preceded, seemingly newer transport techniques. Rickshaws needed the metalled roads which were built for cars and buses and lorries. Yet in the great expanding cities of Asia they were seen as demeaning technologies of poverty, and as technologies of the past that needed to be got rid of. The city governments of Asia, whether colonial or post-colonial, wanted to control them, restricting licenses, and indeed in places banning them outright. Yet if governments had success in getting rid of machines like the spinning mule in the middle of the century, they failed miserably in the case of the rickshaw, for numbers, as we have seen, continued to rise. They have now appeared in places they had never been before, including central London, where they now operate regularly from the Soho entertainment district.

Water transport provides some good examples of creole technologies, in particular of creole technologies used in hybrids. In Bangkok the great river which runs through that megacity is home to a remarkable breed of craft. Long, thin, wooden boats have been converted to a species of power-boat by the addition of a large car engine mounted on gimbals which powers a propeller on the end of a long shaft. The operator controls the boat by moving the whole engine and associated propeller, a brilliant variant of the outboard motor. The 'long-tailed boats' first appeared in Bangkok, but have since spread through Thailand, not just for the tourist trade, but as a standard means of powering a boat. The tails are made in Bangkok and cost $100; engines can be bought for around $600, compared with a motorbike at $500.[61] They are also present on the Mekong, in Cambodia and Vietnam, and some say on the Amazon in Peru.

Another case of a creole technology is the use of irrigation-pump motors in the 'country-boat' of Bangladesh, a country where millions depended on water transport. These boats, hand built by itinerant, and miserably poor, boat builders, were decreasing in use, as they lost out to land transport. It was in the north west of Bangladesh that they were transformed in the early 1980s. New wells, powered by petrol pumps, were installed there, but these were idle most of the year. An anonymous engineer used one of these engines to drive a boat; by the late 1980s many were used in the wet season and on market days in the dry season. Increasingly engines were permanently fitted, but irrigation-pump engines remained the most popular since they were subsidized. The transplantation of the engine to a new context resulted in a new kind of hybrid boat. In the 1980s iron sheet started to be used to make boats. For bigger boats, recycled steel plates from the shipbreakers on the coast began to be used.[62]

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[61] Informal interviews with a number of Thai tour guides etc, 2001

[62] Erik E. Jansen et al, *The Country Boats of Bangladesh social and economic Development and decision-making in inland water transport* (Dhaka: The University Press, 1989).

The use of creole technologies in new hybrids, which can themselves be called creole technologies, is a common feature of the modern poor world of the twentieth century. In many parts of the world donkey carts were made using motorcar axles and especially wheels. Wooden fishing boats of the most primitive sort were made much more efficient by synthetic fishing nets; larger wooden boats of craft construction were fitted with engines, with radar, and with sonar as a visit to any number of the world's small fishing ports will confirm.

An extreme case and some conclusions

I have used the concept of creole technologies to suggest that the technology poor world cannot be reduced either to its stock of rich world technologies, or traditional, local technologies, or hybrids between the two. A new technological world of technologies derived and adapted from those of the rich world in complex ways, and then often entering into hybrids, are some of the complexities the term seeks to capture. Yet while the term is very suggestive, it reaches the end of its usefulness when confronted with some technological novelties in the poor world. While it can usefully, for example, be used to conceptualize in a richer way than transfer, not only the cases discussed above, but also, for example, the development of industrial production in the poor world, it becomes problematic when confronted with the novel phenomenon of absolute technological retrogression at a global level, graphically illustrated by shipbreaking.

After the Second World War, as especially since the 1960s, Taiwan became a major force in the ship-breaking industry, using purpose-built facilities in Kaosiung. In the 1980s Taiwan was the largest shipbreaker by far, demolishing more than 1/3 of the world's ships. By the early 1990s Taiwan was out of this industry, which was now dominated by India, Pakistan and Bangladesh, which between them had more than 80% of the world market by 1995.[63] Demolition was done on beaches, far from electricity let alone any docking facility, and was carried out with the most minimal equipment by thousands of barefoot workers. It is not too fanciful to suggest that ship-breaking was more capital intensive in 1900 than in 2000. It makes no sense to see Arabian Sea and Bay of Bengal shipbreaking as an old, let alone traditional industry, which has survived into the twenty-first century. It is a new kind of new industry. As shipbreaking moved geographically it, for the first time, retrogressed leaving practically no more capital intensive operations in existence.

I hope I have suggested that looking at technologies-in-use, and looking at them globally, points to the signifycance of whole new technological worlds which have emerged in the twentieth century which have hitherto had no place in histories of technology. Understanding their significance involves much more that adding some hitherto neglected technologies to our histories, or simply of placing

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63 Martin Stopford, *Maritime Economics*, (London: Routledge, 1997), second edition, pp. 485-6. See also the excellent William Langewiesche, "The Shipbreakers", *The Atlantic Monthly*, 2000, 286(No. 2): 31-49. Thanks to Eric Schatzberg.

technologies in new geographical and chronological spaces: it involves rethinking the whole map of technological history.

This paper is not meant as programmatic – it does recommend a particular way of studying the history of technology. It does not call, for example, for a history of the use of technologies, or that of technologies-in-use; nor does it call for the study of what many would regard as peripheral technologies, like corrugated iron. If it calls for anything it is for the history of technology to ask and answer historical questions, to engage in historical and other debates. It argues that to do this we need to attend very carefully to nature of the standard narratives that are at work in *today's academic* histories, which, for example, privilege the 'question of technology'; conflate invention/innovation/technology and equate technology with the rich world, or the internal study of technology with invention, and much more besides. For all the rhetorical decentring, deconstructing, incredulity towards meta-narratives, there is too often in our studies an implicit credulity towards *some* meta-narratives. For example, for all the tilting at Whig history, technological determinism and linear models, it is hardly difficult to note the continuing importance, in the very same works that criticize these, of historical models and agendas of a very familiar sort. We need to be aware of these models and their power, so that we can ask fresh historical questions. Depending on the historical question asked, and they might be big or small, global or local, we might answer with a history of invention, a history of technologies in use, an internal study of technologies, either as they are made or are in use, and do each of these and many other kinds of studies in many different ways. That includes the history of invention and innovation, which itself looks different once it is released from its conflation with the history of (some) widely used technologies, and is treated both in its own right, and in relation to the history of technology-in-use. A global history of invention, which will necessarily be a history largely of failure, and only partially of R&D and patents, is still to be written, but it is one in which the poor world will also have a place, and one in which the rich world will look different too.

Skulls without words:

the order of collections from Macao and Timor, 1879-82

By Ricardo Roque[*]

Introduction

This article explores the emergence of silent museum objects by analysing a segment of the history of one collection of human skulls. In 1882, a set of thirty-five human skulls from the Eastern half of the island of Timor, a remote and isolated colony of the Portuguese empire in Oceania, was received at the Museum of Coimbra University, where the collection continues to be held today. The skulls were sent by the provincial colonial authorities at Macao, then also a colony of Portugal, included in a larger and heterogeneous consignment of objects destined to the Colonial Museum in Lisbon and to Coimbra University. In

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taking this episode of travelling of an object collection, this paper touches upon a topic that has been recently feeding on a lively field of studies in anthropology and the history of science. Historians of science have been calling attention to the inherent biographical historicity of 'scientific objects' while, within anthropology, 'material culture studies' have flourished around the idea that objects are in a state of becoming as they move through different cultural contexts and are put to different uses.[1] Circulations of objects in space and time, their 'biographies', can thus be used either to discuss the formation of scientific knowledge, or to access the cultures and meanings of people.

The methodological focus on the movements of things can be a fruitful point of departure in the historical study of museum objects, but a particular approach to the study of these 'movements' is here proposed. In offering a glimpse of the history of this collection, I am interested in bringing out the work and the contingencies that intervened in the

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[1] Lorraine Daston, ed., *Biographies of Scientific Objects* (Chicago: University of Chicago Press, 2000); Igor Kopytoff, "The Cultural Biography of Things: Commodification as Process', in *The Social Life of Things: Commodities in Cultural Perspective*, ed. A. Appadurai (Cambridge: Cambridge University Press, 1986), pp. 64-94; Arjun Appadurai, "Introduction: Commodities and the Politics of Value", in Appadurai (ed) *The Social Life of Thing*s, pp. 3-63; Nicholas Thomas, *Entangled objects: exchange, material culture, and colonialism in the Pacific* (Cambridge, Mass.: Harvard University Press, 1991); Chris Gosden and Yvonne Marshall "The Cultural Biography of Objects", *World Archaeology,* 1999, *31*:169-178. The 'travels' of collections across national and imperial networks have also been a focus of interest in the history of natural history. See Nicholas Jardine, James Secord and E. C. Spary, eds., *Cultures of Natural History* (Cambridge: Cambridge University Press, 1995); Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994).

shaping of the attachments of words and things.[2] The object of analysis, though, is not the travelling of 'objects' *per se*. It is the unfolding of 'attachments', in Bruno Latour's phrase, the trajectories of the links between words and things, texts and solid objects. The purpose is not a description of the viewpoints that add different meanings to objects as these pass through different cultural contexts. Instead, it is the exploration of the 'engagement of things into discourse' and of how this 'engagement' is embedded in practice.[3] The paper then offers a description of the work involved in making and unmaking associations between words and materiality, by this means hypothesizing that the presence, quality, and durability of these associations plays a central role in the constitution of museum collections. A particular attention is paid to these associations as process of circulation located outside the geographical boundaries of museums. 'Circulation' expresses here every regime of practices affecting not just the temporal and spatial movement of a material body, but also its constitution as object of knowledge. The argument is that a set of physical 'things' comes into being as a 'museum collection' through the complexities, practicalities, and contingencies of holding

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[2] Heuristically, this focus on words and things also finds inspiration in Foucault's seminal discussion of the problem of the 'order of things' (cf. Foucault, 2002).

[3] See Bruno Latour, *Pandora's Hope. Essays on the Reality of Science Studies* (Cambridge, Mass.: Harvard University Press, 1999), p. 48. For arguments on the 'embeddedness' of scientific things in heterogeneous networks see also Hans-Jörg Rheinberger, "Cytoplasmic particles. The trajectory of a scientific object", in *Biographies of Scientific Objects*, ed. Lorraine Daston, (Chicago: University of Chicago Press, 2000), pp. 270-294; Lorraine Daston, "Introduction: the coming into being of scientific objects', in *Biographies of Scientific Objects*, ed. Daston; pp. 1-14.

together and/or setting apart texts and physical objects in the very process of their circulation.

Because the quality of things as museum objects is approached as a function of their attachments to words and texts, museum things in circulation can emerge with different degrees of visibility and invisibility, with diverse modes of association with words and with silence. This dynamic is in effect a striking and puzzling feature of the story of the collection of skulls sent from Macao in 1882. For it was without words that the collection of skulls reached the museum at Coimbra. In this regard, this paper represents an attempt to make sense of absences, silences, and blank spaces in epistemic orderings as a particular effect of classificatory and discursive arrangements.[4] How and why can things be silenced? Under what conditions, for instance, can discursive practices and classification systems produce 'things without words' rather than things associated with signs and inscriptions? And what are the consequences of such absences for science-making?

This paper is concerned with explaining how such silences come into emergence by analysing the skulls' *dynamics of attachments*. This means that silence is not a prearranged property of physical things, but an unstable outcome of practices and circumstances. 'Things-in-them-

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[4] The 'exclusion' and the rejection of discordant or 'anomalous' elements, as Michel Foucault and Mary Douglas respectively argued, are critical to the functioning of discursive orderings and systems of symbolic classification. See Michel Foucault, *L'ordre du discourse* (Paris: Gallimard, 1971); Mary Douglas, *Purity and Danger. An analysis of concept of pollution and taboo* (London: Routledge, 2002). However, I here suggest that discordant elements might also be ambiguously present in the silent zones of classificatory and discursive arrangements.

selves', in other words, can be viewed as *one* possible ontology of things that comes into being in practice.[5] From this perspective, I argue that the attachment of things to silences can be the consequence of the contingent travelling of objects and the work done with a view to meaningfully ordering sets of physical materials. The attempts at arranging a varied array of things as 'a museum collection' can produce discursive absences, as much as it can generate things thickly embedded in words. The narrative that follows thus traces the epistemic and material interactions between things and words, as they emerged in practice throughout the travel of that Timorese collection from Macao to Lisbon. Although I will not be able to examine this issue here at length, it should be pointed out that the understanding of this circulatory dynamic of attachments can explain how physical objects might become, or become not, suitable for museum science. How is, for instance, proper scientific knowledge possible when the 'real world' comes to the hands of museum anthropology practitioners in the form of collec-

5 Eventually this interferes with a pervasive tendency in the history of anthropological collections to consider the silence of things as paradigmatic property of museum objects in nineteenth century anthropological culture; the late-nineteenth century anthropologists – some scholars have argued – valued things as 'self-sufficient data'. In contrast, I am interested in tracing this 'property' in emergence. See for example Michael O'Hanlon, "Introduction" in *Hunting the Gatherers. Ethnographic Collectors, Agents and Agency in Melanesia, 1870s-1930s*, eds. Michael O' Hanlon and Robert Welsch (Oxford: Berghan Books, 2000), pp. 1-34, on p. 2; George W. Stocking, Jr., "Essays on Museums and Material Culture", in *Objects and Others: Essays on Museums and Material Culture*, ed. George W. Stocking, Jr. (Madison: Univ. of Wisconsin Press, 1985), pp. 2-14, on p. 4.

tions of things devoid of appropriate 'references' or 'inscriptions'?[6]

In effect, to trace the knowledge-shaping practices of the collection of Timorese skulls before and outside the museum especially matters because later on and inside the museum the effects of such practices upon anthropological constructs could be considerable. The early configuration of links between skulls and words would turn out crucial for the claims of the Portuguese museum anthropologists who studied the collection of skulls. In the second half of the nineteenth century, human skulls from 'savage' populations and remote parts of the world were desirable scientific objects for museum scholars working along the principles of the emergent science of anthropology. They were expected to provide crucial evidence to the construction of a universal table of the 'races of men'. But the 'information' associated with skulls throughout their travels to the museum could bear greatly on the taxonomic endeavours of scientific practitioners. In 1894, an anthropologist at Coimbra University, Barros e Cunha, produced a craniological study about the collection with a view to classifying the races of Timor.[7] Yet, decades later, the validity of this study was to be dramatically questioned by colonial officers, who claimed the collection was not 'authentic' because the skulls sent from Macao and Timor in 1882 did not belong to Timorese

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[6] Scientists, Bruno Latour has stated, 'master the world only if the world comes to them in the form of two-dimensional, superposable, combinable inscriptions'. Latour, *Pandora's Hope*, p. 29.

[7] J. G. de Barros e Cunha, "Noticia sobre uma série de craneos da ilha de Timor existente no museu da universidade", *O Instituto*, 1894, *XLI*(14): 852-60; (15): 934-41; (16): 1044-48.

indigenous people. Instead, they represented a mixed group of Portuguese, Africans, Timorese, and Indians slaughtered by Timorese head-hunters in the course of colonial wars.[8] The skulls had arrived at the Coimbra museum in 1882 without words and texts indicating whereabouts and how they had been collected, or whose bodies they represented. This paper makes no claim to resolve this uncertainty. Rather, it is intended to explain how such 'uncertainty' could have arisen from gaps and twists in the trajectory of attachments of skulls and words, as the human remains were put to circulate as 'a collection' from Timor to Macao, and from Macao to Portugal.

The paper comprises two sections. The first section deals with the commercial orientation of the collection and the organizational form of the social networks that sustained the circulation of skulls between Macao, Timor, and Portugal. It describes the constitution of different government Committees in Macao and Timor and points to the resulting messiness and heterogeneity of Timorese object collections, regardless of Macao's attempts to provide clear commercial orientations. Human skulls were still invisible at this stage of the trajectory. For, as we will see in detail, they were not part of the original intentions of the Committee in Macao. From the standpoint of Macao, it was somewhat accidentally that the networks and the scripts in place by 1880 would later be activated to arrange the trajectory of a collection of skulls to

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[8] For a summary of this controversy see J. G. de Barros e Cunha, *A autenticidade dos crânios de Timor do Museu da Universidade de Coimbra, e o estado actual dos nossos conhecimentos sôbre o problema da composição étnica da população de Timor* (Coimbra: Imprensa da Universidade, 1937).

Portugal. The second section analyses the classification and description system according to which the Timorese collections were shaped at Macao. It is here shown the ways in which these practices condemned the objects that did not fit into the classification system of the collection to silence.

The commercial script and the heterogeneity of the Timorese collections

In 1877, the governor of the Province of Macao and Timor received instructions from the government in Lisbon to assemble a collection from Macao and Timor.[9] The orders were effectively executed at Macao only three years later, due to the initiative of the newly appointed secretary-general of Macao and Timor (a position ranking right below the governor), José A. H. Côrte-Real. Eventually Côrte-Real persuaded the provincial governor, José da Graça, of the importance of assembling a local collection of products to help invigorating the commerce between Macao and Lisbon.[10] In 1880, a government Committee composed of local officials and merchants, and headed by the secretary-general was put in charge of organizing a collection. Their task was 'to assemble, classify, coordinate and methodically exhibit the [Ma-

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9 In 1877 the governor of Macao and Timor was Carlos Eugénio Correia da Silva. See Carlos Eugénio Correia da Silva, "Portaria n.º 66. 25 de Julho de 1877", *Boletim da Província de Macau e Timor,* 1877, *XXII* (30):155.

10 J. A. H. Côrte-Real, "Relatório", *Boletim da Província de Macau e Timor*, 1880, *26*:172-73; *J. José da Graça to Secretary and Minister of the Navy and Overseas Affairs,* 16 May 1880, Lisbon, Arquivo Histórico Ultramarino (Overseas Historical Archive, hereafter cited as **A. H. U.**), Museu Colonial de Lisboa, Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744-766.

cao] products to be sent to the colonial museum in Lisbon and to the museum of Coimbra University'.[11] The assembling of object-commodities for the Colonial Museum was a formal obligation to the imperial government. The involvement of Coimbra University, however, had informal origins.

The Coimbra University traditionally attracted a great deal of official collections since the eighteenth century.[12] Yet, in this case the involvement of the university originated in a personal promise of Côrte-Real (a former student at Coimbra) to attend a request for botanical specimens formulated by Júlio A. Henriques, Director of the Botanic Garden and professor at the Faculty of Natural Philosophy of the Coimbra University.[13] Henriques was strongly involved in the reform of the natural sciences commenced at the university in the 1860s, and was then working hard to organise the decadent botanic garden and museum in the image of the Kew Gardens: rich botanic collections from Portugal and the

[11]Joaquim José da Graça, "Administração Geral. Portaria n. 51. 15 Maio 1880", *Boletim de Província de Macau e Timor,* 1880, *26*:172. All passages originally in Portuguese have been translated into English by the author.

[12] Until the creation of the Colonial Museum, the imperial government was in the habit of recommending objects collected by special expeditions or colonial authorities to the Coimbra University. For a survey of collections sent to Lisbon and Coimbra in the eighteenth and early nineteenth centuries, see Manuela Cantinho, *O Museu Etnográfico da Sociedade de Geografia de Lisboa: Modernidade, Colonização e Alteridade* (Lisbon: Fund. Calouste Gulbenkian, 2005), pp. 21-81.

[13] Côrte-Real graduated in Law at the university, and some members of the Faculty of Natural Philosophy were common friends of Henriques and Côrte-Real. Emotional reasons seem to have been important to Côrte-Real. He understood his dedication to botanic collecting as a gift in exchange for the invaluable education he received at Coimbra. See Côrte-Real, "Relatório" (cit. n. 10); J. A. H. Côrte-Real to Júlio Augusto Henriques, 4 June 1880, *Correspondence of Júlio Augusto Henriques.* Coimbra, Coimbra University – Archives of the Department of Botany (hereafter cited as **ADPUC**).

colonies were to be assembled so as to serve study and teaching and to be put on public view.[14] He held great hopes about Côrte-Real's collaboration, when, in 1878, he asked for his help: 'I then thought of resorting to various people', Henriques revealed in retrospect, 'who, by various means, could help me, and I lost neither my time, nor my work. Mr. J. A. Côrte-Real was then being appointed to the post of secretary-general of Macao. I addressed him and exposed him the wish of having again vegetable products from the colony in the museum [...]; soon he proved his promises had not been vain.'[15] With the creation of the Committee headed by Côrte-Real two years later, in 1880, the informal commitments to Coimbra and the formal obligations to Lisbon merged into a same project of collecting ruled by commercial principles. Consequently, botanical collecting became subordinate to economic guidelines.

In effect, the Macao Committee worked under the guidance of a clear strategic vision of the role and purposes of the collection. Following Akrich and Latour, this strategic vision might be termed a 'script'.[16] In Macao, the script of the

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[14] Henriques was also developing an interest in the study of the 'utility' of African plants, and in the coming years carried pioneer work on 'colonial agriculture'. See José Silvestre Ribeiro, *Historia dos estabelecimentos scientificos litterarios e artisticos de Portugal nos successivos reinados da monarchia* (Lisbon: Academia Real das Ciências, 1889) vol. XVI: 211-212, 230-231; Júlio Augusto Henriques, "O Museu Botanico da Universidade e as collecções de productos de Macau e Timor", *O Instituto,* 1883, *XXX*:60-65, esp. p. 60.

[15] Henriques, "O Museu Botânico...", pp. 60-61.

[16] The notion of script is borrowed from Akrich and Latour, who use it to designate the type of work done by the designers of 'technical objects'. See Madeleine Akrich, "The De-Scription of Technical Objects", in *Shaping Technology/Building Society. Studies in Sociotechnical Change,* eds. Wiebe Bijker and John Law (Cambridge, Mass.: Harvard University Press, 1992), pp. 205-24. Madeleine Akrich and Bruno

collection was chiefly mercantile, a 'commercial script' designed to assert the economic value of Macanese objects as profitable commodities in the then weakened trading networks of the Portuguese Eastern empire. A key trading post in Eastern commodities in the seventeenth-century, during the 'Golden Age' of the Portuguese maritime empire in Asia, Macao had then dramatically lost its economic importance. Portugal's imperial energies had turned away from India to Brazil, whist, in Asia, the Dutch and the British had been taking over the maritime trade. By the late 1870s, however, there was hope among the Portuguese community of officials in Macao. Many officials were convinced that the colony could attract capitalist investment and strengthen the ties with the motherland, thereby recovering its former spleendour as trading post.[17] Collecting was seen as a way of providing solution to the commercial problem. Indeed, the collections from Macao were made to respond to a principal concern of the colonial administration shared by the secretary-general Côrte-Real and governor Graça: the lasting decadence of Macao's trading relationships with Portugal.[18]

Latour, "A Summary of a Convenient Vocabulary for the Semiotics of Human and Nonhuman Assemblies", in *Shaping Technology/Building Society,* eds. Bijker and Law, pp. 259-65.

17 Fernando Figueiredo, "Os vectores da economia", in *História dos Portugueses no Extremo Oriente*, dir. A. H. de Oliveira Marques (Lisbon: Fundação Oriente, 2000), Vol. III: 93-296.

18 See J. A. H Côrte-Real, "O commercio e industria do chá em Macau e a Lei de 27 de Dezembro de 1870", *O Instituto,* 1879, *19*:113-29; *J. José da Graça to Minister and Secretary of the Navy and Overseas Affairs*, 20 Oct. 1881, Lisbon, A.H.U., Macao and Timor, ACL_SEMU_DGU_1R_002_Cx 3, 1882-1883. Attempts of colonial authorities to change the commercial situation of a territory by presenting collections of industrial and natural products to museums in Lisbon and exhibitions abroad finds parallel in other colonial settings, such as Goa and Angola. See Ricardo Roque, *Antropologia e Império:*

This 'commercial script' had local foundations, but the capitalist interests of the Macanese officials and businessmen were also in line with official concerns of the imperial administration in Lisbon. A similar preoccupation with imperial trade and economic progress was behind the creation of the Lisbon Colonial Museum. The Colonial Museum had been established by the Portuguese government in 1871 at Lisbon with the intention of restoring the empire as profitable commercial space by the assembling of natural and commercial objects from the colonies. Its official purpose was clear: 'to collect, preserve, and display for public examination the various products and objects that can help the knowledge, economic study, and profitable use of the varied wealth of our overseas possessions.')[19] The concentration of colonial raw materials and manufactured articles at the museum was envisaged as a strategy to restore the Portuguese empire as profitable commercial space. Throughout its twenty-two years of existence (1871-92), the Colonial Museum acted less as a space for permanent display than as an intermediary. In receiving colonial objects, it was responsible for organizing Portugal's representations to the World Exhibitions then mushrooming throughout Europe.[20]

Fonseca Cardoso e a expedição à Índia em 1895 (Lisbon: Imprensa de Ciências Sociais, 2001), pp. 336-37; Filipa Vicente, "The Colonies on Display: Representations of the Portuguese *Estado da Índia* in Exhibitions Abroad", 2003, *Estudos do século XX*, *2*:37-55.

[19] Cit. in Ribeiro, *Historia dos estabelecimentos scientificos* (cit. n. 14), p. 304; See also *Luís de Andrade Corvo to Governors of Angola, Cap Vert, St. Thomé, and Guinea*, 10 April 1891, Lisbon, A.H.U., Museu Colonial de Lisboa, Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744-766.

[20] The Colonial Museum also maintained a gallery for exhibitions at the Naval School in Lisbon. See Cantinho, *O Museu Etnográfico*, pp. 81-97.

From the outset, the Colonial Museum tried to take a position at the centre of flows of donation of colonial objects. Patriotism but also commercial profit was to inspire private donations. The museum organizers waved the profit caused by the mere exhibition of products in Europe as reason enough for traders, industrialists, and farmers to give samples of their products to the Colonial Museum, through the mediation of colonial authorities.[21] The participation of colonial authorities conferred upon the project the formal character of an enterprise internal to the institutional obligations and hierarchies of state administration. Because it was a bureaucratic obligation and a national project, the collecting of object-commodities for the Colonial Museum was to be part of the role-description of colonial officials. The colonial governors, therefore, could from time to time be ordered to send collections to the Colonial Museum, and it was on such an occasion that in 1877, as we saw, the government in Lisbon had instructed the governor of Macao and Timor to organise a collection 'proving the productive wealth of Macao and Timor', to be sent to the Colonial Museum and, then, forwarded to the Paris Universal Exhibition of 1878.[22]

The collecting activities of the Côrte-Real Committee in Macao soon produced significant results. In 1880, a collection of Macanese products was shipped to Lisbon and Coimbra with stately pomp. Before departure to Portugal, an exhibition of the collections – more than two thousand arti-

[21] See *Andrade Corvo to Governors of Angola, Cap Vert, St. Thomé, and Guinea*, 10 April 1891 (cit. n. 19).

[22] Silva, "Portaria n.º 66. 25 de Julho de 1877" (cit. n. 9).

cles 'which the Chinese use daily in ordinary life' – was held at Macao's Loyal Senate.[23] The exhibits included papers of different colours, rattan and bamboo 'in every shape and form', and many other 'nick-nacks' presented by merchants or bought by the colonial government at the local market. Provincial governor Joaquim José da Graça inaugurated the event with pomp and circumstance. It was 'the first Industrial exhibition ever done in the colony'.[24] The 'exhibition of articles in the museums' in Lisbon, governor Graça hoped, will make 'their qualities, applications and prices' known and therefore 'restore the commercial ties between Macao and the Kingdom'.[25] A few months later, the successful arrival of the Macanese collection at Lisbon and at Coimbra provided an occasion for celebration. The various authorities in Macao, Lisbon, and Coimbra presented the collectors with official eulogies on their honourable and patriotic action of giving their time to collect objects for the nation. In Macao, for instance, the governor recommended the Committee for royal medals, and published in the official Bulletin an encomiastic eulogy, most especially on his president, Côrte-Real, given the 'spontaneity and disinterest' of his undertaking

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[23] Anonymous, *The Hong Kong Catholic Register*, 15 May 1880, *III*(27):2; Anonymous, "Exposição de Productos enviados aos Museus de Lisboa e Coimbra", *Boletim da Província de Macau e Timor*, Official section, 1880, *26*:171; *José da Graça to Minister and Secretary of the Navy and Overseas Affairs,* 16 May 1880 (cit. n. 10).

[24] Graça, "Administração Geral. Portaria n. 51. 15 Maio 1880" (cit. n. 11), p. 172.

[25] Graça, "Administração Geral. Portaria n. 51. 15 Maio 1880". See also Côrte-Real, "Relatório" (cit. n. 10), pp. 172-73; *José da Graça to Minister and Secretary of the Navy and Overseas Affairs*, 16 May 1880.

and its importance for the 'progress' and 'civilization' of the colony.[26]

The praise, according to Graça, was an obvious act of 'justice', but served also as an 'encouragement' to the Committee 'to continue this work, which I much desire to see finished, at least in relation to Timor, a colony that, trusting on what I am usually told, is still unknown.' [27] Indeed, another collection was yet to come. Governor Graça and the secretary-general Côrte-Real expected the district governor in Timor (hierarchically subordinate to the governor of Macao), to collaborate in the formation of the commercial collection. The expansion of the commercial script to Timor, involved an increase in the scale and complexity of the work of collecting. As we will see, as a result of this expansion, different Committees in Timor were to emerge, over which Macao had little control from a distance.[28] From the viewpoint of the commercial orientations, messy Timorese collections were to be later forwarded to Portugal. Let us then shift focus to the contingencies involved in extending the demand

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[26] *José da Graça to Minister and Secretary of the Navy and Overseas Affairs*, 16 May 1880

[27] *Joaquim José da Graça to Secretary and Minister of the Navy and Overseas Affairs, 2 July 1880,* Lisbon, A.H.U., Museu Colonial de Lisboa. Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744. See also Graça, "Administração Geral. Portaria n. 51. 15 Maio 1880" (cit. n. 11).

[28] As science studies scholars have noted, as socioscientific networks grow in scale density, spatial distance and heterogeneity the difficulties in achieving cooperation and regulation increase. See Bruno Latour*, La Science en action* (Paris: Folio, 1995); Susan Leigh Star and James R Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39", *Social Studies of Science*, 1989, *19*:387-420.

for commercial and industrial products to the colony of Timor.

The extension of collecting work to Timor

In May 1880, after the Macanese collections were sent to Portugal, governor Graça commissioned the Côrte-Real Committee to carry on collecting for the Colonial Museum and Coimbra University. This time, their principal objective was to assemble a collection of products from the district of Timor 'whose wealth', the governor remarked, 'it is also important to know'.[29] Again, the governor's interest in putting an end to ignorance about Timor had politico-economic motivations. The intention was to extend the commercial script of 1880 to a Timorese collection, seen as a 'continuation of the consignments sent in 1880'.[30] From Timor, Macao expected samples of raw materials and industrial products to support its hopes of profitable trade in Timorese commodities. Finally, the collection was to provide evidence of the prevailing myth of the geological and agricultural treasures hidden in the country. Certainly, from Macao the district of Timor looked too far and too strange, and most provincial governors saw the island as an unwanted burden, a source of political trouble, and a waste of resources. Nonetheless, many expected Timor's mythic 'wealthy territo-

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[29] Graça, "Administração Geral. Portaria n. 51. 15 Maio 1880" (cit. n. 11).

[30] *Joaquim José da Graça to Secretary and Minister of the Navy and Overseas Affairs, 15 Feb. 1882,* Lisbon, A.H.U., Museu Colonial de Lisboa. Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744-766.

ry' would soon pay back Macao with economic profit.[31] Fertile virgin soils were available for cultivation while legendary geological riches – such as gold and copper – were just waiting discovery and mining.[32] By coming into possession of a collection of Timorese objects, therefore, Macao's dreams of running a prosperous exploration of its problematic district could finally materialize.

In extending to Timor the requests made by Lisbon, the commercial framework was preserved. Further, the Botanical Garden of Coimbra University should also continue to be granted collections of vegetable products from the island. In fact, at the same time governor Graça promised a further Timorese consignment to the Ministry, Júlio Henriques at Coimbra received a personal letter from Côrte-Real promising more botanical products: 'if God wishes to keep me [in Macao], Your Excellency will still get a quite developed collection from here and Timor, as well as Flora, which I am on the way to ensure, and everything else I can.'[33] The intention of satisfying Coimbra's demands for Timorese vegetable products reinstated the promise made to Henriques earlier, in February 1879:

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[31] See *José Maria Lobo d' Ávila to Minister and Secretary of the Navy and Overseas Affairs, [xx] 1876*, Lisbon, A.H.U., Macao and Timor, ACL_SEMU_DGU_RM_005_Cx 45, 1879-1880; *Joaquim José da Graça to Minister and Secretary of the Navy and Overseas Affairs, 8 March 1880*, Lisbon, A. H. U., Macao and Timor, ACL_SEMU_DGU_1R_002_Cx 1, 1879-1880.

[32] For the mythic imagery of Timor's natural wealth see, for example, Alfred Russell Wallace, *The Malay Archipelago* (1869, New York: Dover, 1962); Armando Pinto Correia, *Timor de lés a lés* (Lisbon: Agência Geral das Colónias, 1944).

[33] José A. H. Côrte-Real to Júlio Augusto Henriques, 4 June 1880, Coimbra, A.D.B.U.C., Correspondence of Júlio Augusto Henriques.

> I have asked the Governor of Timor, and he has already promised me a collection from the three kingdoms, which is of great importance there. Once I receive it, I hope the collection from Macao will be ready, and will send them both to Your Excellency, if the usual human contingencies don't deprive me of the necessary time.[34]

Côrte-Real revealed to Henriques that he had already taken action to secure the cooperation of the district governor in Timor. In stating that the district governor was 'asked' the favour of establishing Timorese collections, Côrte-Real concealed the fact that he had ordered the district governor to undertake collecting work in Timor, in accordance with Timor's subordination to the governorship of Macao. Indeed, it was as an administrative instruction from the provincial government that the call was received in Timor. On 18 October 1878, the governor of Timor, Hugo de Lacerda, was asked by Macao what had been done so far to enforce the provincial decree of June 1877, which ordered the district authorities to assemble a collection of products for the Colonial Museum.[35] Lacerda expressed unawareness of that decree, apparently never implemented by his predecessor. In reply, he announced prompt measures to correct the failure. He sent pharmacist Costa Duarte on a collecting expedition to the 'three kingdoms', i.e., the Eastern indigenous kingdoms of Laleia, Veimasse, and Laga around Dili. But in the governor's opinion, Duarte's works proved 'quite

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34 José A. H. Côrte-Real to Júlio Augusto Henriques, 25 Feb. 1879, Coimbra, A.D.B.U.C., Correspondence of Júlio Augusto Henriques.

35 Côrte-Real's letter to the district governor, Hugo de Lacerda, on behalf of the provincial government cannot be found. Only Lacerda's response is available. Hugo de Lacerda, "Portaria 21. Governo de Timor. 30 April 1879", *Boletim da Província de Macau e Timor*, 1879, *XXV*(28): 149.

disappointing', and there were no collections to send to Macao in 1880, to Côrte-Real's regret.[36]

Governor Hugo de Lacerda took other measures. He assigned a permanent Committee to the task of 'executing the work required to constitute collections of products for showing [Timor's] productive wealth at the colonial museum in Lisbon'.[37] The purpose was 'to collect and classify the products considered worthy of presentation by the [Timor] Committee', and then send them to the Colonial Museum, via Macao. Part of these collections was also intended to stay in Timor, laying the foundations of a municipal museum at Dili.[38] The Committee members were chosen from the ranks of colonial administration in Timor: Reverend João Gomes Ferreira, missionary and parson of Dili; pharmacist Albino Costa Duarte; second-lieutenant Jayme Henrique de Sá Vianna; and the Superior of the Catholic Mission in Timor, Reverend António Joaquim de Medeiros, president of the Committee. The 'Medeiros Committee' was active from April 1879. Yet, nothing was known at Macao about the Committee's activities until its abrupt dissolution in February 1881, by decree of the new district governor, Cardoso de Carvalho.

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36 Lacerda, "Portaria 21"; Côrte-Real, "Relatório" (cit. n. 10), p.172. Duarte's report was published in the Official Bulletin: Albino da Costa Duarte, "Relatório ácerca da digressão feita a alguns pontos de leste da ilha de Timor. 12 Dezembro 1879", *Boletim da Província de Macau e Timor*, 1879, *XXV* (28):149.

37 Lacerda, "Portaria 21...".

38 Cf. António Joaquim de Medeiros to D. Manoel, Bishop of Macao, 3 June 1880, Lisbon, *A.H.U.*, ACL_SEMU_DGU_1R_002_Cx 2, 1881; Anonymous, 'Exposição', *O Macaense – Jornal Político, literário e noticioso,* 28 February 1882, *1*:2-3; Joaquim José da Graça to Secretary and Minister of the Navy and Overseas Affairs, 15 Feb. 1882, Lisbon, *A.H.U.,* Museu Colonial de Lisboa. Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744-766.

Carvalho extinguished the Committee with short and cold praise, allegedly because it had already 'presented its work' and all accounts were closed.[39] The extinction of the Committee was another episode in the political conflict that virtually since the arrival of the new governor opposed Carvalho to the Catholic missionaries.[40] Let us continue looking at the events from the perspective of Macao, examining the travels of the Timorese consignments to Portugal. Particular attention will be paid to the contingencies of the collections assembled by the Medeiros Committee, for these were to include the set of human skulls.

The Committees in Timor and the messiness of the three consignments

The extinction of the Medeiros Committee caused perplexity in Macao. In April 1881, governor Carvalho was authoritatively reminded by the provincial governor to send collections to the Colonial Museum, in obedience with the 'repeated orders from the metropolitan government'. All Timorese 'products that can be obtained', he ordered, were expected forthwith in Macao, 'on time to be sent to Lisbon in the next transportation'.[41] The urgency of this request was precipitated by information brought by Rev. Medeiros him-

39 Cardoso de Carvalho, Portaria n. 20. Governo de Timor, 11 Feb. 1881, Macao, *Arquivo Histórico de Macau* (Macao Historical Archive, hereafter, ***A.H.M.***), AC, P-274.

40 For an ecclesiastical perspective on this episode see Manuel Teixeira, *Macau e a sua Diocese. Missões de Timor* (Macao, 1974), Vol. X.

41 Joaquim José da Graça to A. Cardoso de Carvalho, 13 April 1881, Macao, *A.H.M.*, AC/17/P-27855

self, who had just arrived in Macao and was quick to exert his influence near the provincial governor. Rev. Medeiros told governor Graça about him having been forced to leave behind the collection assembled by the Committee under his charge since 1879. Back in Dili, five boxes with objects, a catalogue, and an appendix report authored by the Rev. Medeiros were just awaiting orders to be shipped to Macao. This circumstance must be emphasised, *i.e.*, the Medeiros Committee prepared packages of objects and produced associated information in the form of catalogues and reports. However, so as to reach Macao the objects and the texts had to be released by governor Carvalho: 'From the Rev. Superior Head of the Mission', Graça explained to Carvalho, 'I know that he has left there [in Dili] some cases with objects already collected; if Your Excellency does not wish to keep them in that district, Your Excellency will send them to Macao, and regard them as satisfaction of part of the request made by the [Macao] Committee.'[42] In addition, Carvalho received orders to continue with the 'acquisition of collections', of 'all the objects that Your Excellency considers useful to science, commerce, or the development of that district.'[43]

Carvalho observed these instructions. In May 1881, he assigned a new Committee at Dili to the task of 'collecting and classifying the natural products of the Timor district' as a means of publicising the 'productive wealth' of the colo-

[42] Ibid.

[43] *Ibid.*; Joaquim José da Graça to A. Cardoso de Carvalho, 9 May 1881, Macao, *A.H.M.*, AC/17/P-27855

ny.[44] The goal was in conformity with Macao and Lisbon's commercial interests. This time, the Committee comprised state officials of Carvalho's personal trust, and was presided over by the government secretary, major José dos Santos Vaquinhas.[45] In June 1881, Carvalho attended Macao's demands, sending a consignment of 'ten volumes' with objects.[46] It is unclear whether all, or just part of these volumes corresponded to those 'five boxes' left behind by Rev. Medeiros, a few months before; or whether new items assembled by the 'Vaquinhas Committee' were included.[47] Nevertheless, it is certain that this consignment included Medeiros's collections, and probably the catalogues and appendix report.

The collections of the Medeiros Committee had no easy journey to Macao. The contingencies of the trip threatened their integrity, durability, and even physical existence. On 8 August 1881, governor Graça acknowledged their receipt with serious losses. Out of the ten volumes, only nine reached Macao; the tenth remained, unexplainably, at the Dutch port of Makassar. Moreover, 'many of the objects arrived broken,' complained Graça, '[or] gnawed by the rats,

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44 Cardoso de Carvalho, Portaria n. 39. Governo de Timor, 8 May 1881, Macao, *A.H.M.*, AC/17/P-274.

45 For the constitution of this Committee, see Carvalho, Portaria n. 39; J. A. H. Côrte-Real et al, "Relatório", *Boletim da Província de Macau e Timor*, 1882, supplement to n. 9:67.

46 Joaquim José da Graça to Cardoso de Carvalho, 8 Aug. 1881, Macao, *A.H.M.*, AC/17/P-27855

47 The fact that 'ten volumes' instead of 'five boxes' were sent to Macao might suggest that the Vaquinhas Committee added new collections to this consignment. However, in his report on the Timorese collections, Côrte-Real stated that the first consignment comprised only collections arranged by the Medeiros Committee. See Côrte-Real et al, "Relatório", p. 67.

or deteriorated, the ants, corn and wheat, for example, are useless, other specimens, like those conserved in alcohol, must be put aside, and some specimens were totally ruined.'[48] Graça concluded that bad conservation work at Timor had been a major reason for the losses and urged Carvalho to continue sending more and properly packed collections, comprising 'everything [in Timor] that can be object of trade'. Nevertheless, were it not for the damages, Medeiros's consignment would have been outstanding. This fact was observed by Côrte-Real in referring to Medeiros's collections in the final report: 'because of the number and quality of the products, and because of the value of some [objects] and the information that accompanied them, this consignment would doubtless be the greatest, but many [objects] got to our hands completely lost, some due to deterioration, others due to bad packing.'[49] Macao received damaged objects. In contrast, the catalogues and reports authored by Medeiros seem to have arrived safely. Côrte-Real might be in possession of a broken collection but he had 'the information' that accompanied the materials 'unbroken'.

The Timorese collections that came together in Macao were thus a jumble of things gathered by different Committees in Timor between 1879 and 1882. In effect, that was the first of three consignments with collections sent from Timor in 1881. The second consignment arrived successfully in November 1881, and had been assembled by another group of agents, the Vaquinhas Committee. Côrte-

[48] Joaquim José da Graça to Cardoso de Carvalho, 8 Aug. 1881.
[49] Côrte-Real et al, "Relatório", p. 67

Real considered it 'very valuable' in 'agriculture, mineralogy, and forests'.[50] Accordingly, major Vaquinhas received official eulogy and was urged to continue sending to Macao 'everything that can represent Timor's natural production, small and big industries, flora, history, customs, etc.'[51] Vaquinhas, then interim governor, complied with Macao's requests and in December 1881 another consignment was forwarded.[52] This consignment was Vaquinhas's personal present to the provincial government. For these reasons, the interim governor received all the credit; again, he was praised on the pages of the Provincial Bulletin.[53] Albino Costa Duarte's 'valuable' private collection of birds, reptiles, butterflies, and molluscs, was offered to the Timor government in April 1881, and later sent along with the consignments to Macao; Côrte-Real would present it to Coimbra.[54]

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[50] Côrte-Real et al, "Relatório" (cit. n. 45), p. 67.

[51] Joaquim José da Graça to A. Cardoso de Carvalho, 11 Nov. 1881, Macao, *A.H.M.*, AC/17/P-27855.

[52] Yet, the loss of some objects was considered unproblematic because many of the damaged materials were duplicates of originals already in possession of the Macao Committee (see Joaquim José da Graça to José dos Santos Vaquinhas, 11 Feb. 1881, Macao, *A.H.M.*, AC/17/P-27855).

[53] See José da Graça to Vaquinhas, 11 Feb. 1881; Joaquim José da Graça, 'Portaria n. 20. 8 March 1882', *Boletim da Província de Macau e Timor,* 1882, *9*:66.

[54] For this gift, the governor Carvalho praised Costa Duarte. See Côrte-Real et al, "Relatório" (cit. n. 45), p. 67; Cardoso de Carvalho, Portaria n. 45. Governo de Timor, 11 April 1881, Macao, *A.H.M.*, AC/17/P-274..

Fig. 1: The heterogeneity of the Timorese collection: spoons, knives, flutes, little baskets, axes, preserved insects, vegetables, wood samples, betel boxes, etc. The objects shown in this picture are part of the Timor collection displayed at the Coimbra Museum of Anthropology. Photo by the author, October 2004.

Although Macao still kept an interest in receiving more Timorese collections, no further consignments would come. In any case, the main purpose seemed to be achieved. After two years of troubles in their dealings with the district authorities in Timor, the Côrte-Real Committee was finally in possession of Timorese products. But for this Committee the work had just started. In Macao, great efforts in 'restoration, conservation, and packing' of 'almost every object' were necessary to rehabilitate the damaged collections.[55]

[55] Côrte-Real et al, "Relatório" (cit. n. 45), p. 66

Further, the collections had to be ordered and classified. But the Timorese consignments revealed to be messy assemblages of things, which did not straightforwardly agree with the view of the commoditisation of Timor. The next section analyses the epistemic work done by the Côrte-Real Committee in order to cope with this messiness and impose order upon the Timorese collections (Fig. 1).

The order of classification and description

The commercial programme designed in 1880 crucially shaped the career of the Timorese collections as objects of knowledge. In February 1882, the Timorese collections were ready to be shipped to Portugal. Shortly before their departure to Lisbon, the objects were put on public display in Macao, arranged and classified with the purpose of providing visual demonstration of the economic wealth of Timor.[56] Côrte-Real clarified to the audience of the exhibittion the underlying principles of the Committee's work of organizing the collection: 'to put within view of the country, the trade, its capitalists, its public men and the press, the objects that constitute the natural, industrial, and comercial wealth of Macao as well as Timor'.[57] The objects were exhibited as commodities, evidence of Timor's economic wealth. The organization of the Timorese consignments by the Macao Committee thus accorded with the original comercial

[56] See Anonymous, 'Exposição', (cit. n. 38), p. 3.
[57] Ibid.

vision. Besides, the arrangement of the collection in Macao agreed with the *Instructions for collecting various products in the Overseas Provinces* devised in 1876 by the then director of the Colonial Museum, the agronomist Luís de Andrade Corvo.[58] The Côrte-Real Committee followed the *Instructions* in organizing the classifycation and description of the objects. As a result, the Committee's ordering of the collection produced commodities with words, and objects, irrelevant for commoditization, without words.

The classification system of the Côrte-Real Committee

The *Instructions* were intended to standardize the work of collecting and of informing the objects by the collaborators of the Colonial Museum. They contained clear indication of the categories of things deemed appropriate to the museum, *i.e.*, exclusively objects of a commercial or industrial character; no reference was made to skeletal remains.[59] The *Instructions* also set standards for the classification and description of the objects, and paid particular attention to the organization of the collective work of

[58] Similar instructions were used in Portugal since the 1860s for organizing collections to World Exhibitions. They were made in the image of French museum instructions. Luís de Andrade Corvo, *Instrucções para serem colligidos nas Províncias Ultramarinas os diversos productos que devem figurar no Museu Colonial de Lisboa* (Lisbon, 1876). See Cantinho, *O Museu Etnográfico* (cit. n. 12), pp. 84-85.

[59] The objects sent to the museum should belong to the following categories: 'Natural products'; 'Agriculture'; 'Industries'; 'Commerce'; 'Curiosities and artworks' ('archaeological objects' were here mentioned); 'Foreign colonies'. From Corvo, *Instruções*, p. 4.

gathering information about the objects. This was designed as a cumulative and hierarchical chain of information production, partially juxtaposed to administrative hierarchies. At one level, 'producers or exhibitors' would describe the products and give such descriptions to the local or district authorities, together with the objects. Afterwards, these authorities would record and synthesize the producers' data in a partial catalogue and a partial report, 'short reports in which the greatest number of clarifications on the true importance of each of the products are offered.' [60] Finally, the governors had the task of synthesizing the partial information given by the district authorities in the form of 'general catalogues' and one final report.[61] The general catalogue should 'incorporate the explanatory notes necessary for clarifying any doubts', and the reports should show 'the state of the various industries represented by the products sent to the Lisbon colonial museum, the causes obstructing their increment and means to be employed for their development and improvement.'[62] The colonial authorities were also entitled to interfere with the data produced at earlier stages. They should 'correct inaccuracies', add new details, and, above all, make the synthetic coordination of data. However, the partial documents authored by the subordinate or district authorities were also to be sent to Lisbon, along with the final synthetic documents and the

[60] Ibid.
[61] Ibid, p. 2.
[62] Ibid.

collections. This, too, was the responsibility of the governor.[63]

The Côrte-Real Committee occupied the top level of this chain of information. Accordingly, the Committee produced two documents on the Timorese collections: a general catalogue and a final report, both to appear later in the Provincial Bulletin. The production of these documents required difficult coordination of the three consignments. When in 1880 the Committee first organized at Macao a collection of local Macanese products, the members had themselves selected or collected the objects and written the explanatory notes. In 1882, however, this task increased in complexity. Hundreds of different objects in bad condition arrived at different points in time, collected by different Committees over whom Macao had had only indirect control. Unexpected objects collected by other people and 'partial reports' authored by other colonial authorities in Timor had to be incorporated into a coherent whole. The Macao Committee could thus be confronted with objects and information inadequate to the commercial script or the *Instructions*, but which the Committee had nevertheless to coordinate. As a result, the Côrte-Real Committee produced a synthetic collection. In the texts as in the boxes, the three consignments were merged into one single collection subordinated to a single organizing script. The objects were classified and described as if they constituted a homogeneous ensemble, put together from the outset in straightforward agreement with commercial principles. Further,

[63] Ibid, pp. 2, 4-5.

with the exception of Costa Duarte's collection, the final catalogue synthesized things in such a manner that it was virtually impossible to determine which objects had been sent by which Committee. The Medeiros's and Vaquinhas's collections, for instance, were haphazardly put together.

In Macao, the homogenizing classification system of the collections followed closely the recommendations of the *Instructions* and the mercantile script. In 1882, regardless of greater heterogeneity in the Timorese consignments, the Côrte-Real Committee applied to the Timorese collections a strategy of classification and description previously followed with regard to the Macanese collections of 1880. The purpose was to produce information that enhanced the commercial or industrial value of the objects. The Macao Committee, Côrte-Real remarked, did not make 'a regular classification, nor a scientific description of the products'; it tried to act in conformity with the government instructions, offering 'the greatest number of news and explanations that were possible to gather and verify, giving about many objects the information most convenient to their understanding and the clarification of the commerce, as much as possible'.[64] The classification system was prepared with a view to shaping the objects as commodities, and it was but a variant of standard entries suggested by the Colonial Museu.[65] The catalogue categories thus contained 'information about the prove-

[64] Côrte-Real, "Relatório" (cit. n. 10), p. 173.
[65] Corvo, *Instruções* (cit. n. 58), pp. 5-6.

nance, uses, prices and quantities in the markets'.[66] Accordingly, each object was attributed a number, a name, a geographic origin, and then economic information, such as the price, exporting, etc., was given. The generalist entry, 'observations', completed the catalogue table.[67] The constitution of objects as commodities was, therefore, the main goal of the knowledge practices of classification. The conesquence, though, as we will see, was that this knowledge system produced well-informed object-commodities as much as it generated things dispossessed of words and information.

The unequal distribution of words in the collection

The final report authored by the Committee went along the lines of the classification system. Only items in accordance with perspectives of capitalist exploration of Timor, things from which economic profits could be foreseen (*e.g.*, coffee, sandalwood, or gold), were objects of descrip-

[66] Joaquim José da Graça to Secretary and Minister of the Navy and Overseas Affairs, 15 Feb. 1882, Lisbon, *A.H.U.*, Museu Colonial de Lisboa. Diversos Documentos, Deposit 1, Case 4, Shelf 6, Folders 744-766.

[67] The catalogue categories were: 'number'; 'names'; 'provenance'; 'uses and applications'; 'production'; 'price by retail and wholesale'; 'distance between the places of production and the nearest ports'; 'means of transportation'; 'annual exportation'; 'observations'. The catalogue of 1880 employed similar categories (cf. José A. H. Côrte-Real *et al*, "Relação de objectos de Timor enviados para os muzeus do Reino", *Boletim da Província de Macau e Timor*, 8 March 1882, supplement to n. *9*: 69-75; José A. H. Côrte-Real *et al*, "Catálogo de objectos remettidos ao Museu Colonial de Lisboa e ao Museu de Coimbra", *Boletim da Província de Macau e Timor*, Official section, 28 June 1880, supplement to n. *26*:177-84.

tion.[68] The collections, however, included many Timorese things not adapted to profitable commoditization or Industrial exploration, such as handcrafted cartridge-boxes used by the Timorese warriors. These other 'non-commoditizable' objects were not described; they were virtually unclassifiable, and were left with all economic entries empty. Perhaps these omissions were due to a lack of information; or perhaps, and more likely, they were due to the rigidity revealed by the classification and description system. In any case, it is striking the extent to which the catalogue list was cut across by what Lorraine Daston called the 'fault line of language' in nineteenth century conceptions of objectivity.[69] 'Things with words' coexisted with 'things without words'; in the catalogue, objectivity was simultaneously performed as a twofold principle. The objectivity of some objects depended on them being profusely described and worded. In contrast, the objectivity of other objects was a function of them being left wordless, as if they could speak for themselves. This type of wordless objectivity seemed to be implicit in the Committee's explanation for the absolute dissipation of language from certain material things in the collection: 'With regard to these [Timorese] products', Côrte-Real observed, 'the Committee has almost nothing to say. Their mere observation suffices as a recommendation.'[70]

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68 Côrte-Real *et al*, "Relatório" (cit. n. 45), pp. 67-68

69 Lorraine Daston, "Scientific objectivity with and without words", in *Little Tools of Knowledge*, ed. Peter Becker and William Clark (Ann Harbour, 2001), pp. 259-84.

70 Côrte-Real *et al*, "Relatório" (cit. n. 45), p. 67.

In producing a collection with wordless things, the Côrte-Real Committee did not follow the principle of holding words and things closely together, as recommended by the *Instructions*. In yet another aspect the *Instructions* would be broken. The texts produced by the authorities in Timor did not travel together with the objects. In March 1881, receipts, lists, the general catalogue, and the final report were sent to the Minister, accompanied by a letter from the governor.[71] Yet, the partial reports and catalogues authored by the Timor Committees were not included in these consignments. Only the final synthetic documents published in the Provincial Bulletin were to become accessible to the museums in Lisbon and Coimbra. Connection with information eventually produced in Timor was lost.

The exception was a quotation from a certain 'Rev. Priest Medeiros's report' in the final report of 1882. The passage from the 'Medeiros's report' referred to samples of copper and gold ores collected by the Medeiros Committee, and to difficulties in obtaining information from indigenous people about the exact location of trees and precious metals.[72] The citation had been selected with a view to agreeing with the mercantile script from a longer and more detailed account. For the 'Rev. Medeiros's report' itself would never travel together with the collections to Portugal, and thus the information that it may have contained about the objects (and indeed the very existence of the document)

71 Joaquim José da Graça to Secretary and Minister of the Navy and Overseas Affairs, 15 Feb. 1882, Lisbon, *A.H.U.*, Museu Colonial de Lisboa. Diversos Documentos, Deposit 1, Case 4. Shelf 6, Folders 744-766.

72 A. J. Medeiros cit. in Côrte-Real et al, "Relatório" (cit. n. 45), p. 67.

was to become unknown to metropolitan scholars.[73] The Medeiros's collection, therefore, might have arrived physic-cally damaged in Macao. But once the Côrte-Real Committee subtracted the associated reports and catalogues, it arrived in Portugal adding to its physical damage an important epistemic fracture. The Côrte-Real Committee justified the absence of descriptions about a number of material things by subtly evoking a concept of scientific objectivity that exempted things from information.

Thirty-five human skulls

The dominance of the mercantile script, the rigidity of the economic orientation of the classification system, and finally the separation of objects from their Timorese texts had a great impact on the epistemic configuration of the set of human skulls included in the consignment sent from Macao to Portugal in 1882. The final report makes no mention whatsoever of the presence of human skulls in the collection. Their existence is signalled in the catalogue list with the following minimalist information: 'Number: 197. Name: Human skulls. Origin [*Naturalidade*]: Timor.'

The other catalogue entries, which concerned the economic value of objects, were blank, as were also blank the entry 'observations'. The geographic origin was the only

[73] Indeed, further evidence suggests that Rev. Medeiros actually produced a report and a catalogue concerning the collections assembled by the Committee under his charge. These were sent to governor Carvalho in Timor, and then to Macao. Cf. Joaquim de Medeiros to Bishop of Macao, 3 June 1881 (cit. n. 38).

informative detail: Timor. Yet, even this 'detail' was a rather general indication compared with more detailed information on the origin of other Timorese items. In the catalogue, the geographic origin of things could be specifically attributed to Timorese kingdoms or settlements (e.g., 'Cová'; 'Viqueque'), or to the specific locations where they had been collected (e.g., 'Found on the beaches of Batugadé'; 'River of Bibiçusso').[74] Further, the catalogue system hindered the indexation of 'Number 197' to one of the three consignments. It was not possible to know whether the human skulls had been collected by Vaquinhas, or Medeiros, or Costa Duarte. Perhaps skulls were not considered the 'natural, industrial and commercial' products that Macao desired; perhaps no more information about the skulls was sent from Timor; or perhaps that information was filtered, considered irrelevant in the light of the commercial script and the *Instructions*; one effect, therefore, of the 'synthesis' done by the Côrte-Real Committee while having to cope with the heterogeneity of the Timorese consignments.

In any case, the blank spaces in the catalogue expressed a dissonance between the physical objects, the information possibly associated with them at Timor, and Macao's expectations about the unity and identity of the 'collection'. Further evidence of this dissonance was the exclusion of the skulls from the exhibition held at the Macao Loyal Senate in 1882, before the *Africa*'s departure to Lisbon with the Timor collections on board. Trusting the reporter of *O Macaense*, human skulls were not put on display (cf. Anonymous,

[74] Ibid, p. 71.

1882).[75] In an exhibition oriented to satisfying colonial interests in the capitalist exploration of the island, skulls were things 'out of place'. Their mere visibility seemed to threaten the foundational order of the collection.

Still, although obviously unsuitable for commercial use, skulls could be given value as 'scientific things'. The incorporation of skulls in the collection in Macao was possibly structured by their implicit categorization as objects with scientific utility. Soon after the exhibition, the Timorese collections were shipped to Lisbon. Captain Dores, former member of the Vaquinhas Committee, was put in charge of accompanying the collections, presenting them to the Ministry of Overseas Affairs, and guaranteeing that the objects were delivered to their respective destinations.[76] In Portugal, Dores ensured the division of the collections between Coimbra and Lisbon, as previously decided in Macao.[77] In fact, the Côrte-Real Committee determined the exact museum destination of each object and each pack beforehand. In the presence of 'duplicates' (for example, two samples of gold) both Coimbra and Lisbon were entitled to receive one exemplar. Yet, the division of objects between Lisbon and Coimbra principally followed a dichotomous categorisation

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75 Anonymous, "Exposição" (cit. n. 38), pp. 2-3.

76 See. J. José da Graça, "Portaria n. 13. 31 Janeiro 1882", *Boletim da Província de Macau e Timor*,
1882, p. 31. See also Raphael das Dores, "Apontamentos para um diccionario chorographico de Timor", *Boletim da Sociedade de Geografia de Lisboa*, 1903, *7-12*, p. 783.

77 Dores himself presented his private collection of Timorese birds to the naturalist F. Mattoso Santos, as a gift to the Zoological Museum of the Lisbon Polytechnic School. See Raphael das Dores, *Como se adquire a fama ou história d'um caluniado* (Lisbon, s.d.), pp. 84-85; F. Mattoso Santos, "Uma collecção de aves de Timor", *Boletim da Sociedade de Geografia de Lisboa*, 4ª série, 1883, *8*:453-60.

opposing 'economic usefulness' to 'scientific value'. Accordingly, for example, Côrte-Real explained that because butterflies, birds, reptiles, and insects were primarily things with embodied zoological knowledge, preference was given to Coimbra University in their acquisition.[78] This criteria for separation corresponded to distinct regimes of value and the 'usefulness' of things. Objects endowed with economic value were to be sent to the Colonial Museum. Whereas objects perceived as valuable because they embodied pure knowledge constituted scientific things and as such should be sent, as Côrte-Real remarked, to 'exclusively scientific museums'.[79]

It was eventually in accordance with these criteria that the Côrte-Real Committee allocated the collection of human skulls to Coimbra University, rather than the Colonial Museum. Therefore, in 1882, the Coimbra University received a significant quantity of boxes and packs containing Timorese collections, forwarded by Lisbon from Macao. Along with the packs, Coimbra also received a register signed by José Alberto Côrte-Real. One of the boxes contained thirty-five skulls. About the box and the skulls the register kept a single record: 'Box number 33 – 35 human skulls'.[80] Thirty-five human skulls, number 197, box 33, origin Timor. This was all scholars at Coimbra could know about the

[78] Côrte-Real et al, "Relatório"(cit. n. 45), p. 6.
[79] Ibid, p. 66.
[80] J. A. H. Côrte-Real, *Relação de objectos embarcados no navio África Comandante A. Pedrozo para o Museu de Coimbra*, 15 Feb. 1882, Coimbra, Arquivo do Museu Antropológico da Universidade de Coimbra (Archive of the Anthropological Museum of the University of Coimbra, M.A.U.C.).

'history' of the collection, a very small world of references to rely on if they were to use the human skulls as a testimony to the ancient races of Timor.

Conclusion

Students of museum collections have pointed out that for an object grouping to count as a collection some meaningful purposes or 'principles of organization' have to be present.[81] The concept of 'collection script' proposed here made these principles visible as general strategic designs, verbalized calculations that people inscribed into objects so as to distinguish them as collections and define what role they should play in the human world. In the light of this design, the presence of human skulls in Macao was neither expected nor calculated, and the rigidity of Macao's collection script seemed to leave little meaningful space for human skulls. But scripts do not exhaust the activities that create a collection. This article has suggested that museum collections should be approached as unstable compositions of objects and a multitude of inscriptions and narrations crafted by the work of people across time and space. Therefore, the analysis of collections in circulation requires careful attention to how attachments between things and words, objects and their textual artifacts are contingently reconfigured. In effect, in the case of the Timor collection, the intertwinement of the skulls' museum trajectory with the

[81] Susan Pearce, *On collecting: an investigation into collecting in the European tradition* (New York: Routledge, 1995), p. 33.

story of one commercial collection was a contingent and equivocal event. Further contingencies, in addition, prevented the objects sent to the Lisbon Colonial Museum from producing the ambitious commercial results expected by their collectors in Macao. In 1883-4, the Portuguese government decided not to send a representation to the World Exhibition of Amsterdam, as it had been planned in 1877. The objects given to the Colonial Museum were then transferred to the museum stores of the Geographical Society of Lisbon.[82] Although an assessment of the impact of this collection after 1882 would require further research, it is unlikely that the objects caused any national or international upsurge of commercial interest in Macanese and Timorese products.

In mapping the contingencies through which objects come about as collections, the analysis also brought to light the different types of work necessary to shape things as object collections in this segment of the collection's trajectory: conservation, classification, and description. These notions have already been mobilized in the course of the

[82] According to Cantinho, part of the collections at the Colonial Museum travelled to the Geographical Society by 1883-4. In 1892, when the Colonial Museum merged with the Ethnographic Museum of the Lisbon Geographical Society, the remainder of the collections came into possession of the Geographical Society. Cantinho seems to suggest, however, that the Geographical Society eventually sent some of these collections to an agriculture exhibition in the early 1880s. See Cantinho, *Museu Etnográfico* (cit. n. 12), pp 274-75. In Coimbra, the first systematic catalogue of the ethnographic collections from Macao and Timor was produced as late as 1955. See F. B. Pacheco de Amorim and M. H. X. Morais, "Catálogo-inventário do Museu de Etnografia do Ultramar do Instituto de Antropologia da Universidade de Coimbra", *Anais da Junta de Investigações de do Ultramar,* 1955, X(I); Maria do Rosário Martins, "Timor na colecção do Museu Antropológico da Universidade de Coimbra", in *Os Espaços de um Império*. Exhibition Catalog, coord. A. M. Hespanha (Lisbon: CNCDP, 1999), pp. 247-250.

above analysis, and now require brief explanation. Conservation expresses the 'enormous care' that distinctly surrounds object collections.[83] It refers to the actions of keeping object-bodies from harm, decay, loss, or waste (e.g., packing, storing, shipping, etc.), and which are directed to preserve and shape the bodies' physical trajectory, the physicality and durability of an object-body, throughout space and time. Classification and description, on their turn, express the practices oriented to shape the objects' epistemic trajectory, the process of shaping a physical object as an object of knowledge. If classification can refer to the actions of arranging and ordering physical objects according to a system of categories, description refers to the practices of verbalizing objects in speeches, correspondence, labels, catalogues, index cards, reports, sometimes on the object itself, etc. Conservation, classification, and description can draw more or less connected, even contradictory, trajectories. The relative autonomy of their respective careers makes the history of one collection a complex interaction between multiple activities. Perceived thus, furthermore, a collection must be defined as an unstable composition of words and things. In effect, the Macanese and Timorese collections were worked out not as simple compositions of things, but as complex combinations of physical objects and textual artefacts, object-bodies and bodies of texts. The epistemic trajectory of museum collections was crucially dependent on the trajectories of the texts that were expected

83 Krzystof Pomian, *Collectors and Curiosities. Paris and Venice, 1500-1800* (Cambridge: Polity Press, 1990), p. 8.

to remain associated with the objects (*e.g.*, catalogues, labels, reports).

In order to understand the processes of constitution of museum objects as scientific things, then, careful attention must be paid to the ways in which the associations between things and words, objects and their textual artifacts are historically reconfigured and shaped. In this regard, the paper suggested that the wordless condition of some objects can result from the attempts to manage the inclusion of discordant elements within systems of classification and description. The analysis above also revealed how interactions between classification systems, descriptions, collection scripts, and physical objects twisted the life of human skulls as objects of knowledge. Sociologists Star and Bowker have argued that classifications can 'break, twist, or torque' the biographies and bodies of persons (Star and Bowker, 2000: 26, 190-94).[84] Analogously, classification and description systems can also twist the lives of bodies of objects.[85] The Timorese collections arrived physically damaged in Macao. They got broken on the trip. Yet, the collections also suffered epistemic twists while physically immobile in Macao. In effect, the epistemic condition of the skulls sent from Timor was drastically twisted as it encountered the systems of classification and description of collections

[84] Susan Leigh Star and Geoffrey Bowker, *Sorting things out. Classification and its consequences* (Cambridge, Mass.: The MIT Press, 2000), pp. 26, 190-4.

[85] Compare the study on the impact of legal classification systems upon the biographies of art works. Christopher Steiner, "Rights of passage: on the liminal identity of art in the border zone", in *The Empire of Things: Regimes of Value and Material Culture*, ed. F. R. Myers (Santa Fe/Oxford: James Currey Press, 2001), pp. 207-232.

proposed by the Macao Committee. Drastic twists in the skulls' links to words and texts took place in Macao. There, skulls emerged as things without words. The skulls were in dissonance with Macao's principles of organization and classification of the collection and accordingly the physical objects were emptied of description. There, too, skulls emerged as things without Timor's texts. In the consignment sent to Portugal, the Macao Committee dissociated the skulls from actual documentation produced at Timor by the other Committees. The movement of skulls to Portugal was nonetheless made possible by the implicit understanding of their scientific utility. They were eventually expected to re-surface as wordy things the moment they were made to speak somewhere else, in the Coimbra museum, perhaps, through the voice of anthropologists. Yet, henceforth the Coimbra scholars had to cope with an inescapable fact. They had in their possession a collection of thirty-five human skulls virtually without words. Further events would reveal that indeed such an apparently minor fracture was to imply major consequences. In the 1930s, the absence of 'information' about the skulls was to be effectively used to contest the identity of the crania as authentic representatives of 'Timorese natives'. For, if not previously attached to words, the crania in the museum were likely to become problematic anthropological objects.

Bringing it all back home:

Portuguese engineers and their travels of learning (1850-1900)

By Ana Cardoso de Matos[*] and Maria Paula Diogo[**]

Travels of learning are, undoubtedly, one of the most appealing features of the European intellectual tradition, dating back, at least, from the 15th century. During the Enlightenment, travelling across Europe became, we dare to say, an epistemological affair, as it meant to oppose the "enlightened space" (that is England, France, the Netherlands, the German States, Swizerland and Italy) to the obscure regions of Southern and Eastern Europe, where reason, the new sciences and the new technologies were

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slowly arriving. Those who embarked on the long journey of the *Grand Tour* aimed not only to improve their education and culture, but also to gain or reinforce their position in the community of learned men populating the Republic of Letters.[1]

During the 19th century travels of learning became more and more focused, within a framework of a growing professionalisation and specialisation of sciences and technology. The dilettante and the polymath of the 18th century gave place to the professional man; the uncompromising travel diaries and notebooks gave place to the technical and scientific report or the textbook; the concept of learning itself swift from a general approach to a well circumscribed field of expertise.[2]

It is within this context of the growing specialisation of both the travel and the travellers that the travels of Portuguese engineers during the 19th century will be examined in our paper. The tradition of going abroad to study goes back to the 18th century, mainly through the *Estrangeirados* (Europe-oriented intellectuals) who grouped together in private literary societies where 'daring' subjects were discussed, methods questioned and traditional references, analytic concepts and representations of the cognitive and physical world

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[1] A. Simões, A. Carneiro, M. P. Diogo, "Introduction", in *Travels of Learning: towards a geography of science in Europe*, eds. A. Simões, A. Carneiro, M. P. Diogo (Dordrecht: Kluwer Academic Publishers, 2003), pp.1-18; J. Black, *The Grand Tour in the Eighteenth Century* (New York: St. Martins Press, n/d); B. Dolan, *Exploring European Frontiers* (London: MacMillan Press, 2000); D. Livingstone, W.Withers, *Geography and Enlightment* (Chicago:The University of Chicago Press, 1999); M. Blay, E. Nicolaidis (eds), *L'Europe des Sciences:Constitution d'un Espace Scientifique* (Paris:Seuil, 2001).

[2] Simões, Carneiro, Diogo, "Introduction".

challenged.[3] One of the finest examples is Manuel de Azevedo Fortes, a member of the “Ericeira Circle” who was appointed chief-engineer in 1719.[4] The education he received outside Portugal (in Spain and in France), his professional career which also began abroad (as professor of mathematics at the University of Sienna), the contacts he maintained with the intellectual elite of Enlightened Europe, definitively replaced the traditional view of engineering strongly associated with empiricism, by a perception of the engineer as a practical figure with his feet on the ground but whose thinking was shaped by the rigour acquired from a solid body of theoretical and scientific knowledge. This new attitude towards the role to be played by science and technology in modern societies, with which Fortes had become acquainted abroad, is amply reflected in his works, namely the well known textbook *The Portuguese Engineer*.[5]

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3 A. Carneiro, A. Simões, M. P. Diogo, “The Scientific Revolution in the Eighteenth century Portugal: The Role of the Estrangeirados (Europe-Oriented Intelectuals)”, Social Studies of Science, 2000, 30:591-619; M. P. Diogo, A. Carneiro and A. Simões, “Ciência Portuguesa no Iluminismo: os estrangeirados e as comunidades científicas europeias”, in Enteados de Galileu? A Semiperiferia no Sistema Mundial da Ciência, eds. J. Arriscado Nunes, M. Eduarda Gonçalves (Porto: Afrontamento, 2001), pp. 209-238.

4 The Count of Ericeira’s circle was one of the havens where the new ideas found a place to take root and grow. Azevedo Fortes was one of the count’s protégés, focusing on philosophy in his contributions to the series of ‘Erudite Conferences’ held at the count’s residence. He was also the only member of the Ericeira circle who had technical knowledge and skills.

5 M. P. Diogo, A. Carneiro e A. Simões, “El Grand Tour de la Tecnología: El Estrangeirado Manuel de Azevedo Fortes”, in Maquinismo Ibérico, eds. A. Lafuente, A. Cardoso Matos, T. Saraiva (Aranjuez: Doce Calles, 2007), pp. 101-121; M. P. Diogo, A. Cardoso Matos, “Being an engineer in the European Periphery: three case studies on Portuguese engineering", History of Technology, 2007, 27:125-146.

By the mid 19th century Portugal undergoes a significant change in the economical agenda, which favoured an intense growth of circulation as the core of the industrial take off. The idea of the existence of a close relationship between technological advances and progress is the main key to understand the all period following 1851 (which is called in Portuguese history Regeneração – the Regeneration Period) and the policy of its leader Fontes Pereira de Melo. Fontes was himself an engineer and firmly believed that railways played a decisive role in the development of the country's leading economic areas allowing Portugal to step in the international web of modern economic relationships.[6] In numerous public statements Fontes Pereira de Melo refers to railways as the most important feature of the new economic

[6] The acknowledgement of the role played by railways in a modern economy goes back some ten years when in 1842, Costa Cabral, then the Portuguese prime-minister, suggested building two railway lines (Lisbon-Oporto and Lisbon-Badajoz), a proposal that was denounced by his opponents as the "lunacy of a seer". Quoted in Oliveira Martins, *Portugal Contemporâneo* (1881; Lisbon: Guimarães Editores, 1979), p. 135. In 1844, Benjamim de Oliveira, a Portuguese citizen living in England, proposed to the Count of Tojal, the treasury minister, to build a railway line between Lisbon and Oporto, passing through Santarém, Leiria, Coimbra and Aveiro, an idea that was considered not have any obvious benefit. See Federico Abragão*, Caminhos de Ferro Portugueses – Esboço de uma história* (Lisbon: Companhia dos Caminhos de Ferro Portugueses, 1956), pp.120-124. Despite this lack of interest in 1844 the Companhia de Obras Públicas (Portuguese Public Works Company) was founded at the initiative of a group of Lisbon merchants. The Company's principal objective was "to undertake all the major works legally authorised for the improvement of communications in the country under the Government's supervision". The Company was founded by public deed on 19 December 1844 and its Statutes were approved by licence of 30 December 1844. In 1845 the Count of Tomar charged the Portuguese Public Works Company with building a railway along the bank of the Tagus river, linking Lisbon to the frontier with Spain. However, the project was suspended because of political instability and the company was wound up in 1848. For economic context see D.Justino, *A Formação do Espaço Económico Nacional* (Lisbon: Vega, 1988 and 1989), 2 vols.; P. Lains, Á. Ferreira da Silva eds., *História Económica de Portugal* (Lisbon: ICS, 2005), 3 vols.

and cultural framework, stating that “Above the horse driven carriage, there is the trolley, above this the locomotive and above this, progress.”[7] In this context a new ministry was created in 1852 – the Ministry of Public Works, Commerce and Industry (MOPCI) – fostering the technological-driven agenda of the *Regeneração* and hence the career and work of a significant number of engineers, including Fontes Pereira de Melo himself.[8] Through the MOPCI engineers made his presence felt in the new economic atmosphere. The fact that public works, such as the railway lines, were the main hope for Portuguese modernization and that they embodied the public welfare, significantly raised the status of engineers as a professional group. On the other hand, these very same close liaisons between engineers and public works shaped the face of the technological community in Portugal.[9]

From 1850 to 1880 the Portuguese government was easily able to raise foreign funds for building national infrastructures, supported by its own credibility (Portugal was part of a selected group of countries using gold as its monetary standard) and by the interest of British capitalists in investing their money in “material structures”. These foreign companies were invited to participate in the Regeneration infrastructural project by applying both their capital

7 Speech given on 18 January 1855.

8 Before this ministry was created public works were part of the Ministry of the Kingdom (Ministério do Reino). Fontes Pereira de Melo was the first to serve as minister of the Ministry of Public Works, Commerce and Industry (MOPCI). Other well-known engineers were also ministers of the MOPCI, namely João Crisóstomo de Abreu e Sousa, João de Andrade Corvo and Elvino de Brito.

9 Maria Paula Diogo, “In search of a professional identity – The Associação dos Engenheiros Civis Portuguezes”, *ICON*, 1996, 2:123-137.

and technical expertise. As these companies used their own technological know-how, management models, and engineers, Portuguese engineers were only used to suggest minor changes and to approve the plans which were presented to the Ministry of Public Works, Trade and Industry[10].

In 1853, when Fontes Pereira de Melo signed a contract with the Companhia Central e Peninsular dos Caminhos de Ferro Portugueses (Central and Peninsular Railway Company), its leader, Hardy Hislop, chose an English engineer, Thomas Rumball, to design the first railway line (Lisbon-Carregado).[11] Although in this initial phase the work of Portuguese engineers was not very visible some adjustments to the initial plans were made by João Crisóstomo de Abreu e Sousa and Joaquim Tomás Lobo d'Ávila. The next stage in the building of the railway network proved to be an excellent opportunity for Portuguese civil engineers to show their proficiency. The Northern and Eastern lines were already planned and directed by the most important Portuguese engineers of that period.[12]

The relationship between Portuguese and European engineers was, hence, always double folded: on one hand, European engineering was accepted as the main reference concerning know-how and expertise; on the other hand, being praised by European fellow engineers meant to be

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[10] Magda Pinheiro "Os engenheiros portugueses e a construção ferroviária no século XIX", Unpublished paper presented at the *XX Encontro da APHES*, 2000.

[11] Thomas Rumball (1824-1902) was a railway engineer who worked in England, Portugal, Spain and Argentina. He was a member of the Institution of Civil Engineers.

[12] João Evangelista de Abreu, Pedro Inácio Lopes, Manuel Espregueira.

recognized as members of a wider community. Therefore Portuguese engineers envisaged international contacts as a powerful tool for both promoting technical exchange within the European space and building a professional identity back home. These contacts were made mainly through: (i) academic training of Portuguese engineers at foreign schools; (ii) "travels of learning", including going to world exhibitions and international meetings and visiting railway facilities and factories; (iii) institutional contacts with European and American professional associations of engineers.

Studying Abroad

In Portugal, academic training engineers remained, until quite late, within the borders of military training. It was commonly accepted that engineers should be able to perform both military and civil engineering tasks; their academic training aimed, therefore, to develop military expertises, which were complemented by a set of subjects related to civil engineering. This kind of "hybrid" training is the core of the Civil Engineering Course taught at the Army School: as usual, students had a previous scientific training at the Polytechnic School of Lisbon or at Academia Polytechnic Academy of Oporto, where they learned mathematics, physics, chemistry, natural history, geology and astronomy; they then pursued their studies at the Army School, with a two years degree on civil engineering, based on an extended version of one of the subjects taught at the military course.[13]

The idea of having specific schools or courses in order to train civil engineers was not a peaceful matter in Portuguese political circles. Already in the beginning of the 19th century, when the Polytechnic School was founded, the question of technical education was only the forefront of a deeper debate between different strategies for national modernisation. In 1854 Júlio Máximo de Oliveira Pimentel, a well known chemist and teacher at the Polytechnic School as well as a member of the Parliament, submitted a project that aimed at converting part of the military training institutions into Scientific and Technical Professional Schools: the Army School (for cavalry and artillery officers and military engineers) and the Navy School (for navy officers and shipbuilders) would be kept as part of the military training, but a Public Works School (for civil engineers, builders, architects, geographical and hydraulics engineers and mining engineers) and an Industrial School (for mechanical, chemical and metallurgy engineers and foremen) were created. This highly controversial project, especially regarding the poor role played by polytechnic schools, generated a strong opposition, in particular from the teaching staff of the

13 M. P. Diogo, A. Cardoso Matos, "Aprender a ser ingeniero. La enseñanza de la ingeniería en el Portugal de los siglos XVIII y XIX" in Maquinismo Ibérico, eds. A. Lafuente, A. Cardoso Matos, T. Saraiva (Aranjuez: Doce Calles, 2007), pp. 123-145.

Oporto Polytechnic, which addressed a petition to the Members of Parliament. The proposal was never approved.[14]

In 1859, the Parliament resumed the debate on the training of Portuguese engineers. The obvious lack of schools was, once again, the keystone of the discussion. However the solution which was considered the most suitable was not to create new schools in Portugal but to send abroad the best students. The Ministry of Public Works, Commerce and Industry was bound to send at least three students per year to study abroad. The *École des Ponts et Chaussées*[15], the *École des Mines* and the engineering schools at Gand, Freiberg and Liège were considered the top schools at the time, and thus the ideal scientific and pedagogical milieu to complete their engineering training. After this period abroad students were expected to return to the motherland "with the training required to fulfil the noble functions of an engineer and through useful work payback Portugal what the country had invested."[16]

The idea of sending students abroad to study instead of investing in a national plan of high education was part of a long tradition. In fact, Portugal always preferred to “buy” knowledge, science and technology in the European marketplace and not to create its own centres for developing

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[14] This petition was later published as, "Breve Memória sobre a Instrucção Publica Superior no Porto e nas Provincias do Norte, offerecida aos Senhores Deputados da Nação Portugueza pelos Lentes da Academia Polytechnica”, *Jornal da Associação Industrial Portuense,* 1854, 19:296-304; 20:312-320; 21: 330-336.

[15] On the *École des Ponts et Chaussées* see A. Picon, *L’invention de l’ingénieur moderne. L’École des Ponts et Chaussées, 1747-1851* (Paris: Presses de l’école nationale des ponts et chaussées, 1992).

[16] *Diário do Governo*, 1859, 251:1361.

expertise and skills. The notion of "payback" allowed, on the other hand, to emphasize the obligation of using what was learnt abroad at home, by dedicating themselves to public works, that is to say, to the modernization of Portugal, thus "paying" back the government investment. Students attending foreign schools should have a high performance in order to be able later, as engineers, to allow Portugal to free itself from foreign dependence.[17]

Based on data from the Portuguese Association of Civil Engineers, the academic training profile of Portuguese civil engineers showed, on one hand a clear hybrid pattern (military and civil training at the same time) and on the other hand a steady interest in studying abroad.[18]

For those who went abroad, France was the favourite choice, reaching almost 70% of the preferences of the students[19]. Most of the future civil engineers applied to the Éco-

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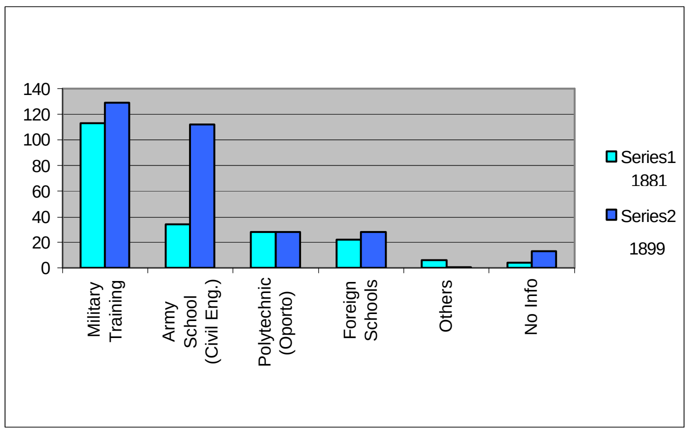
[17] In a petition presented to the government – Representação dirigida aos Senhores Deputados da Nação Portugueza pelos Engenheiros e Conductores do Extincto Corpo d´Engenharia Civil e seus Auxiliares (Petition Addressed to the Members of the Portuguese Parliament by the Engineers of the late Corps of Civil Engineers and Assistant Engineers) – Portuguese engineers argue that "Part of our students should be sent abroad to study both theoretical and practical subjects. By attaining the highest standards of engineering training, these new engineers will be able to free our country from foreign dependence as far as public works are concerned."

[18] In 1864, the government had created the Corpo de Engenharia Civil e Auxiliar (Civil and Auxiliary Engineering Corps), thus indicating the importance, both in number and in work, of Portuguese civil engineers. When in 1869 the Civil and Auxiliary Engineering Corps was and surprisingly abolished, civil engineers were already powerful enough to build their own professional association – the Associação dos Engenheiros Civis Portuguezes (A.E.C.P.) (Portuguese Association of Civil Engineers). Diogo, "In search of a Professional Identity", cit. n.9.

[19] On models concerning the training of engineers see Irina Gouzévitch, André Grelon, Anousheh Karvar eds., *La formation des ingénieurs en perspective. Modèles de références et réseaux de médiation, XVIIIe-XXe siècles*, (Rennes, Presses universitaires de Rennes, 2004).

le des Ponts et Chaussées (in 1881, 41% of Portuguese engineers with a degree from a foreign school came from the École des Ponts et Chaussées; in 1899, 30% came from the same school); the Parisian École des Mines, was the first choice for mining engineers.

Graphic 1: Comparative data on the academic training of the members of the Portuguese Association of Civil Engineers, 1881 and1899



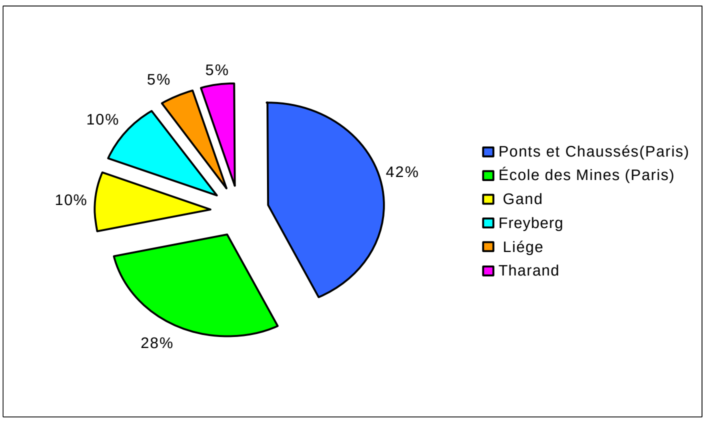
Source: "Relação dos Sócios em 2 de Abril de 1881", Revista de Obras Públicas e Minas, 1881, XII(135/136):46-58; "Sócios efectivos e aggregados em 30 de Abril de 1899", Revista de Obras Públicas e Minas, 1899, XXX(351/352): 167-201.

Up to 1851 we identified seven Portuguese engineers who attended the École de Ponts et Chaussées, all of them future leading actors of the Regeneration agenda.[20]

[20] Following Picon, *L'invention* (cit. n. 15), pp. 405-406, until 1851 19 Portuguese engineers attended postgraduate courses at the École de Ponts et Chaussées. However until now we have only been able to

From 1852 onwards the Ministry of Public Works, Commerce and Industry financially supported engineers who went to study abroad, in order to provide them with the theoretical and practical know-how necessary for the public works that were being undertaken all over the country.

Graphic 2: Foreign Schools attended by the members of the Portuguese Association of Civil Engineers, 1881 and1899



Source: "Relação dos Sócios em 2 de Abril de 1881", Revista de Obras Públicas e Minas, 1881, XII:46-58; "Sócios efectivos e aggregados em 30 de Abril de 1899", Revista de Obras Públicas e Minas, 1899, XXX(351/352): 167-201.

At first these engineers were freely appointed by the Minister, but after 1855 a competitive examination establi-

identify Joaquim Simões Margiochi, Joaquim Nunes de Aguiar, Francisco Maria de Sousa Brandão, Joaquim Tomás Lobo d'Ávila, José Anselmo Gromicho Couceiro, Joaquim Júlio Pereira de Carvalho and Jaime Larcher. See A. Cardoso de Matos, "Asserting the Portuguese civil engineering identity: the role played by the École des Ponts et Chaussées", in A. Grelon, M.P. Diogo, A. Cardoso de Matos I. Gouzevitch eds., *Jogos de Identidade: os Engenheiros, a Formação e a Acção* (Lisbon:Colibri, forthcoming).

shed new criteria for the selection.[21] Nevertheless some Portuguese students and engineers went abroad at their own expenses. During the second half of the 19th century, twenty-seven Portuguese engineers enrolled at the École des Ponts et Chaussées. To guarantee a sustainable policy a group of students was sent to Paris every three years, which meant that new trainees were only sent when the previous group of students had finished their degrees. Up to 1866 sixteen Portuguese students attended the École des Ponts et Chaussée; between 1866 and 1878 there are no registers of Portuguese students; and after 1878 the number of those attending the École each year is uneven.[22]

For Portuguese future engineers going abroad to improve their academic training and expertises was, thus, a popular choice during the second half of the 19th century. A considerable number of future and senior engineers with a Portuguese degree applied for grants to study in European Engineering schools, both at undergraduate and postgraduate levels. Some of the most influential Portuguese engineers of the second half of the 19th century complemented their academic training by attending courses at the most prestigious European engineering schools.

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[21] Article 30, Law of 17 July 1855.

[22] Matos, "Asserting the Portuguese Civil Engineer Identity".

Travels of learning

Going abroad to "study" foreign railway systems (tracks, trains, organization and the people needed to operate it), harbours or factories became more and more common among Portuguese engineers. A considerable number of these travels of learning were made at the expenses of the Portuguese government and aimed at improving specific expertise concerning mostly public works. Between 1845 and 1897, we have already clearly identified 20 travels most of them from 1850 to 1880. The main destinations were France, Belgium, the Netherlands and, in a second row, Spain.

Once again we find influential Portuguese engineers committed to these technical pilgrimages which allowed them to acquire a significant amount of technical expertise that proved to be crucial to the new technocratic agenda.

In 1845, José Vitorino Damásio, known among his colleagues has the "pope of Portuguese engineering", was invited to work with the Portuguese Public Works Company[23], which commissioned him to supervise the construction of the Alto da Bandeira to Carvalhos road in Vila Nova de Gaia. Because of his mastery of road building technology and his knowledge of the road building techniques used in other countries (such as Polonceau's rolling method) he was asked by the Company to make a research visit to France and Belgium. The purpose of the visit was to study leading Industrial plants on the spot and to determine which machinery and industrial processes would be best suited to the Arsenal

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[23] See n. 6.

de Obras Públicas (Public Works Depot) that the company planned to set up in Portugal. Another aim was to choose foreign plants where Portuguese craftsmen who were to work on the company's projects could be sent as trainees. However, the closure of the company meant that these goals would not be achieved.

Damásio, gifted with an immense scientific curiosity and a desire to keep up-to-date with technological developments, used his visit to Paris to take a course at the École des Ponts et Chaussées in locomotive engines and, uniting theory with practice, also studied the building of these engines at the Resrones & Cail plant.

Although he was not able to give them any practical application at the Portuguese Public Works Company, the skills he acquired on his visits as well as the studies and research he carried out at this time were fundamental in his decision to set up the Bolhão factory, an industrial venture launched in 1847[24]. The plant, where he was responsible for technical management, introduced a new chemical process for 'manufacturing malleable iron, or making pig iron objects malleable by means of a new chemical process'. This enabled the production of new iron products, including small pieces of ironware for domestic use, many of them enamelled. The growth of the plant also led to the production of machinery, including the first dredger to be built in

[24] In partnership with Joaquim Ribeiro de Faria Guimarães and Joaquim António da Silva Guimarães.

Portugal and the first mechanised rope-making plant to be set up in Oporto.[25]

In 1846, João Crisóstomo de Abreu e Sousa, the future President of the Portuguese Association of Civil Engineers[26] and a firm supporter of the Regeneration project, traveled at the expenses of the Portuguese government to England, France and Belgium to get acquainted with the construction of roads, canals and railways. Ten years later he would return to these countries and traveled also to the Netherlands to study the progress being made in the operation and management of railways and other transportation systems.

In 1844, Manuel Afonso Espregueira, another future leading figure in the modernizing agenda of the Regeneration, also visited France, Belgium and the Netherlands to collect information about their railway systems. In 1865 Bento Fortunato Almeida d'Eça, travelled during ten months across France, Italy, Belgium and Spain in order to study management and law issues applied to irrigation systems; in 1878 he returned to Belgium to study the prison facilities at Louvain. In 1868 Joaquim Nunes de Aguiar, chief engineer at the Companhia das Águas de Lisboa (Lisbon Water Company) went to Paris to study issues concerning water supply and mostly to buy pumping machines to raise the water for supplying the eastern part of Lisbon[27]. In 1887, Frederico Ressano Garcia, an engineer who shaped the face of Lis-

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[25] Diogo and Matos,"Being an engineer" (cit. n. 5).

[26] See n. 16.

[27] T. Saraiva, *Ciencia Y Ciudad: Madrid y Lisboa, 1851-1900* (Madrid: Ayuntamiento de Madrid, 2005), p. 128.

bon[28], travelled to Italy, Spain, France and Belgium, to study the construction and maintenance of sea harbours.[29]

Although the majority of these travels had as main target different issues related to public works, urban infrastructures included, we have some examples concerning the industrial *milieu*. The weakness of the Portuguese Industrial structure, unable to break with old technological routines, didn't promote travels sponsored by private firms. However it is possible to find a few exceptional cases in which technology transfer through travels does occur: in 1873, the Companhia de Torres Vedras, a textile factory, asked the engineer Jaime Larcher to study the most updated features of mecha-

[28] Ressano Garcia assumiu o cargo de engenheiro da Câmara Municipal de Lisboa em 1874 e a ele se ficaram a dever algumas das mais importantes obras de melhoramento da cidade de Lisboa como foi o caso da abertura da Av 24 de Julho. Raquel Henriques da Silva dir., *Lisboa de Frederico Ressano Garcia, 1874-1909* (Lisbon: Câmara Municipal de Lisboa / Fundação Calouste Gulbenkian, 1989).

[29] We used mainly the database built during the research project *Portuguese engineering and engineers – 18th to 20th centuries* (FCT/PRAXIS XXI,1999-2001). This database only covers information about engineers who were members of the Portuguese Association of Civil Engineers. We collected other information from other sources but further research may bring new data, namely concerning private travels. In addition to the engineers mentioned in the text we have the following information on other engineers who travelled abroad: Afonso Soares (1875, six monthes, to study European harbours, mostly concerning machines and management); Alfredo Freire de Andrade (travelled to South Africa to study mining technics); Carlos Ribeiro (1858, France, Spain, Italy and Austria) and later Nery Delgado (1878, Spain) both well know geologists, travelles abroad to study different geological surveys and to establish a network of scientific relationships; Carlos du Bocage who went to Belgium, France and Spain (1878 and 1879) to study military issues; João Schiappa de Azevedo stayed in Spain during nine months studying mining technics; João Maria Magalhães after graduating at Nancy travelled across the Alps to Germany to study irrigation and forestry; João Castanheirinho went to Antwerp to study the local harbour in order to apply some og the Belgium solutions to the harbour in Lisbon; Joaquim Sousa Gomes, after graduating at the École des Ponts et Chaussées travelled across Russia, Italy, Germany, France and Spain in order to broaden his training.

nical of looms in Northern Europe. When returning to Portugal, Jaime Larcher presented a set of plans for a new factory and renewed the existent machinery. In 1894, when the firm António Moreira Rato & Filhos decided to build a factory for producing Portland cement, it also sent an engineer, Herculano Galhardo, to several European factories in order to study the latest innovations concerning both knowledge and machinery. In fact, when Galhardo returned, he reported to his sponsors all the latest advancements and novelties in the field of cements and introduced them in the factory.[30]

Going to the Fair

World exhibitions were a unique arena for technological exchange and transfer of knowledge. While the most developed countries displayed their technical superiority, countries from the European periphery, such as Portugal, sent their engineers to the exhibitions to see the myriad of new mechanisms which were presented, how they worked and how could they be useful for the national economic modernization. Coming back home, Portuguese engineers wrote their reports, trying not only to describe what they

30 A. Cardoso de Matos, M. Luísa Santos and M. Paula Diogo, "Obra, Engenho e Arte nas raízes da engenharia em Portugal" in *Momentos de Inovação e Engenharia em Portugal no século XX,* eds. M. Heitor, J. M. Brandão de Brito and M. F. Rollo (Lisbon: D. Quixote, 2004), vol.2, pp. 10-44.

have seen, but also to compare the Portuguese industrial *milieu* with the much livelier European one.[31]

Although it is still a provisional result, we have information on travels made by engineers, either officially or privately, to the World exhibitions of Paris (1855), London (1862), Paris (1867), Philadelphia (1876), Paris (1878), Paris (1889), Chicago (1893) and Paris (1900).[32]

As we have already mentioned, for these men going to a World fair meant a very accurate agenda: when they set out from Portugal, they had already selected their "targets" at the exhibition, according to national political and economic strategies. In 1855 (Paris) and 1862 (London), José Maria da Ponte e Horta, was appointed by the Portuguese government to observe steam machines; in his report he stated the importance of this new source of energy as a pivotal resource for industrialization; José Vitorino Damásio was also appointed by the government to go to Paris in 1855, to establish contacts in order to buy locomotives for the Portuguese railways. In 1855 Joaquim Júlio de Carvalho was commissioned by the municipality of Lisbon to go to the World fair in Paris to collect information on new machines that could be used in urban infrastuctures. In 1862, Carlos Augusto Ferreira went to London (he had been also at the World exhibition in Paris in 1855 at his own expenses) and five years later, together with Alberto Ribeiro, he visited the Word Fair in Paris. In 1878, Bento Fortunato Almeida d'Eça

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31 A. Cardoso de Matos, "World exhibitions of the second half of the 19th century: a means of updating engineering and highlighting its importance", *Quaderns d'Història de l'Enginyeria*, 2004, 6:225-235.

32 See n. 24.

went to the exhibition in Paris to study railways and stayed there until January 1879 in order to fulfil his mission. In 1889, Afonso Soares, Adolfo Ferreira Loureiro Augusto Carvalho, went to Paris to visit the exhibition and the later was specifically commissioned to record novelties concerning the construction of harbours. In 1900, José de Matos Cid and José Vitor Sequeiro were sent to visit the world exhibition in France.

In all the five exhibitions that took place in Paris, the Portuguese government used the engineers who were in Paris attending the École des Ponts et Chaussés or the École des Mines to get further information or contacts. For instance, in 1867, three of these engineers, Cândido Celestino Xavier Cordeiro, Augusto Luciano Simões de Carvalho and Bento Fortunato Almeida d'Eça, were in charge of collecting information on the "state of the art" concerning railways.

As we reach the end of the century, the power of World exhibitions grows, as they become THE place to see and to be seen. In this context the Portuguese Association of Civil Engineers committed itself to be present, as a showcase of Portuguese engineering. In 1893, they sent to Chicago a set of five *Memoirs* on engineering works in Portugal, twenty eight albums with photographs, drawings and printed pictures of the most important works and monuments of our country, a descriptive catalogue and a collection of all the issues of the *Journal of Public Works and Mines* (the Journal of the Association). Financial problems didn't allow Portugal to have an official representation; however a member of the Portuguese Association of Civil Engineers travelled, at his own expenses, to the United States in order "to be present, in flesh and bone, at such an important event and to establish contacts with our fellow American engineers".[33]

In 1900, at Paris, the "capital of the civilized world" the Portuguese representation was impressive. The Portuguese Association of Civil Engineers, the representative of Portuguese engineering, sent once again a significant number of *Memoirs*, albums and catalogues on Portuguese engineering and organized a trip to Paris in which a large number of its affiliates participated. The Portuguese representation, headed by Ressano Garcia, was considered a huge success, wining 21 medals.

Closely related to the World exhibitions, numerous *international meetings* took place. Portuguese engineers, who often attended these international *forums* of debate, regarded them as an opportunity to keep updated with the main issues concerning engineering and to merge in a wide, transnational, "family". Portuguese engineers were present at the most important international meetings that would shape the face of modern Europe, namely those concerning telegraphs, railways and electricity. Just as an example and using some of the leading engineers we have been referring to, in 1878 José Damásio, who later that year was appointed head of the Portuguese Telegraphs, represented Portugal at the Telegraphic Conference in Paris; the International Railways Meeting was attended by Portuguese engineers on a regularly basis: Frederico Ressano Garcia (1887), Manuel

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33 Luciano de Carvalho, "Exposição Universal de Chicago", *Revista de Obras Publicas e Minas*, 1895, XXVI: 68.

Espregueira (1889),Joaquim Pires Gomes (1892), António José Antunes Navarro and Angelo Sarrea de Sousa Prado (1895) and Bento Fortunato Almeida d'Eça (1900). In 1895 and in 1897 José Castanheira das Neves was the Portuguese representative in the International Meeting of Structural Analysis.

A large number of the Portuguese engineers, who attended the World Exhibition in Paris at the turn of the century, also went to the international meetings that took place during the major event, namely those concerning steam machines, mechanics, chemistry, electricity, agriculture and technical training. [34]

Exchanging knowledge through professional journals

Portuguese engineers were closely in touch with their fellow engineers abroad. As we have already mentioned before, being part of a professional community with no frontiers, the 19th century version of the "Republic of Letters", was crucial for Portuguese engineers. The Portuguese Association of Civil Engineers tried since its early years to establish steady contacts with European and American professional associations of engineers. In 1872, formal relationships were established with the Institution of Civil Engineers, the Societé des Ingénieurs Civils and the American

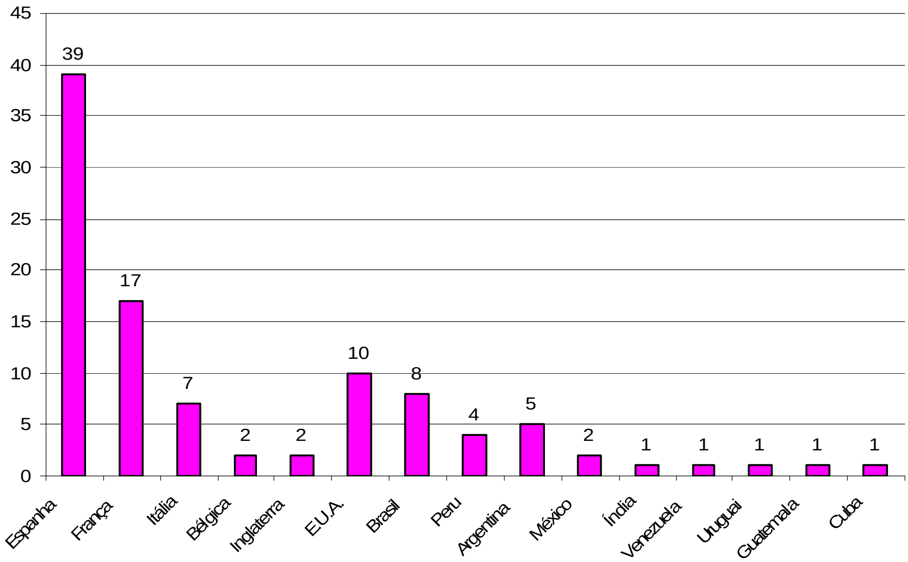
34 An extensive and detailed list of the World Exhibitions can be found in Brigitte Schroeder-Gudehus, Anne Rasmussen, *Les Fastes du Progrès: le guide des Expostions Universelles, 1851-1992* (Paris, Flammarion, 1992).

Society of Civil Engineers, the three most important world associations as far as engineering was concerned. The list kept growing all along the life of the Portuguese Association of Civil Engineers. The prestige value of these contacts, which implicitly meant the recognition of specialized knowledge and training, allowed Portuguese engineers to assert their professional identity both in the national and international arenas. In addition to these institutional contacts, exchanging journals was also a key strategy for Portuguese engineers to keep in touch with the main issues concerning engineering all over the world. The Portuguese Association of Civil Engineers exchanged its journal, the *Journal of Public Works and Mining*, with a very large number of European and American professional associations of engineers and even subscribed some of them.

It s difficult to assess the impact of the journals received by the Portuguese Association of Civil Engineers on Portuguese engineers, as the information published by the *Journal of Public Works and Mining* is not always clear or detailed. However, some general trends may be drawn upon a rough statistical analysis.[35] Using the information publicshed by the *Journal of Public Works and Mining*, from 1870 to 1900, it is possible to get the following picture:

35 This statistical analysis is a very preliminary and rough approach to the information published by the *Journal of Public Works and Mining*, The detail of the information varies from annual report to annual report, it is not possible to be sure of how many issues of a particular journal were received and for how long. It is possible that some journals are counted for several times. Nevertheless we think it is still worthwhile to use this data in order to define general trends.

Graphic 3: Journals received by the Portuguese Association of Civil Engineers (1870-1900)



Source: "Relatorio e Contas da Associação dos Engenheiros Civis Portuguezes com referencia ao anno de 1878", Revista de Obras Públicas e Minas, 1879, X(111/112): 113; 1881-1910, XIII-XLII; 1923, LIV(627):110-111; 1932, LXIV(680): 61-62.

Not surprisingly Spain and France are clearly the main partners of Portuguese engineers in their international network. The Spanish strong presence is the result of both the geographical proximity and the close relations between the Portuguese and the Spanish engineering communities, which often worked together. One should recall that it was D. José de Salamanca, a Spanish aristocrat and businessmen that founded in 1860 the Companhia Real dos Caminhos de Ferro Portugueses (Portuguese Royal Railway Company) that ruled the Portuguese railway system during the second half of the 19th century. Together with Salamanca came other Spanish engineers, namely Eusebio Page chief engineer of the Portuguese Royal Railway Company, and Adolfo Ibarreta who was in charge of the Northern line.[36] When the Portuguese Association of Civil Engineers was founded Eusebio Page was appointed its only foreign honorary member. Recent studies also show the strong similarities between the urban renewal of Lisbon and Madrid.[37]

The French strong position mirrors the French powerful influence on the overall design of the Portuguese engineering community, both concerning its training and its professional models. It is understandable that Portuguese engineers tried to keep pace with their French fellow engineers whose reputation was well known all over Europe. On the opposite side, it is remarkable that only two British journals were received by the Portuguese Association of Civil Engineers.[38] In fact the British engineering model based on an informal training of engineers and anchored in a much more private driven economy was little influential in the Portuguese engineering community.

It is also worthwhile to look at the main thematic areas covered by the journals, as they mirror the main interests of Portuguese engineers and give us some clews on which themes they sought in foreign journals. Engineering

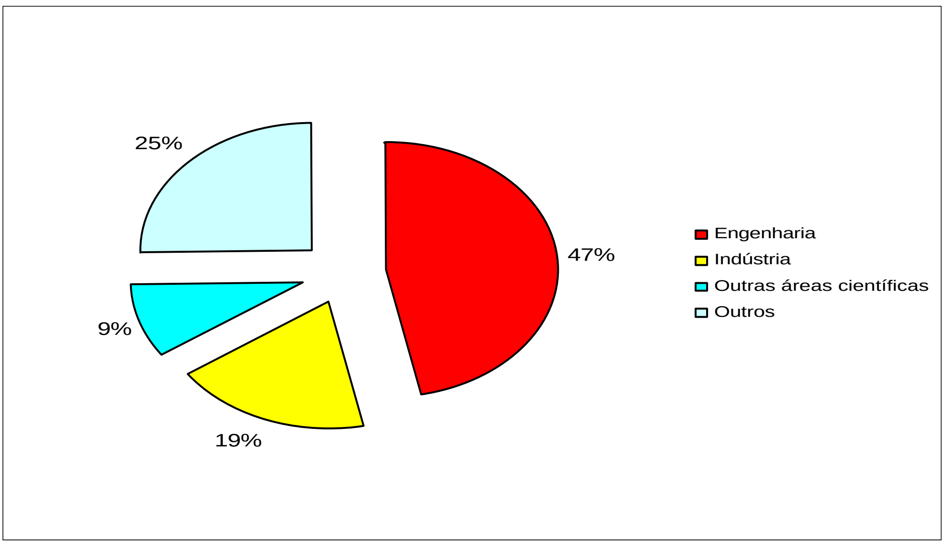
36 Both the Northern and the Eastern lines were soon under the responsibility of the Portuguese engineer João Evangelista de Abreu, a former student at the École des Ponts et Chaussées.

37 Saraiva, *Ciencia y Ciudad* (cit. n. 27).

38 The British journals were the *Mechanic's Magazine* and the *Minutes of Proceedings of the Institution of Civil Engineers*.

journals were by far the most representatives, followed by economic/industrial journals. The interest on industrial issues is quite interesting as it confirms that although Portuguese engineers had a difficult relationship with the industrial milieu, they were nevertheless fully aware of its importance.

Graphic 4: Thematic areas covered by the journals received by the Portuguese Association of Civil Engineers (1880-1900)



Source: "Relatorio e Contas da Associação dos Engenheiros Civis Portuguezes com referencia ao anno de 1878", Revista de Obras Públicas e Minas, 1879, X(111/112) 113; 1881-1910, XIII-XLII; 1923, LIV(627):110-111; 1932, LXIV(680): 61-62.

Concluding remarks

From the mid 19th century onwards, going abroad to improve one's education or to visit and "study" a factory or an exhibition became more and more common among Portuguese engineers.

These "travels of learning" and the networks they allowed engineers to build were powerful tools in promoting technical exchange within the European space and in building a professional identity back home.

In a country of the European periphery such as Portugal the pursuit of new and updated technological knowledge relied deeply on the efficiency of a network of formal and informal channels, which acted has vehicle for learning and spreading new skills, new machines and new expertises. Travelling abroad was part of this overall strategy aiming to appropriate foreign knowledge and to adapt it to local needs and expectations.

The geography of these professional pilgrimages shaped the face of Portuguese engineering, ascribing France a strong role. The Portuguese engineers trained at the École des Ponts et Chaussées, the quintessential institution for engineering training, or at the École des Mines, brought to Portugal the French approach to engineering. Senior engineers travelled frequently to France to catch up with the more recent technical novelties and the world exhibitions held in Paris were the most successful as far as the presence of Portuguese engineers was concerned. Moreover, the

French model fitted the Portuguese state driven agenda of modernization in which the state was itself an economic agent and main employer.[39]

To study at the École des Ponts et Chaussées, to go to a World exhibition, to attend an international congress, to visit a factory or to read a specialized journal must be understood as part of the wider political agenda leading Portugal to modernity. Portuguese engineers were leading actors of this complex play, bringing back home the new trends of technological knowledge and practise

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[39] M. P. Diogo, "Engineers", *The Dictionary of Transnational History*, eds. Akira Iriye & Pierre-Yves Saunier (Palgrave Macmillan , 2007); I. Gouzevitch, I, Inkster eds., *History of Technology*, 2007, 27 (special issue); Grelon et al, *Jogos de Identidade*, (cit. n. 20); K. Chatzis, *A Lasting Exception: Training French Engineers from the Ancien Règime tio the Present Day*, Unpublished paper presented at INES 1st Meeting, Virginia Tech, Blacksburg, U.S.A., 2006.

The Status of Mathematics in Portugal in the 16th-17th Centuries

By Bernardo Machado Mota[*]

Investigating the status of mathematics in Portugal in the 16th and 17th Centuries is a *sine qua non* condition to a better understanding of how the making, teaching and learning of science developed in the country. After all, there is a consensus that mathematics holds a special status in the realm of science in general. It is as antique as the most ancient types of knowledge and has travelled along history shaping scientific culture. Its uniqueness is tangible also in its bursting out of its borders and becoming an instrument of knowledge for many other fields of research.

Mathematics developed as an axiomatic system in Ancient Greece, and the making of such an organized body of knowledge was shaped by strong criticisms from opponents

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and detractors. These criticisms had indeed extraordinary impact on the development of the discipline; in the first place, they were not made by individuals, but by entire schools of thought, including sophists, sceptics or epicureans; secondly these critics objected to every single part of the mathematical discourse (principles, constructions, demonstrations, textual formulation, relationship with other fields of knowledge, relationship with the world); finally, an historical memoir of such criticisms remained until today. Although their constant presence, several pitch moments along history, corresponding to periods of intense revival, show their key role in the new trends and developments of mathematics. In particular, they dominated the 16th and 17th century's philosophy of mathematics. Many examples illustrate such cultural import from antiquity. The following should be enough to make my point: ancient authors such as Aristotle and Sirianus tell us that Aristippus denied any use to mathematics[1]; Cicero adds that Epicurus thought all mathematical knowledge to be false[2]. As late as the 17th century, Vossius tells us that Peter Ramus called the detractors of mathematics "Aristippeos" and "Epicureos", tracing its citation back to classical culture[3]. Of course it is not the citation itself that is relevant, but the fact that upholders and detractors of mathematics still were considered to

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[1] Metaphysics III, 2.

[2] Academicarum Quaestionum, IV, cap. 32.

[3] Gerardi Joan. *Vossii Operum tomus tertius Philologicus (Tractatus Philologicus de Rhetorica, de Poetica, de Artium et Scientiarum natura ac constitutione*...), (Amstelodami, 1697), p. 63-4.

share a common cultural background that goes a long way back to classical antiquity.

At the same time that mathematics evolved into a body of systematized knowledge, a general theory of science was produced. This simultaneous development of a particular kind of knowledge and its related meta-knowledge created a bias with unexpected historical importance. In the first place, it became hard to know which influenced the other or if there was convergence into a common project. In the second place each of them was always dealt with on the basis of the other. The standard formulation of the classical theory of science can be read in the Aristotelian *Posterior Analytics*. The standard formulation of mathematics as a system can be found in the *Elements* of Euclid. Not unexpectedly, pretty soon criticisms to mathematics started being made in the context of the Aristotelian model of science. When commenting on Euclid's *Elements*, book I, Proclus tells us that incompatibility between mathematics and the standard Aristotelian model of science was already stated by ancient authors like Amphinomus and refuted by others, like Geminus. Proclus himself upholds mathematics in the context of such model of science, using its phraseology and framing its requisites. It provides, for generations to come, the entourage in which to explain the scientific properties of mathematics [4].

[4] *In Euclidem*, p. 202. We cite Proclus according to the edition of G. Friedlein, *Procli Diadochi in primum Euclidis Elementorum librum comentarii*, (Hildesheim: Georg Olms, 1967).

Mathematical progress and the rediscovery of the *Posterior Analytics* reinforced the debate from the 12th century onwards. We can trace it in a modified form in the 14th Century Oxford *Calculatores*. At the same time, in Paris, John Buridan, Hugh of Traiecto and Albert of Saxony dealt with the topic. In the 16th century Italy, the humanist Alessandro Piccolomini strengthened the debate when publishing his *Commentary on the Certainty of Mathematics,* in 1547[5]. In this work, the Italian scholar brought together ancient lines of thought based on Aristotle, Plato or Euclid, along with the commentaries on their work (Proclus, Simplicius, Themistius, Eustratius, Ammonius, Philoponus, or Averrois, among others). In his gathering of arguments against mathematics he not only took profit from arguments continuously taught, but also from those newly discovered through the recovery of ancient authors. Recent studies have already identified other intervenient Italian authors, and their arguments on the subject[6].

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5 The full title of the work is: Alessandri Piccolominei, In *Mechanicas Quaestiones Aristotelis. Paraphrasis paulo quidem plenior. Ad Nicolaum Ardinghellum, Cardinalem Amplissimum. Eiusdem Commentarium de Certitudine Mathematicarum: In quo de Resolutione, Diffinitione, et Demonstratione: necnon de matera, et in fine logicae facultatis, quamplura continentur ad rem ipsam, tum mathematicam, tum Logicam, maxime pertinentia* (Excussum Romae, apud Antonium Bladum Asulanum, 1547).

6 Bibliography on the theme is huge, thus we remind only a few but important works: P. Galluzzi, "Il 'Platonismo' del tardo Cinquecento e la filosofia di Galileo", in *Ricerche sulla cultura dell'Italia moderna,* ed. Paola Zambelli (Bari: editore Laterza, 1973), pp. 37-79; Giulio Cesare Giacobbe, "Il *Commentarium De Certitudine Mathematicarum Disciplinarum* di Alessandro Piccolomini", *Physis*, 1972, *14*(2):162-193; *id.*, "Francesco Barozzi et la *Quaestio De Certitudine Mathematicarum"*, *Physis,* 1972, *14*(4):357-374; *id.*, "La riflessione metamatematica di Pietro Catena", *Physis,* 1973, *15*(2):178-196; *id.*, "Un gesuita progressista nella «Quaestio de Certitudine mathematicarum» rinascimentale: Benito

Considerable attention must be paid to Jesuits as agents of transmission of this debate, of which they made strong echo. The educational goal and the worldwide dimension of the Society enlarged the social impact of the debate. Moreover, forty years after Piccolomini had published his treatise, Jesuits were discussing the plan of studies (*Ratio Studiorum*) for their colleges, and were in need of defining the curricular place of mathematics in the context of a religious education. The debate was a sign of deep social and corporative tensions, since each group of teachers (philosophers and mathematicians) tried to enforce its own influence within the educational system. Among defendants of mathematics, one can find the most important Jesuit mathematical authority, Father Cristopher Clavius, who, besides producing several documents about how to promote the study of mathematics within the Society[7], and arguing for the certainty of mathematics in his works[8], struggled for the

Pereyra", *Physis,* 1977, *19*(1):51-86; N. Jardine, "The Epistemology of the Sciences", in *The Cambridge History of Renaissance Philosophy*, eds. C. B. Schmitt, Q.R.D. Skinner and E. Kessler (Cambridge University Press, 1988), pp. 685-711; Paolo Mancoso, *Philosophy of Mathematics and Mathematical Practice in the Seventeenth Century* (Oxford University Press, 1996); Antonella Romano, *La contre-réforme mathématique – constituition et diffusion d'une culture mathématique jésuite à la renaissance (1540-1640)*, (Rome: École Française de Rome, 1999); Anna De Pace, *Le Matematiche e il mondo – Ricerche su un dibattito in Italia nella seconda metà del Cinquecento* (Milano: Francoangeli, 1993).

7 At least four documents are relevant: "Ordo seruandus in addiscendis disciplinis mathematicis", "Modus quo disciplinae mathematicae in scholis Societatis possent promoueri", "De re mathematica instructio", "Oratio de modo promouendi in Societate studia linguarum politioresque litteras ac mathematicas". All documents can be found in Ladislau S.I. Lukács, ed., *Monumenta Paedagogica Societatis Iesu*, vol. 7, (Romae, Institutum Historicum Societatis Iesu, 1992), pp. 119-122.

8 Cristophori Clavii Bambergensis e Societate Iesu *Operum Mathematicorum Tomus Primus*, (Moguntiae, Sumptibus Antonii Hierat, excudebat Reinhardus Eltz, Anno MDCXI), p. 5.

establishment of an Academy of Mathematics in the *Collegio Romano*, thus providing institutional foothold for investigation on mathematics. This mathematical project, however, faced ferocious opposition from Jesuit professors of philosophy. The most authoritative among these was Benito Pereira, a teacher of philosophy at the *Collegio Romano*, who proposed a more radical thesis than the one by Piccolomini, denying mathematics any value at all as a science[9].

The growing number of students and teachers of mathematics and the developments of both pure and applied mathematics increased the reflection upon its scientific status. The main topic discussed included knowing if mathematics fitted the Aristotelian model of science, and this implied further discussion on the status of mathematical demonstrations. One of the questions asked was if mathematical demonstrations were causal, and if mathematical principles and premises were like to fulfil all Aristotelian requisites, that is, if they were true, primary, immediate, more known, prior and causes of the conclusions[10].

Although the importance of this topic in the rise of modern science is known, it has been only partially studied.

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[9] Benedictii Pererii Societatis Iesu *De communibus omnium rerum naturalium principiis et affectionibus libri quindecim qui plurimum conferunt, ad eos octo libros Aristotelis, qui de Physico auditu inscribuntur, intelligendos. Adiecti sunt huic operi tres indices, unus capitum singulorum librorum; Alter Quaestionum; Tertius rerum. Omnia uero in hac quarta editione denuo sunt diligentius recognita, et emendata. Cum priuilegio, et facultate superiorum*, (Romae, Ex officina Iacobi Tornerii et Iacobi Biricchiae, MDLXXXVI; the first edition dates back to 1576), book 1, chapter XII (Scientiam speculatiuam non dici uniuoce de Mathematicis disciplinis et aliis, quoniam doctrina Mathematica non est proprie scientia) pp. 26-28.

[10] The definition of scientific knowledge and the properties of the premises of a science can be found in Aristotle's *Posterior Analytics* II, 71b9-72b5.

Attention has been paid to printed works and not yet to manuscript sources. Moreover, little work has been done in contexts other than the Italian, French and English one. There is a need for a deeper study in specific local contexts so that we can have a European perspective on the subject.

My investigation tried to detect echoes of the debate in Portugal. First there was the need to set a corpus of texts to search into. Secondly, the debate being so linked to mathematical practice, there was a need to know who did mathematics in Portugal in the period of the scientific revolution, what level of mathematics were Portuguese able to achieve and at what extend there was Portuguese participation in the making of European mathematics. Finally, a twofold investigation was imposed: the study of the debate among scholars in Portugal, and among Portuguese scholars in Paris.

I concentrated on the set of manuscripts that can be found at the National Library (Lisbon). The collection of manuscripts at the National Library (Lisbon) is so vast a collection (the largest in a Portuguese library) that it gives us a representative view on how the theory of science and other logic topics were taught in the classroom, providing useful epistemological, social, geographical and chronological information. Within that set, we restricted ourselves to lessons of logic, which contain the study of the Aristotelian theory of science. Special attention was paid to Jesuits, because of their importance in the Portuguese educational system. Although several official documents were investigated, my main concern was to find out what they usually taught in their courses of Philosophy. Happily, I found out that Jesuit teachers of philosophy usually included a chapter about the scientific status of mathematics in their lessons of logic, in a section often named *De Scientia*. When dealing with the status of mathematics in their courses, many teachers followed closely the contents of the *Commentarii Collegii Conimbricensis e Societate Iesu In Vniuersam Dialecticam Aristotelis Stagiritae*, published in 1606. On the other hand, these influential *commentarii* were based in lessons taught before that date; so, it will not be wrong to say that they presented, in the context of a general theory of science, a printed edition of widespread arguments against mathematics usually taught by Jesuit philosophers in the 16th and 17th centuries.

Two theses were of particular interest despite their traditional appearance: the first one insisted that mathematics should be considered a science *absolute, communiter* or *lato modo,* but not if considered in the proper sense, that is, *proprie,* or, in other words, in the Aristotelian sense, a thesis that might lead to consider mathematics in the context of other scientific models; the second one supported that only pure mathematics was not to be considered a true Aristotelian science, thus allowing a higher status to mathematical physics. Still, the author of the *commentarii*, Sebastião do Couto, strongly believed science should be considered *proprie*, and made his thinking into actions when he forbade the printing of lessons taught in Portugal by a colleague of his, Cristophoro Borri, because of his upholding mathematics. The *Dialectica Conimbricensis* gathered views against mathematics until 1606 and represented the late scholastic final outcome of fifty years of teaching and reasoning on the topic. All arguments presented against mathematics still focused in some of the postulates of the Aristotelian model of science unlike the later *Logic of Port Royal*, also a milestone in the story of mathematical criticisms, which goes a step forward in incorporating other traditions. The theses presented in these commentaries prevailed in the Portuguese context until the end of the 17th Century, when General Tyrso Gonzalez ordered a reformation of the mathematical teaching in Portugal, forbidding philosophers from attacking mathematics.

As to Portuguese Jesuit mathematicians and mathematical practice in Portuguese Jesuit schools, one is struck by the scarce information on the subject. Only recently (and partially), has some light been thrown onto the subject. There was a need again to go into the manuscript sources. Although mathematics was indeed considered a minor subject of teaching, the Jesuit school of Santo Antão, in Lisbon, offered a course on mathematics continuously since 1590 until Jesuits were expelled from Portugal in 1759. The relevance of this school does not end in its unique course on mathematics but also in the fact that its first teacher of mathematics, João Delgado, had been a former disciple of Cristopher Clavius, above mentioned. João Delgado became aware of the debate via Clavius' Academy of Mathematics, and was the first Portuguese mathematician that expressly addressed the subject in his classes, thus providing evidence that there were also Portuguese scholars who contributed to the debate. There is further evidence of a programmatic and systematic defence of mathematics in lectures of successive teachers of that school during the 17th Century. One can see it in the first chapters of the courses offered by Giovanni Paolo Lembo, Cristophoro Borri and others of unknown authorship[11].

One second group of Portuguese intellectuals aware of the problematic about the status of mathematics was located in Paris. Three cases are worth mentioning:

- one of the most interesting episodes of the University of Paris that somehow is linked to Portuguese culture is that of the anti-Aristotelian libellous written by Pierre de la Ramée, entitled *Aristotelicae Animadversiones* (1543). When referring to the *Posterior Analytics,* P. de la Ramée included a strong criticism against the scientific status of mathematics. Most relevant is the fact that it was António de Gouveia, an important Portuguese scholar connected to the college of Santa Bárbara (Paris), the responsible for the first printed reply (*Pro Aristotele responsio aduersus Petri Rami calumnias*, 1543). He was also chosen for a disputation on the subject with Pierre de la Ramée in the presence of the king himself. Defence of the *Posterior Analytics* involved, given the nature of the opponent's attack, the endorsement of mathematics in the context of the Aristotelian model of science. The interest in the episode increases when one realizes the important role Gouveia played in the Portuguese educational system;

[11] The authors cited, their biography and works are listed in Ugo Baldini, "L'insegnamento della matematica nel Collegio di S. Antão a Lisbona, 1590-1640", in *Colóquio Internacional a Companhia de Jesus e a missionação no Oriente* (Lisboa: Brotéria / Fundação Oriente, 2000), pp. 275-310. Among the texts of unknown authorship, the reader is simply referred to the manuscript BN cod. 2260, not cited in Baldini's paper.

- a second case is that of Diogo de Sá who criticized the renowned Portuguese mathematician Pedro Nunes (*De Navigatione libri tres*..., Paris, 1549). Significantly, a part of his work, published in Paris, consisted of a non mathematical criticism; instead, Diogo de Sá criticised the fact that, as mathematician, Pedro Nunes could only aim at a partial study of nature, because of mathematics' failure to meet the requirements of a true science. In this way, Diogo de Sá inscribed his work in the context of the debate on the certainty of mathematics. This example also clearly indicates the need for investigating the men responsible for teaching mathematics in the Portuguese Court (a group that included names like Pedro Nunes and his substitute Domingos Peres).

- a third Portuguese scholar aware of the debate was Francisco Sanches, a prominent professor at the University of Paris, who exposed his opinion on mathematics in a letter written to Cristoph Clavius, citing some topics of the debate[12].

Evidence thus supports the claim that theses against mathematics prevailed among Portuguese philosophers, both in and outside Portugal. Nevertheless, the scarce number of Portuguese mathematicians was not enough to counter balance the controversy because they were unable to provide universities with the necessary human resources for teaching mathematics, as well as to create institutional foothold for developing mathematics.

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[12] The most recent edition of this letter can be found in U. Baldini and P.D. Napolitani, *Cristoph Clavius: corrispondenza* (Dipartimento di Matematica-Università di Pisa, 1992) vol. 6.1, pp. 185-194 and vol. 6.2, pp. 110-116.

To sum up, my work tries to understand the different views on how to relate mathematics and other fields of knowledge among 16th and 17th mathematicians and philosophers. Another perspective I intend to explore is the ways in which institutions assimilate philosophical and social views on the status of the mathematics and solve tensions within their curricula organization. The overall result intends to provide the more general context of humanistic reception and approaches to classical culture. The main topic addressed is the debate on the status of mathematical demonstrations (the *Quaestio de Certitudine Mathematicarum*) and its reception in Portugal. To make such study possible, there was a need for studying ancient mathematics (mainly Euclid, and Proclus' *Commentary on the first book of Euclid's* Elements) and its renaissance reception; ancient philosophy of mathematics (mainly Plato, Aristotle and their commentators) and again its renaissance reception. Stress must be put in the convergence of history of mathematics and a broader understanding of Classical Culture and its modern interpretation, which includes clarifying the Greek mathematical tradition up to the 18th century; the history of institutions and libraries; the transmission of knowledge and circulation of new scientific ideas in Portugal to the end of the 17th century.

Einstein Rewired

Peter Galison, Einstein's Clocks, Poincaré's Maps. Empires of Time (New York / London: Norton, 2003)

By Antonio Lafuente[*]

The Muses always catch you when you are at work, say those who see no incongruity between genius and perseverance. But Peter Galison, accustomed as he is to shunning clichés and to dealing with heavyweight scholars, would say that this expression is confused and conformist, unless we go deeper into the meaning of the word work. For Galison, professor of physics and history of science at Harvard, the Muses must be scared off by contemplative, antisocial, and technophobic attitudes, since what they find when they come to the aid of a scientist, says this historian, is somebody manipulating things, tinkering with objects, moving terms around, negotiating meanings and plugging in apparatus.

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The process of thinking, no doubt, is more manual than cerebral, and always involves a host of professional gadgets, from tabulations and computers to formulae, instruments and libraries. Our histories, however, still insist on describing science and culture as a battle of words, a sort of seepage from the brain and devoid of all the accessories which form the ecosystem of the scientist. It is not that there are few references to machines, for they account for a large part of the time spent on an activity which is of an experimental nature; but rather that laboratory life has completely disappeared. Scientists are often regarded as writers, people who publish things, although their writings have very rarely been analyzed in terms of rhetorical artifacts: after all, their texts are the translation into word and language of what has been done with the hands and visualized by way of machines.

The fact is that Peter Galison sees things in a different way, and to demonstrate it he has chosen the most difficult of all cases: Einstein, the best-known scientist of all time, the most prodigious human mind. Indeed, Einstein's brain is still a cult object. Many think it is incredible that once again others are trying to find a direct relationship between morphology and intelligence.[1] But after applying the most sophisticated analytical techniques, a couple of very extraordinary peculiarities have been discovered in his parietal lobes. Steven Pinker, a well-known neurologist from the Massachusetts Institute of Technology was delighted, and

[1] S.F Witelson, D.L Kigar and T. Harvey, “The Exceptional Brain of Albert Einstein”, *The Lancet*, 1999, *353*:2149-2153.

announced his delight to the world in a series of well-turned phrases: "Still, it is strangely fitting that the brain that unified the fundamental categories of existence — space and time, matter and energy, gravity and motion — should now be helping us unify the last great dichotomy in the conceptual cosmos, matter and mind."[2] And if we can do such exquisite physiological things with his brain, why not take advantage of his name to get into the politics of science? Lee Smolin, an expert on quantum gravity at the Perimeter Institute for Theoretical Physics (Waterloo, Ontario), has just joined in the commemoration of the centenary of Einstein's "Miracle Year" with the question Why No "New Einstein"? [3] in the influential journal Physics Today. Irrespective of the answer to this question, the point is that anything referring to Einstein acquires this aura of mysterious genius, the mystique surrounding a solitary disinterested scholar, whose every movement is to satisfy his innate curiosity and to work towards the public good. Smolin's article is excellent. He begins by stating that, while great discoveries come from independent minds, like Einstein's, our system has evolved in the opposite direction to what is most appropriate. It is not only incapable of harnessing what little revolutionary drive may still exist, but it is threatening the existence of the necessary spirit of criticism: Einstein

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[2] Steven Pinker, "His Brain Measured Up", *The New York Times* (June 24, 1999), http://pinker.wjh.harvard.edu/articles/media/1999_06_24_newyorktimes.html

[3] Lee Smolin, "Why No 'New Einstein'?" *Physics Today*, 2005, *58*:56-57 This text, which is being hotly discussed, is freely available on various blogs, such as http://waltf007.mindsay.com/

would be impossible in a world where scientists are squeezed by the pincer movement of pressure for research into practical subjects, and the obligation to publish in influential journals. The consequence, according to Smolin and the many other scientists who are singing the Big Science "blues", is that democracy itself is in jeopardy. Not only are the creativity and independence of researchers being cut back, but we are seeing the liquidation of the old ideals which made science, according to Merton, into a disinterested, community-oriented, cosmopolitan and skeptical undertaking.

But Galison does not agree. The question is wrong because it is redolent of that ideology which has always contributed to the construction of the myth of old-fashioned science, a science tucked away into small spaces, protected from the public gaze, buttressed by brilliant minds, made up of paradigms without frontiers, and where money, machines, public, administrations, publishers and ministers were only incidental matters, secondary actors, mere props in a theatre blazing with concepts, theorems, crucial experiments and Nobel prizes.

Science, says Galison, should be put into a new context. The history of scientific ideas, together with the frame surrounding them (a bit of institutional history, dressed up with dashes of politics, philosophy and prosopography), ignores what is decisive and gives substance to what is purely anecdotal or even traditional. What Galison has done is to document himself better than his predecessors and then not to reject any facts. Thus he has taken seriously some of the circumstances of Einstein's life which hitherto have received no academic attention: for example, the importance of forming part of a family involved in the development of electrical equipment. It was very important for Galison to have a grandfather who had worked with Edison, and who had an experimental workshop at home which would be the envy of any handyman of the time or any nerd of today[4]. It would be wrong to think that Einstein was not happy while he worked in the Patent Office in Bern where, by the way, he spent between 10 and 12 hours a day, six days a week. And, what is most important, it would be a great mistake to think that his work with electromagnetic devices, watches and dynamos was purely a way of making a living and contributed nothing to his concerns as a theoretical physicist.

Clocks in about 1900 were what computers are today. The synchronization of clocks at that time was a task with as much technical, philosophical and political importance as interconnecting PCs and designing communication protocols and distributed calculations are now. Strange though it may seem, this was really the case. And nothing shows this better than a look at another key figure of the science of the time, a polytechnicien, in other words, a product of the École Polytechnique of Paris, the emblematic institution of French republicanism whose engineers were something between the pupils of the MIT and the students of West Point. We refer to Poincaré, the most popular and most prestigious scientist in France, a character as decisive for the development of the

[4] "Einstein and Poincaré: A Talk with Peter Galison", http://www.edge.org/3rd_culture/galison03/galison_p3.html

Theory of Relativity as he was a key figure in the process of techno-scientific consolidation in the French empire. The point which makes this book such an exceptional work is that it manages to connect one case with the other: for Poincaré did not pass into the history of relativity in spite of his responsibilities for the mapmaking of the colonies in the Bureau de Longitudes, but precisely because of them. And the same may be said of Einstein, for it was his work with those devices for measuring time which taught him to treat it as a purely technical excrescence.

In order to make maps you have to know the longitude of the places which are to be connected topographically. To draw them on the map you have to compare the differrence between two times, local and distant: one, for instance, in Senegal and the other in Paris, the capital of the Empire through which the reference meridian would obviously pass. The first is obtained by in situ observation of some astronomical phenomenon, and the second from a distance, when a signal transmitting the time from Paris arrives in Dakar. The precision of maps, consequently, depends on the quality of the transmissions, first using the telegraph wires and then undersea cables. The organization of the railways also posed problems of coordination, for signals were not instantaneous and they took a certain amount of time to cover distances. For engineers, the notion of local time was absurd and, rallying to the cause of efficiency, they imposed the dictum that a country should choose not only a metric system but also a national time. In short, to find out the time, city dwellers, priests, engine drivers and mapmakers stopped looking at the sky and began to consult the clocks installed in the cities, including those installed in many palace towers and belfries. Bern inaugurated its system of time synchronization in 1890, and it would have been an insensitive person indeed who would fail to be impressed by the spectacle of the hands of all of those clocks moving together, never missing a step. Precision was laudable, but the most important thing was coordination. This book is peppered with fascinating stories. In 1883, for example, the division of the United States into time zones was imposed. Each zone was exactly an hour different from its neighbor. The agreement was reached "railocratically", for each delegate voted according to the number of miles of railroad track he represented, and the result was thus 79,041 miles to 1,714. Our modern, and now century-old, habit of seeing the second hands in Ferrol, Marseilles and Naples all moving in unison not only reflects the conventional nature of time but also the technological challenge called for to maintain time — that is to say, our world.

Local time, as we can see, was a tricky subject not only technically but also theoretically. Lorentz, the greatest living physicist of his time, was the first to observe that the equations of electromagnetism would be much simplified if they were not referred to a fixed external frame (the ether, which ensured the metaphysical validity of absolute time and space), but to another, linked to the movement of the system. And so it was that he introduced the notion of local time, a sort of mathematical device with no basis in fact: it could be deduced but not measured. But Poincaré, who had already simplified these metaphysical questions by translating them into technical problems, resolved the problem in

1900 by showing that time changed according to the velocity of the reference frame. The consequence was clear: Lorentz had not invented a fiction, but had unwittingly discovered the relativity of time and space. After all, absolute space and absolute time, like Euclidian geometry itself, “did not exist”, said Poincaré, “before mechanics, any more than the French language logically existed before the truths we express in French”.

Local time was as real as the theory of the ether was unpredictable. Down with absolutes! Poincaré knew it before Einstein, but fell short of the mark by not rejecting the theory of the ether, that fluid which for centuries was said to be necessary for the transmission of light rays (like water for waves, or air for sound). Einstein was younger, and refuted the need for this intangible fluid; in exchange he proposed two new laws which changed our way of looking at the world: that of the constant speed of light, and that of the invariability of the laws of physics. Both of them would hold true in all frames, no matter what their velocity or their motion. The theory of relativity, as we can see, should really have been called the Invariantentheorie, and Einstein himself several times requested that this name be used. However the media opted overwhelmingly for a name which helped them to understand the direction in which the other vanguards of the early twentieth century were heading (and the crises they would face!).

Let me borrow a metaphor that Galison frequently uses to explain what he is trying to do. In Paris, the Place de l’Étoile is not in Avenue Foch, nor in the Avenue Victor-Hugo: it is precisely the intersection which makes it into a city landmark. The same applies to Relativity, which appeared to be on the crossroads of powerful technological traditions, ancient metaphysical enigmas and unexpected problems of physics. Relativity, contrary to popular opinion, was not the work of one isolated genius, nor was it born in any out-of-the-way location (technologically, culturally or economically speaking). Einstein was right at the centre of science at the time. His greatness is not to be found in his brain, but it comes from his strategic position in the network. This is the reason I have called this review "Rewired Einstein", because it puts him into a new context, showing him as the focal point of a network of interchanges, and as someone who thoroughly enjoyed playing with cables and artifacts. But it also shows him as a person able, like Poincaré, to site himself right at the intersection of many disciplines, whose traditions, protocols, instruments and sources of authority were immeasurably huge. Who could foresee then, in about 1900, that the booming business of selling electrosimultaneity would join forces with that of the railways and of colonialism, to interweave with the dilemmas of Lorentz, the duties of Poincaré and the verdicts of Einstein, and jointly give birth to Relativity?

The subject has always concerned Galison: the "disunity of science", the need to explore the border areas (trading or Creole zones, he calls them) between different disciplines. He has already done it in his previous two works, How Experiments End (Chicago University Press, 1987) and Image and Logic: A Material Culture of Microphysics (Chicago University Press, 1997). In the first, all of 18 years ago, he was interested in the problem of how scientists, with their sophisticated artifacts, know that they are producing facts and not mere artificial effects, and also how they know that they have enough facts, in other words one or more proofs. To put it another way, he was concerned with the way material machines (made of nuts and bolts, cables and glass) interact with theories and concepts. The second book followed up these concerns and dealt with the development of subatomic physics linked to the two generic types of machines (or instruments) each designed to produce differrent types of image (or representations or simulations): analog, like the bubble chamber or the techniques of nuclear emulsion, and logical which, like the Geiger counter, give us an image made of figures which count impulses. The message of all three books is the same: there is a great deal of technology behind every theory and, of course many concepts spring into motion every time we turn a little wheel or press a button. To separate science from the technologies which produce it, to opt for the history of ideas, is to condemn the discipline to a spiral of idealization which is as common as it is destructive. Worse still, to separate our ideas from the machines with which we produce them and realize them is tantamount to refusing to understand how the world in which we live was created. The last two lines of the book say it forcefully: “We find metaphysics in machines, and machines in metaphysics. Modernity, just in time.”

reviews

Robert E. Kohler. Landscapes and Labscapes. Exploring the Lab-Field Border in Biology. (Chicago/London: The University of Chicago Press, 2002). xvi+326 p.

By Jesús Catalá-Gorgues[*]

During the last fifteen years, research on place-located practices has emerged as one of the most fruitful approaches in historical and social studies of science. The present book falls into this category by making specific places of scientific practice its focal point. In this sense, Kohler's book can be considered a good example of a cultural geographical approach to science. Kohler is a well known author by his celebrated *Lords of the Fly:* Drosophila *Genetics and the Experimental Life* (1994), also published by the University of Chicago Press, and by his remarkable career as an expert historian of biochemistry and related medical disciplines. Lately, however, he has moved to a different research area: rather than focussing on experimental disciplines, he has devoted himself to the history of field sciences. This book is the most outstanding result of his recent intellectual pursuits.

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Kohler offers a stimulating and penetrating narration on how the border zone located between the increasingly powerful realm of experimental biology and the unceasingly disturbed region of natural history was negotiated in the United States, between the last decade of 19th century and the 1950s. More specifically, he explored the border zone where new disciplines such as ecology and evolutionary biology germinated and grew for almost sixty years. At the turn of century, some laboratory-trained biologists felt that experimental developments in biology, in particular microscopic morphology which in those days attracted much attention, began failing the targets they were set to achieve. A problem laid in displacing laboratory techniques to the study of life as it presents itself in nature. Laboratory-based biological research entails the dislocation of objects out of their natural environments, that is, living beings are studied in undisturbed laboratory conditions as against unpredictable field ones. But these laboratory practices were found to have their own limitations. Although they facilitated the understanding of structural patterns, they failed to unveil functional processes as a whole. It was the realised that the relations with other living beings and the environment, distinct behaviours, evolutionary pressures, etc., could only be properly studied and understood in the field. However, the traditional approach to field studies in the natural sciences was then poorly considered because not only were their methods seen as unscientific when compared with laboratory ones, but also their obsession with description and collection rather interpretation made them suspicious. Only by combining naturalists' field familiarity with the standards of good scientific practice associated with laboratory-based research one would have a new scientific natural history, a thought which disenchanted biologists.

The idea of a new natural history was an ephemeral episode rather than an effective research programme, as Kohler points up, but it produced some effects in the second and third decades of the 20th century. It opened a process that attempted to incorporate laboratory techniques into fieldwork and some seminal theories in ecology were produced in this context. However, this kind of mixed scientific practice was doomed to failure because techniques which had been conceived for the laboratory usually failed or did not produce optimal results when applied in field conditions. Nevertheless, some authors were determined to walk along this path. For personal reasons and the sake of careers, or for matters of status of scientific disciplines, laboratory-based science represented the desiderata of many practitioners, because the association of field science with laboratory techniques had the potential of increasing personal and disciplinary recognition. Between the 1930s and the 1950s, the landscape began to change as naturalists increasingly oriented themselves towards the development of proper field techniques that could match laboratory standards. This process proved itself to be more fruitful as it produced deep-rooted theories and helped to consolidate ecology and evolutionary taxonomy as respectable scientific disciplines in all senses. Although it seems paradoxical, field biology attained success not because it imported laboratory techniques to the field, but because it revised and designed its own methods and techniques according to standards that were acceptable by laboratory-based biologists.

Kohler describes the fascinating history of this complex process and its numerous main characters with brilliant prose and convincing arguments. He uses copious primary sources, especially letters, but also printed works and unpublished reports, as well as presenting a detailed and comprehensive secondary literature. One only misses some references to French historians of ecology in his contextualization. To some extent, Kohler's book is a traditional historical narrative based on the usual sources; but it is also an important contribution full of rich and suggestive metaphors, searching out an interpretative model for contested cultural territories in science. At the same time, it represents an example of interbreeding between historiographical territories along a border zone: on the one hand, traditional descriptive accounts, full of citations but barely interprettative; on the other, charming and persuasive exercises of imagination that are aimed to open new ways of historical work, with bold proposals often based on scarce critical apparatuses. Both dimensions are not mutually exclusive but indispensable to the development of history of science, which, I believe, is substantially enriched by that interbreeding terrain occupied by books such as Kohler's.

Marc Desportes, Paysages en mouvement: Transports et perception de l'espace XVIIIe-XXe siècle (Paris: Gallimard, 2005). 413 pp.

By Marta Macedo[*]

"Paysages et mouvement" aims both at a scholarly public of historians of technology and a broader range of readers interested in mobility issues. It is a richly illustrated book which describes the transformations of the built environment of modernity taken from the point of view of the interactions between the *individual* and the *forms* he inhabits. Transportation, commonly understood by traditional historiography as one of the main agents of change of collective experience, should also be used – the author suggests – as a way to recognize the "spatial dimension of human existence" (p.13). The book is chronologically organized offering a classic sequential narrative that begins with the roads of the Enlightenment (1730-1770), follows with railways (1830-1860) and automobiles (1900-1920), and concludes with twentieth century high-ways (1920-1940). To present each subject the author built a rigid three block structure supported by extended bibliographical resources. The first block includes the genealogy of the transportation system and its economic, social and political context; the second depicts the system's features and its influence on the forms of appropriating the physical environment; the third

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and final block uses traveller's experiences to show how changes in the ways of seeing defined new landscapes. The careful study of interdependencies, namely those between technology and culture, is one of the author's most cherished topics.

The new network of roads of the eighteenth century is presented as a coherent global project for the construction, integration and enhancement of the French territory. Following Desportes, the straight lines imposed on road design by the *Ponts et Chaussées* engineers, besides their clear esthetical and philosophical implications, made a crucial contribution together with the new means of transportation for improving travelling conditions. The increase in comfort allowed for new ways of appreciating the travel route directly connected to the emergence of a new artistic genre – the landscape painting – that, together with the diffusion of travel accounts, became a very influent way of educating the visual sense. For Desportes, the road landscape captured by the moving vision is a rich and complex discovery that calls upon the enlightened "traveller's sensibility".

Concerning railways, the book advocates for understanding them as occupying the centre of a constellation of innovations developed to increase speed in an economical and safe way. Trains transformed travelling into an ingredient of everyday life collectively experienced, safeguarding class distinctions. Individuals were exposed to a new, many times traumatic, sensorial experience, with their bodies plunged into a material technical dimension. The transitory nature of reality revealed by speed shaped new ways of perception. As photography compensated for the limitations of the human eye, fixing minimum details, impressionist painters exposed the fragility of vision and tried to capture the ephemeral. Desportes shows the resemblances between this “artificial landscape” and a moving panorama.

The twentieth century welcomed the automobile and the user was invited to take part in the action. The car invaded the urban space and immediately new conflicts arose among the many users of the streets. Technical improvements, norms, regulations, codes and signals came together to coordinate traffic and eliminate the frictions that obstructed the flow of cars in the city. In clear contrast with those trains limited to a specific technical space, the new vehicle allowed for a freedom of action that Desportes likes to call “automobility”. Cars are thus held responsible for a rediscovery of the countryside, at the same time that new motorized tools were colonizing the rural world. From inside the moving car the traveller was able to capture a succession of views at different angles. The low speeds of those glorious times also contributed to a new unity between man and its environment.

Things would definitely change with both the mass production of vehicles and the building of a specific infrastructure for car circulation – the highway. Highways may be seen as a hybrid device formed by the rules and technical elements of streets and the mono function of railways. In clear opposition to traditional roads, they were conceived as closed networks, a “set of isolated canals that may only open to the exterior by way of exchange devices” (p. 301). Their trajectory, slope, curves and connection points were designed by engineers using sophisticated calculation methods to ensure both speed and safety. And as in any organization abstractly conceived, signs became crucial elements for understanding the system internal rules. Travelling in highways is thus a deeply subjective experiment. While some drivers fight tediousness and the monotony of the standardized route, others feel attracted by the freedom offered by vertiginous speeds. Of course, once again, the highway landscape is highly artificial, dominated by the infrastructure and by the array of technical mediations.

The author uses his historical narrative as a tool to face contemporary controversial issues, namely urban planning and its obsession with enhancing circulation. He strongly criticizes a process by which cities have been transformed into fragile and discontinuous spaces and urban life has been reduced to the constantly repeated mental activity of decodifying. Trying to overcome the inherent limits of a decontextualized technical approach, Desportes puts forward a "counter-method" to design mobility infrastructures which respects the unity of each place and takes into consideration its multiple components and interrelations. To counter abstract attitudes towards places he recommends seeing such entities as thick and complex historical objects. Finally, and no less important, mobility projects should include anticipations of the future spatial experiences, both body and mental, of individuals.

As already stated, this is an ambitious book concerning potential audiences. The will to contribute to the formation of technical agents directly involved in planning doesn't compromise its historical aspirations. This was a well succeeded strategy as demonstrated by the fact of the author, a *Ponts et Chaussées* engineer with a PhD on urbanism and a large background on planning, having been awarded the Jacques de Fouchier prize by the French Academy for the originality of the argument of the present work

Luís Miguel Carolino, Ciência, Astrologia e Sociedade. A Teoria da Influência Celeste em Portugal (1593-1755) (Lisboa: Fundação Calouste Gulbenkian, Fundação para a Ciência e a Tecnologia, 2003). 431 pp.

By Henrique Leitão[*]

No century is as poorly known in Portuguese scientific history – and in cultural history at large – as the seventeenth century. Even conscious and well informed historians usually treat this period merely as a sort of hiatus, compressed between the always praised sixteenth century and the "enlightened" eighteenth century. Scientific activities in the seventeenth century in Portugal are mentioned, if at all, only by way of contrast. This tells us more, of course, about the historians' preferences than about the real scientific history of the country. Indeed, despite the fact that studies on the scientific practice in Portugal in the seventeenth century are nearly inexistent, historians are hardly ever shy

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to utter strong opinions about the (poor) status of science in Portugal at that time. If not by anything else Luís Carolino's book would be commendable just for the fact that it is a scholarly investigation about a very poorly studied topic.

In this book – a slightly revised version of the author's doctoral dissertation of 2001 – Luís Miguel Carolino provides the first in-depth study of the theory of celestial influence in Portugal in the period 1593 to 1755. The theory of the influence of celestial bodies upon events and beings on the Earth was not only astrology's most important conceptual foundation, but also a basic notion in the interpretation of the relations between man and the cosmos. Carolino documents in detail the intellectual changes that took place and affected these ideas, from the end of the sixteenth century to mid eighteenth century, a period during which the status of this theory altered radically. Celestial influence changed from being seriously treated in the most learned texts of natural philosophy to being considered a fantasy tainted with superstition. The declining importance of this theory – its later apparitions in books and in debates serve only to elicit refutation – signals drastic changes in the theoretical framework, the institutional contexts and the social background where the theory was used and discussed, and the author follows and examines all these evolutions.

The book is divided in three parts. In Part One the author discusses the fundamental theoretical concepts of natural philosophy associated with the theory of the celestial influence. In Part Two he broadens the focus of the analysis by considering the social impact of these ideas and what he calls the "imaginário cosmológico" ("cosmological imagery" is an approximate translation) of Portuguese society. Finally, in Part Three the author studies the crisis and collapse of the older cosmological notions. A prominent place throughout the book is given to Jesuit works and Jesuit themes which are studied in great detail. It is indeed one of the more appealing features of the work the fact that the author systematically avoids the vague characterizations of Jesuit intellectual production as monolithic or uninteresting. On the contrary, Carolino courageously enters the complex and sophisticated world of Jesuit debates and materials, especially Jesuit seventeenth century textbooks of natural philosophy. What he finds is much more interesting than he (or any of us), judging from the general utterances of traditional historiography, could have anticipated. As he puts it: "Contrary to what the historiography of Portuguese culture has stated one finds an intellectual tradition that does not exhaust in repetition, in sterile and barren speculation about worn-out and old-fashioned themes. Contrary to what has been stated, from our study emerges a lively and creative philosophical trend that, above an aristotelian-thomistic basis, finds new synthesis, and incorporates new elements as strange as certain notions directly inspired in corpuscular theories" (p. 346).

This book is a most welcome addition to the history of science in Portugal. Based on a thorough investigation of archival materials and other primary sources, and written with a sound command of the secondary literature, this work will remain a reference for those interested in its subject. It should be compulsory reading for those trying to understand not only the history of astrology but also the history of natural philosophy in Portugal in this period. One can only hope that other studies will soon follow along the new avenues of research that this book has opened.

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